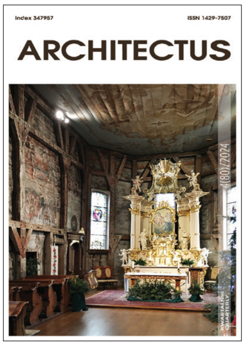

Architectus

2024
4(80)

DOI: 10.37190/arc240409

Agnieszka Ptak-Wojciechowska*

Use of the Analytic Hierarchy Process (AHP) method to assess the urban quality of life of seniors in terms of architectural and urban planning aspects

Abstract

Cities should aim to provide a high quality of life (QoL) for all residents. However, the urban structure often fails to meet the spatial needs of senior citizens, despite ongoing demographic changes. Furthermore, there is a lack of scientific assessment instruments that could be used to evaluate the architectural and urban aspects of a city and guide improvements. Although popular urban rankings may be used for urban policy development, their results are often misinterpreted by their recipients. The use of multi-criteria decision-making (MCDM) methods can facilitate the process of comparing city areas, increase the transparency of the evaluation, and involve different stakeholders in the evaluation process. Machine learning (ML) could be an interesting extension to commonly used statistical methods. This paper presents the latest research methods on the urban QoL of seniors, using a multi-criteria analysis of five neighbourhoods in Poznan as an example. The Analytic Hierarchy Process (AHP) method is discussed as part of the author's tool for measuring the perceptual assessment of senior citizens and the expert assessment of architects and urban planners, in terms of functional and spatial aspects. The AHP method's effectiveness is demonstrated, and the results can support city authorities, designers, and researchers. Additionally, this research presents directions for its development using ML methods.

Key words: participatory methods, multi-criteria methods, quality of life in cities, machine learning, ageing societies

Introduction

According to projections, the number of people aged 65 and over worldwide will be around 16% of the population in 2050 (United Nations 2022), and the number of urban dwellers will account for two-thirds of the population (United Nations 2020). Climate change and its negative impacts threaten people's lives, health and property (Hoornweg, Sugar, and Trejos Gómez 2011). Cities are influential in amplifying the effects of storms, heavy rainfall and heat waves (Pörtner et al. 2022), and the shaping of urban space has an undeniable impact on quality of life (Wojnarowska 2016). Urban quality of life (QoL) assessment tools (e.g., guidelines, rankings) are considered to have potential in the context of urban planning and policy (Lowe et al. 2015). The rationale for addressing the topic was the observation of the inadequacy of urban spaces to meet the needs of older people and the popularity of instruments for its evaluation, such as city rankings. The results of rankings to identify the best places to live attract the attention of the media and communities, as well as city authorities around the world, even though most of the tools were not intended to influence policy. The current and popular tools vary considerably, even though they all seem to touch on the topic of quality of life. The differences relate to the commissioning bodies, the methodology, the focus groups, the target groups of the surveys and the criteria studied. Cities around the world, but also within one country, differ significantly, and yet they are still subject to very uniform evaluation criteria in rankings. The analysed global evaluation tools do not take into account that the quality of life differs depending on the location of residence within the same city, but for example in other neighbourhoods.

An important motivation in taking up the chosen topic is the approach that assumes that in assessing the quality of life in cities, more attention should be paid to subjective

* ORCID: 0000-0002-4833-905X. Faculty of Architecture, Poznan University of Technology, Poland, e-mail: agnieszka.ptak-wojciechowska@put.poznan.pl

indicators regarding residents' perceptions, and that a complete tool should examine both objective and subjective aspects (Gawlak, Matuszewska, and Ptak 2021).

The motivation for undertaking the research is the diagnosed research gaps. In an analysis of a selection of current tools for assessing quality of life in cities, it was shown that global challenges (climate and demographic change) are overlooked in many of them, and that aspects of the spatial (architectural-urban) quality of cities and the importance of perceptual assessment are underestimated. Comparisons of places to live are global – they apply to entire cities – and should also be local. Indeed, the study of urban quality should also include neighbourhood units representing an intermediate urban scale: larger than a single building with its immediate surroundings and smaller than the entire city within its administrative boundaries. Moreover, seniors use cities locally and their activities are most often narrowed down to their flat and immediate neighbourhood (Garau, Pavan 2018). Assessment tools are too general and ambiguous. Rankings should serve as a good example – not a source of competition. A city ranking system and governance should be well linked (Ptak-Wojciechowska 2023).

The aim of the research presented in this article was to formulate guidelines for the definition of an assessment tool taking into account spatial aspects, expert and perceptual evaluation, in addition to sustainability principles and socio-cultural context. The guidelines were created on the basis of a comparative analysis of selected current assessment tools. It was crucial to select a transparent methodology.

The following research hypothesis was formulated: The development of tools for assessing urban quality of life should include participatory methods involving researchers, experts and residents. These tools need to take into account more criteria related to aspects of the shaping of the spatial structure of cities. In addition, they should be adapted to the demographic context, local conditions and global environmental risks.

The research problem related to the inadequacy of urban spaces and tools for assessing urban quality of life to current challenges is also presented. The latest methods and techniques used in urban quality of life research are then discussed. This is followed by a presentation of the author's own research, with particular emphasis on the selection of a multi-criteria method and the process of constructing the author's urban assessment tool. This is followed by a demonstration of the verification of the tool, including expert and perception surveys, as well as the final ranking of neighbourhoods. The last part includes a summary, involving recommendations for continuing research using machine learning methods.

State of research

Quality of life is studied both in Poland and internationally in various ways. For example, researchers' attention is drawn to the importance of the interrelationship of objective and subjective measures. Adam Okulicz-Kozaryn (2013) examines the relationship between Mercer's Quality of Living Ranking and survey data from a satisfaction survey. According to the analysis, the relationship between objective measures of quality of life and subjective measures is weak, and the author argues for more attention to be paid to subjective indicators of quality of life. Other researchers present an integrated approach using GIS (Geographic Information System)[1] and multi-criteria decision making/aiding (MCDM/A) methods to assess the quality of urban open spaces in Milan. The authors propose criteria and sub-criteria covering features of the built environment, its organisation and the perception of users. Data to complete the individual indicators were obtained from GIS, Open Street Map and Google Maps, as well as through direct observation (Oppio et al. 2021). Also, researchers from Poland point out the need to extend social and economic indicators to include subjective aspects related to the opinion of the inhabitants and, in addition, to use geographical research methods (e.g., geo-survey[2]) (Czepkiewicz, Jankowski 2015). Quality of life can be narrowed down to its individual criteria – for example, accessibility of space. Other authors propose a Decision Support System (DSS) and a conditioned tool – the online Walkability Explorer (WE) application to support design and planning for assessing the walkability and accessibility of a space for pedestrians. The researchers present a case study in which they discuss the results of an example application in the Lisbon area (Blečić et al. 2015). Models are proposed to assess the age-friendliness of cities, such as Best Cities for Successful Aging. This tool evaluates the spaces of US metropolitan areas against nine categories and 83 indicators, and aims to highlight and encourage good practices that improve the quality of cities and the quality of life of residents (Kubendran, Soll, and Irving 2017). In turn, the report commissioned by UNECE and DG EMPL gives numerous examples of the use of the Active Ageing Index (AAI), its practical instrument for identifying areas where appropriate policies can harness the active potential of older people. The index is multidimensional, and environmental factors, including infrastructure to promote well-being, social cohesion and digitalisation, among others, are taken into account. Twenty-eight countries in the European Union joined the survey, plus Iceland, Switzerland and Canada (Lamura, Principi 2019). A methodology for assessing the quality of life of older adults on a suburban scale is also available, integrating objective indicators, derived from statistical data, and subjective indicators, taking into account the opinions of both experts and older people (Garcia et al. 2017). In addition, a study based on the Survey of Health, Aging, and Retirement in Europe (SHARE) is worth mentioning. The study analysed the direct impact of perceived accessibility on the quality of life of 13,828 Europeans aged 65 and over and the indirect impact after taking into account aspects related to loneliness, place attachment, marital status and functional disability (Vitman Schorr, Khalaila 2018). Of interest is the analysis of older people's sense

[1] Geographic Information System – is used to collect, visualize and process geographic data, as well as support the decision-making process.

[2] Geosurvey, as one of the forms of conducting online public consultations, is used during the spatial planning process. In this form, respondents provide answers using maps.

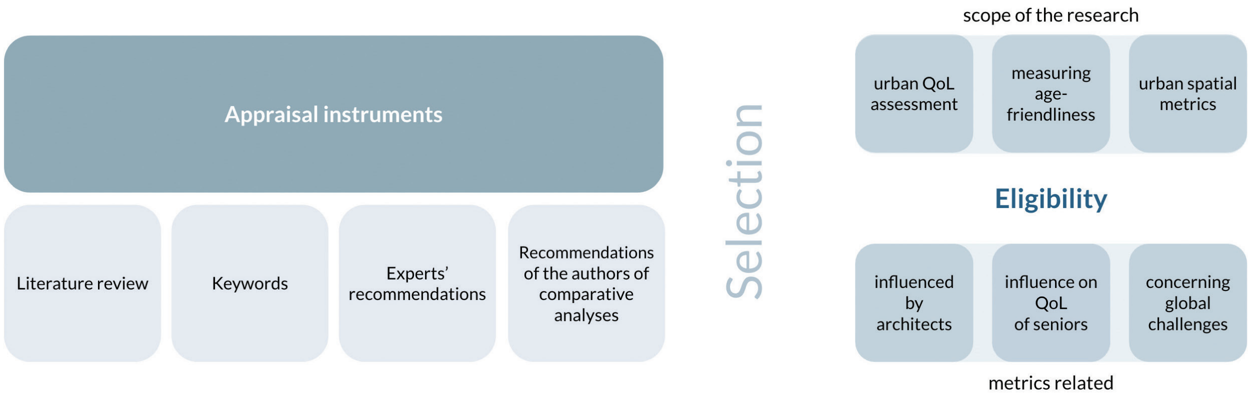

Fig. 1. Criteria for the selection of representative tools (elaborated by A. Ptak-Wojciechowska)

Il. 1. Kryteria wyboru narzędzi reprezentatywnych (oprac. A. Ptak-Wojciechowska)

of safety in the context of the built environment, for which the starting point was the framework of age-friendly cities and the quality of life aspect of neighbourhoods (Donder et al. 2013). There is also interdisciplinary research on the relationship between the health of ageing Australians and urban sustainability. The authors present a method to explore the relationship between subjective and objective measures of built environment characteristics of settlements (number of buildings, street capacity and connectivity, diversity of functions, continuity of elevations, number of seats) and health for communities of people aged 55 years and older (Brewer et al. 2014).

Description of original research

The original research was conducted between 2020 and 2023. The study adopted a specific methodology. In the first part, the method of logical argumentation was used. A literature analysis was carried out to be able to identify the state of the art of the global challenges faced by cities (climate change, demographics and urbanisation), the measurement of quality of life in spatial terms, current tools for assessing urban quality of life and their classification, in addition to architectural, universal and inclusive design. This was followed by a quantitative and qualitative study of the available assessment tools. Statistical techniques and comparative studies were used, as described in more detail in the dissertation (Ptak-Wojciechowska 2023). A selection of spatial criteria and sub-criteria, extracted from the analysed existing tools, was then made. The synthesis was done according to the recommendation formulated from Miller's figure that the number of elements within the model groups should be 7 ± 2 (Miller 1956). The defined criteria and sub-criteria were subjected to expert evaluation by collating and comparing them. Subsequently, a mathematical multi-criteria method was applied. The final stage was quantitative and qualitative participatory research.

Literature research, criteria for the selection of tools

The subject of the study were publicly available evaluation instruments, both international and Polish. Documents that meet the specified eligibility have been selected on the basis of literature and keyword research as well as recommendations of experts in the field of design for seniors (who are both researchers and practicing architects), as well as creators of other comparative analyses. Eligibility was related to the scope of the study (including quality of life in cities, age-friendliness and spatial indicators) and the characteristics of the indicators included (Fig. 1).

Comparative analysis of tools

The comparative research included an analysis of 24 tools created in the years 2007–2021, such as: rankings (selecting the best locations to live), guides (measuring accessibility for seniors), other Polish instruments (taking into account surveys and assessing the quality of life using a set of indicators), as well as assessment models proposed by the researchers. The set of assessment tools consists of three international guides and one Polish guideline, 13 international rankings, and two Polish and five other Polish tools (Table 1), as well as 14 models proposed by scientists (Table 2) (Ptak-Wojciechowska 2023).

Comparative research revealed that in most Polish assessment tools and rankings, aspects related to the aging of societies were not taken into account in detail. Issues related to population ageing have been given special attention in the guides created to study the accessibility of cities for the elderly and in two rankings "Best Cities for Successful Aging" and "Active Ageing Index" on similar topics, as well as in the Polish study "Jak się żyje osobom starszym w Polsce" [How do older people live in Poland]. In 16 tools, on the other hand, the aspect of demographic change was included, among other things, by providing information on life expectancy and taking into account different age ranges when analysing the results. Despite environmental threats, water and climate aspects were not included in the assessment at all in the Polish and foreign guides. Indicators assessing climate aspects were included in 5% in international rankings, 6% in Polish rankings and 1% in other Polish tools, and water-related metrics – only in 3% in international rankings, in 1% in Polish rankings and 0.6% in other Polish tools (detailed data can be found in Ptak-Wojciechowska 2023).

Table 1. Summary of current assessment tools analysed:
foreign and Polish guides, international and Polish rankings and other Polish assessment tools (elaborated by A. Ptak-Wojciechowska)
Tabela 1. Zestawienie analizowanych aktualnych narzędzi oceny:
wytycznych zagranicznych i polskich, rankingów międzynarodowych i polskich oraz innych polskich narzędzi oceny (oprac. A. Ptak-Wojciechowska)

Tool	No.	Name	Contracting Authority	Source
International guides	1.1	Global Age – friendly Cities – A Guide	World Health Organisation	(World Health Organization 2007)
	1.2	Measuring the age-friendliness of cities. A guide to using core indicators	World Health Organisation	(World Health Organization 2015)
	1.3	Age-friendly rural and remote communities: a guide	Federal/Provincial/Territorial Ministers Responsible for Seniors	(Federal/Provincial/Territorial Ministers Responsible for Seniors 2007)
Polish guides	1.4	System wsparcia osób starszych w środowisku zamieszkania – przegląd sytuacji, propozycja modelu. Synteza [A system of support for the elderly in a residential environment – an overview of the situation and a proposal for a model. Synthesis]	Rzecznik Praw Obywatelskich (RPO)	(Błędowski et al. 2016)
International rankings	2.1	EIU's Global Liveability Index	The Economist Intelligence Unit	(The Economist Intelligence Unit 2019)
	2.2	Mercer's Quality of Living Ranking	Mercer	(Mercer 2019)
	2.3	Monocle's Quality of Living Survey	Monocle	(Monocle 2019)
	2.4	Deutsche Bank Liveability Survey	Deutsche Bank AG/London	(Reid, Nicol, and Allen 2019)
	2.5	Euro Health Consumer Index	Health Consumer Powerhouse	(Björnberg, Phang 2019)
	2.6	IMD Smart City Index	IMD World Competitiveness Center's Smart City Observatory Singapore University of Technology and Design (SUTD)	(IMD World… 2019)
	2.7	Best Cities for Successful Aging	Milken Institute Center for the Future of Aging Milken Institute Research Department	(Kubendran, Soll, and Irving 2017)
	2.8	Human Development Report	United Nations; Human Development Report Office	(United Nations Development Programme 2019)
	2.9	Quality of life (well-being of Europeans)	Eurostat	(Eurostat 2017)
	2.10	The European Quality of Life Survey (EQLS)	Eurofound	(Eurofound 2017)
	2.11	How's Life? 2020 Measuring Well-being	OECD	(Organisation for Economic Cooperation and Development 2020)
	2.12	Quality of life in cities. Perception survey in 79 European cities	European Commission	(European Commission… 2013)
	2.13	Active Ageing Index	UNECE + DG EMPL (European Commission)	(Lamura, Principi 2019)
Polish rankings	2.14	Ranking jakości życia. Wymiary szczęścia [Quality of life ranking. Dimensions of happiness]	POLITYKA and the AGH University of Science and Technology	(Polityka and Akademia Górniczo-Hutnicza 2018)
	2.15	Uciekające metropolie. Ranking 100 polskich miast [Runaway metropolises. Ranking of 100 Polish cities]	Klub Jagielloński	(Wałachowski, Król 2019)
Other Polish appraisal instruments	3.1	Jakość życia w Polsce. Edycja 2017 [Quality of life in Poland. 2017 Edition]	Główny Urząd Statystyczny (GUS)	(Bendowska et al. 2017)
	3.2	Zadowolenie z życia [Life satisfaction]	Centrum Badania Opinii Społecznej (CBOS)	(Centrum Badania Opinii Społecznej 2020)
	3.3	Diagnoza społeczna 2015. Warunki i jakość życia Polaków [Social Diagnosis 2015. Conditions and quality of life of Poles]	Rada Monitoringu Społecznego	(Czapiński, Panek 2015)
	3.4	Jakość życia mieszkańców Łodzi i jej przestrzenne zróżnicowanie [Quality of life of Lodz's inhabitants and its spatial diversity]	Urząd Miasta Łodzi	(Rokicka 2013)
	3.5	Jak się żyje osobom starszym w Polsce [How do older people live in Poland]	Główny Urząd Statystyczny (GUS)	(Główny Urząd Statystyczny 2012)

Multicriteria methods

On the basis of the comparative analysis, it was noted that the available tools often use a non-transparent methodology (without indicating the specific sources on the basis of which the own set of evaluation criteria is created; without providing data on the number and characteristics of experts participating in the study; without specifying how the weights and the aggregate index were calculated) and that the perspectives of different stakeholders (such as experts and seniors) were not combined. Therefore, a search was started for a method that would be transparent and would allow for including various aspects in the assessment. It was decided to use multi-criteria methods widely used in decision-making (Afshari, Vatanparast, and Ćoćkalo 2016). The number of available multi-criteria decision support methods is significant (over 200), and their diversity means that the selection of the method itself is a multi-criteria problem (Trzaskalik 2014).

Method selection

The use of various multi-criteria methods was considered, both with the help of an expert (a university professor and practitioner whose specialization is the use of multi-criteria decision support methods in urban mobility management) and the Multiple Criteria Decision Analysis Methods Selection Software (MCDA-MSS[3]) tool for matching multi-criteria methods to a specific decision problem (Cinelli et al. 2021). Initially, the AHP and ELECTRE-III-H methods (the so-called Electre with sub-criteria) were taken into account together with the expert, while the algorithm resulted in the recommendation of the MCHP-PROMETHEE method. The practical aspect, related to the selection of a less complicated and more understandable method for decision-makers, experts in the discipline of architecture and urban planning, finally confirmed the effectiveness of the AHP method (Saaty 1986). The individual stages of the procedure are presented in the diagram (Fig. 2).

[3] A tool using many questions (concerning, among others, the type of problem, the way of ordering, the set of evaluation criteria and its structure, or the way of measuring the performance of the variant) enabling step-by-step rejection of a method that does not meet the criteria – ultimately leading to the recommendation of methods that meet all selected assumptions.

Table 2. Set of scientific studies analysed
(elaborated by A. Ptak-Wojciechowska)
Tabela 2. Zestaw analizowanych opracowań naukowych
(oprac. A. Ptak-Wojciechowska)

No.	Title	Source
1	Developing a checklist for assessing urban design qualities of residential complexes in new peripheral parts of Iranian cities: A case study of Kerman, Iran	(Abousaeidi, Hakimian 2020)
2	Urban design assessment tools: A model for exploring atmospheres and situations	(Abusaada, Elshater 2020)
3	Responsive environments: A manual for designers	(Bentley et al. 2005)
4	Socially sustainable suburbia: Linking neighbourhood characteristics to health outcomes in an ageing population	(Brewer et al. 2014)
5	Towards an urban quality framework: Determining critical measures for different geographical scales to attract and retain talent in cities	(Esmaeilpoorarabi, Yigitcanlar, and Guaralda 2016)
6	Assessment of and improvement strategies for the housing of healthy elderly: Improving quality of life	(Feng et al. 2018)
7	Evaluating Urban Quality: Indicators and Assessment Tools for Smart Sustainable Cities	(Garau, Pavan 2018)
8	Assessment of an urban sustainability and life quality index for elderly	(Garcia et al. 2017)
9	City planning and population health: A global challenge	(Giles-Corti et al. 2016)
10	Developing and testing a framework for the assessment of neighbourhood liveability in two contrasting countries: Iran and Estonia	(Maleki et al. 2015)
11	Assessing urban quality: A proposal for a MCDA evaluation framework	(Oppio, Bottero, and Arcidiacono 2022)
12	How to assess urban quality: A spatial multicriteria decision analysis approach	(Oppio et al. 2021)
13	Model for Assessment of Public Space Quality in Town Centers	(Wojnarowska 2016)
14	Neighbourhood sustainability assessment: Evaluating residential development sustainability in a developing country context	(Yigitcanlar, Kamruzzaman, and Teriman 2015)

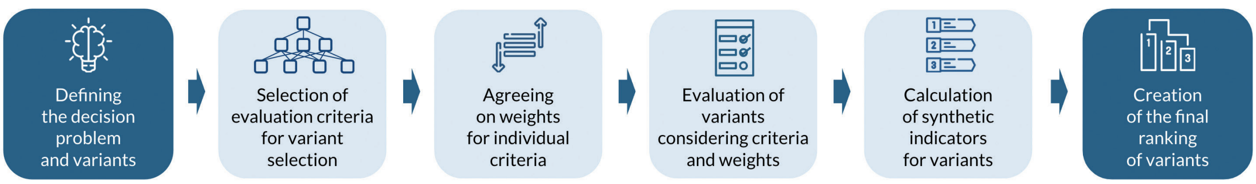

Fig. 2. Tool development process – on a diagram of how multi-criteria decision methods work
(elaborated by A. Ptak-Wojciechowska based on: Kobryń 2014)

Il. 2. Proces tworzenia narzędzia – na schemacie działania metod wielokryterialnego wspomagania decyzji
(oprac. A. Ptak-Wojciechowska na podstawie: Kobryń 2014)

Formulation of criteria and sub-criteria related to the selection of the variant

A literature analysis of current assessment instruments and models yielded 2189 metrics. Metrics are understood as the smallest components for assessing the quality of life in cities, constituting a component of the sub-criteria. Only those related to the assessment of the spatial structure affecting quality of life were included. After removing redundancy, 128 relevant metrics were finally obtained. In the course of their analysis, certain relationships between them were diagnosed – consequently, they were grouped into sub-criteria[4]. Metrics that were recurrent in the various reference materials or non-recurrent, but proposed in significant tools/studies, or assessed as highly relevant, were taken into account. The reference tools were in particular the most influential publications: the WHO guides *Global Age-friendly Cities. A guide* (2007) and *Responsive environments. A manual for designers* (Bentley et al. 2005).

In the end, a list of criteria and sub-criteria was created that was considered the most effective for the study. The need for both expert and perceptual evaluation was taken into account, hence each criterion included sub-criteria for measurement by experts and one sub-criterion each related to the subjective evaluation of the residents of the neighbourhoods (Fig. 3). The characteristics of each sub-criterion can be found in the dissertation (Ptak-Wojciechowska 2023).

[4] The grouping was performed and verified by at least two people.

	K1 Accessibility of urban area for ageing population
expert assessment	K1.1 Inclusiveness of architecture and urban space
	K1.2 Neighborhood spatial proximity
	K1.3 Neighborhoods accessibility for pedestrian and cyclist
	K1.4 Neighborhood permeability
perceptual assessment	K1.5 Perception (of older inhabitants) on urban area accessibility
	K2 Age-friendliness of the urban function
expert assessment	K2.1 Neighborhood mixed-use, robustness and space efficiency
	K2.2 Open space provision
	K2.3 Availability of diverse urban equipment improving comfort of using the space
	K2.4 Availability of socializing space (housing)
	K2.5 Availability of housing choice for elderly
	K2.6 Neighborhood natural surveillance and protection
	K2.7 Functional division for public, semi public and private realm
	K2.8 Availability of equipment and installations
perceptual assessment	K2.9 Perception (of older inhabitants) on urban function age-friendliness
	K3 Age-friendliness of the urban form
expert assessment	K3.1 Quality of housing architecture, materials and structure
	K3.2 Neighborhood human scale and density
	K3.3 Quality of urban landscape
perceptual assessment	K3.4 Perception (of older inhabitants) on urban form age-friendliness
	K4 Environmental friendliness of urban area
expert assessment	K4.1 Share of blue-green infrastructure
	K4.2 Emission level of harmful substances
	K4.3 Share of environmentally friendly design and technology solutions
perceptual assessment	K4.4 Perception (of older inhabitants) on environmental friendliness of urban area
	K5 Urban area legibility for older inhabitants
expert assessment	K5.1 Visual permeability
	K5.2 Different spaces explicitly defined
perceptual assessment	K5.3 Perception (of older inhabitants) on urban area legibility
	K6 Adaptability for seniors aging in place
expert assessment	K6.1 Availability of housing and areas modifications for seniors ageing in place
	K6.2 Availability of personalization
perceptual assessment	K6.3 Perception (of older inhabitants) on housing adaptability
	K7 Affordability of housing for older people
expert assessment	K7.1 Affordability of property
	K7.2 Affordability of maintenance
	K7.3 Affordability of housing modifications and repair
perceptual assessment	K7.4 Perception (of older inhabitants) on housing affordability
	K8 Quality of multisensory experience of the built environment
expert assessment	K8.1 Adequate illumination
	K8.2 Adequate natural light
	K8.3 Noise quality
	K8.4 Sensual experience of space
	K8.5 Adequate insulation and aeration
	K8.6 Adequate temperature
perceptual assessment	K8.7 Perception (of older inhabitants) on multisensory experience of the built environment

Fig. 3. Formulation of evaluation criteria and sub-criteria including expert and perceptual evaluation (elaborated by A. Ptak-Wojciechowska)

Il. 3. Sformułowanie kryteriów i podkryteriów oceny z uwzględnieniem oceny eksperckiej i percepcyjnej (oprac. A. Ptak-Wojciechowska)

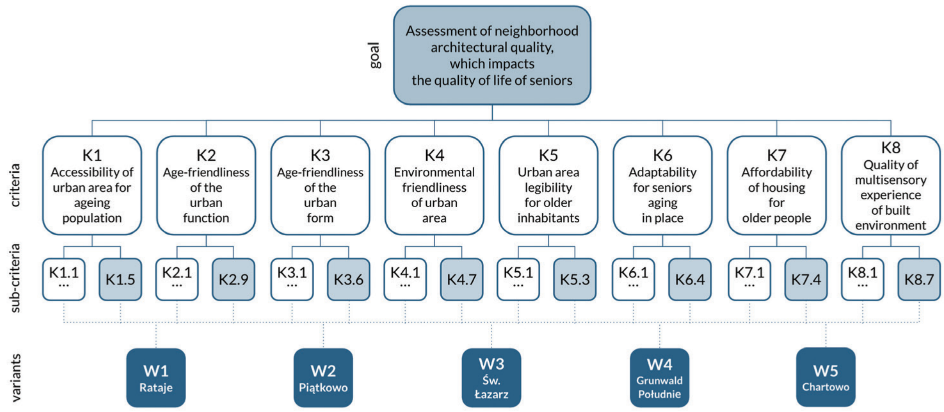

Fig. 4. Hierarchical structure of the author's evaluation model (elaborated by A. Ptak-Wojciechowska)

Il. 4. Struktura hierarchiczna autorskiego modelu oceny (oprac. A. Ptak-Wojciechowska)

Constructing the tool, ranking the criteria by importance

The next part of the study consisted of making pairwise comparisons, according to the AHP multi-criteria method using the AHP-OS program (Goepel 2018) in order to rank the criteria and sub-criteria by weight. Ten experts were invited to the study, of which eight finally participated. The experts were a group of architects (n = 6) and urban planners (n = 2) – both scientists and practitioners working actively in the profession. The experts included people specialising in designing for ageing societies (n = 2) and in health care (n = 4).

AHP calculation procedure

The initial stage of the calculation procedure for the AHP method is related to the decomposition of the decision problem. A hierarchical model is created consisting of elements such as: overarching goal, criteria, sub-criteria, decision variants (Fig. 4).

The calculation procedure presented in this article only concerns the main criteria in order to illustrate the sample calculations made by the AHP-OS system. It should be noted that a matrix is constructed at each level of the AHP model and, as part of the work in AHP-OS, eight matrices were constructed for the sub-criteria importance analysis, i.e., there were nine matrices in total. Sample calculations were performed in Google Sheets on the basis of the individually prepared matrices, the results of which appeared to coincide with the results of the calculations in the software by Klaus D. Goepel (2018). However, it should be emphasised that the specialised tools are more accurate than the calculations made in Google Sheets, as obtaining accurate results involves the execution of complex mathematical procedures, and the literature on AHP shows simplified methods for obtaining similar results (Stefanów, Prusak 2011). Hence, a slight difference, e.g., in the third digit after the decimal point, is visible in the results performed by the system and the author of the study in question.

The first step was to create a comparison matrix **A** of dimensions ($n \times n$) (1), where n is the number of criteria being compared.

$$\mathbf{A} = \left[a_{ij}\right]_{qxq} \begin{bmatrix} 1 & a_{12} & \cdots & a_{1n} \\ 1/a_{12} & 1 & \cdots & a_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ 1/a_{1n} & 1/a_{2n} & \cdots & 1 \end{bmatrix} \text{for } i,j = 1,2,\ldots,n \quad (1)$$

The matrix consists of criteria compared in pairs (K1–K8) and scores awarded by experts according to the Saaty scale. On this scale, the higher number of points awarded by the expert is associated with the greater importance of the criterion (Fig. 5).

Fig. 5. The comparison scale of pairwise (elaborated by A. Ptak-Wojciechowska based on: Saaty 1986)

Il. 5. Skala porównań Saaty'ego (oprac. A. Ptak-Wojciechowska na podstawie: Saaty 1986)

Intensity of importance	Definition
1	Equal importance
2	Weak or slight (intermediate value between equal and moderate importance)
3	Moderate importance
4	Moderate plus (intermediate value between moderate and strong importance)
5	Strong importance
6	Strong plus (intermediate value between strong and very strong importance)
7	Very strong or demonstrated importance
8	Very, very strong (intermediate value between very strong and extreme importance)
9	Extreme importance

According to the principle of inverse preference applied here, where the first criterion compared to the second criterion is more important to a certain extent (expressed on an accepted point scale), the second criterion compared to the first criterion is proportionally less important (and expressed as a fraction). The experts' preferences were explored in the form of a questionnaire, in which they were asked to indicate an advantage individually for each pair of criteria. Each expert's individual responses were then aggregated using a geometric mean expressed by a formula:

$$\left(\prod_{i=1}^{n} a_{ij}\right)^{\frac{1}{n}} = \sqrt[n]{a_1 a_2 \ldots a_n} \quad (2)$$

Square matrix **A**=[a_{ij}]

	K1	K2	K3	K4	K5	K6	K7	K8
K1	1.00	2.36	2.68	2.46	1.61	1.46	0.69	3.45
K2	0.42	1.00	1.85	1.41	0.78	0.57	0.67	2.21
K3	0.37	0.54	1.00	1.36	0.68	0.62	0.49	1.09
K4	0.41	0.71	0.74	1.00	0.68	0.47	0.51	1.71
K5	0.62	1.28	1.47	1.47	1.00	0.73	0.71	1.95
K6	0.68	1.75	1.61	2.13	1.37	1.00	0.75	2.07
K7	1.45	1.49	2.04	1.96	141	1.33	1.00	3.63
K8	0.29	0.45	0.92	0.58	051	0.48	0.28	1.00

Normalised matrix **B**=[b_{ij}]

	K1	K2	K3	K4	K5	K6	K7	K8
K1	0.1905	0.2461	0.2178	0.1988	0.2002	0.2190	0.1354	0.2016
K2	0.0807	0.1043	0.1503	0.1140	0.0970	0.0855	0.1315	0.1292
K3	0.0711	0.0564	0.0813	0.1099	0.0846	0.0930	0.0962	0.0637
K4	0.0775	0.0739	0.0597	0.0808	0.0846	0.0705	0.1001	0.0999
K5	0.1183	0.1337	0.1195	0.1188	0.1244	0.1095	0.1393	0.1140
K6	0.1305	0.1829	0.1311	0.1719	0.1704	0.1500	0.1472	0.1210
K7	0.2761	0.1556	0.1658	0.1585	0.1752	0.2000	0.1963	0.2122
K8	0.0552	0.0472	0.0745	0.0473	0.0638	0.0725	0.0541	0.0584

Fig. 6. Consolidated matrix **A**, transformed into normalised matrix **B** (elaborated by A. Ptak-Wojciechowska)

Il. 6. Macierz skonsolidowana **A** przekształcona w macierz znormalizowaną **B** (oprac. A. Ptak-Wojciechowska)

This resulted in a consolidated a_{ij}^{cons} matrix. The next step was to transform the pairwise comparison matrix **A** into a normalised matrix **B** = [b_{ij}] (Fig. 6). For this purpose, the values of the a_{ij} cons were summed in the individual columns of the matrix **A** = [a_{ij}].

Then, the elements appearing in the individual columns of matrix **A** were divided by the result of the sum from the previous step (for example, 2.36/9.5912 = 0.2461) according to formula (3). The individual elements are therefore equal:

$$b_{ij} = \frac{a_{ij}}{\sum_{i=1}^{n} a_{ij}} \tag{3}$$

where: n – number of elements compared in pairs.

Example calculation:

$$b_{ij} = \frac{2.36}{9.5912} = 0.2461$$

The matrix has normalized.

In order to determine the weights of the evaluated criteria, the arithmetic mean in each row of the normalized matrix **B** was calculated according to the formula:

$$w_i = \frac{1}{n}\sum_{j=1}^{n} b_{ij} \tag{4}$$

Example calculation:

$$w_i = \frac{1}{8}(0.1905 + 0.2461 + 0.2178 + 0.1988 + $$
$$+ 0.2002 + 0.2190 + 0.1354 + 0.2016) = 0.2012$$

In the case of pairwise comparisons by experts, it is possible that the principle of transitivity of preferences is violated. If the expert considers the first criterion more important than the second and the second criterion more important than the third, he cannot at the same time consider the first criterion less important than the third. The AHP method allows the consistency of pairwise comparisons to be verified. For this purpose, it is necessary to determine the maximum eigenvalue of the **A** matrix. In the present study λ_{max} was determined according to the formula (Cabała 2018):

$$\lambda_{max} = \frac{1}{n}\sum_{j=1}^{n} \frac{(Aw)_i}{w_i} \tag{5}$$

The measures used to assess the consistency of pairwise comparisons are:

– consistency index (CI) increasing with increasing inconsistencies in estimates calculated according to the formula:

$$\mathrm{CI} = \frac{\lambda_{max} - n}{n-1} \tag{6}$$

where:

λ_{max} – maximum eigenvalue of the matrix,

RI – random index dependent on the degree of the matrix n (see Table 3),

n – matrix degree.

Table 3. The value of the random index RI (elaborated by A. Ptak-Wojciechowska based on: Saaty 2004)
Tabela 3. Wartość indeksu losowego RI (oprac. A. Ptak-Wojciechowska na podstawie: Saaty 2004)

n	1	2	3	4	5	6	7	8	9	10
Random index	0	0	0.52	0.89	1.11	1.25	1.35	1.40	1.45	1.49

The consistency ratio (CR) which is the ratio of the matrix consistency index (CI) to the random index (RI) depending on the degree of this matrix is calculated according to the formula:

$$\mathrm{CR} = \frac{\mathrm{CI}}{\mathrm{RI}} \cdot 100\% \qquad (7)$$

Taking into account the maximum value of the matrix ($\lambda_{max} = 8.11$) a consistency index has been determined:

$$\mathrm{CI} = \frac{(8.11 - 8)}{(8 - 1)} \cong 0.016$$

And finally, the consistency ratio was calculated:

$$\mathrm{CR} = \frac{0.016}{1.41} \cong 0.01$$

$$\mathrm{CR} = 0.01 \cdot 100\% = 1\%$$

The calculations presented show that CR < 10% and therefore pairwise comparisons of the evaluation criteria are consistent.

It should be emphasised that, thanks to the AHP-OS system, the expert is automatically informed when his/her individual answers are inconsistent, so he/she can correct them at any stage during the completion of the survey.

The result of this part of the survey was the weights given to the individual criteria and sub-criteria and the calculation of global priorities[5]. The K1: *Accessibility of urban area for ageing population* criterion was indicated as the most important (0.202), then K7: *Affordability of housing for older people* (0.193) and K6: *Adaptability for seniors aging in place* (0.150). The K8 criterion received the lowest weight: *Quality of multisensory experience of the built environment* (0.059). The share of individual criteria in percentages is presented in Figure 7.

Tool verification

The stage following the creation of a decision hierarchy using the AHP method and assigning weights to criteria and sub-criteria was the verification of the tool. Due to the argument raised in the literature regarding the validity of assessing urban quality within the boundaries of neighbouring units instead of within the boundaries of entire cities, the following variants were indicated: the neighbourhoods of the city of Poznań most frequently inhabited by seniors: Rataje, Piątkowo, Św. Łazarz, Grunwald Południe, Chartowo (Fig. 8).

The experts received a research questionnaire consisting of two parts: a table and a legend with a description of each of the sub-criteria. The table included variants, i.e., selected neighbourhoods in the city of Poznań, as well as their assessment criteria and sub-criteria – all excluding the sub-criteria concerning the perception of seniors. The experts were asked to enter a rating for the individual variants, on a scale of 0–10. The rating was to be assigned to the neighbourhoods in the individual criteria based on their own knowledge and experience and the attached supporting materials in the form of maps and photos. The group of experts consisted of eight researchers and practitioners: architects specializing in designing for the disabled and seniors (*n* = 1), health care (*n* = 1), as well as in both of these areas (*n* = 2), also – architects/historians/urban planners (*n* = 2) and architects/urban planners (*n* = 2).

In parallel with the expert study, a questionnaire survey was conducted on the perceptual assessment of architecture and urban planning in Poznan according to senior citizens. The survey design underwent a four-stage validation process. At the first stage, the survey questionnaire was analysed and refined on the basis of expert consultation with a senior citizen. At the second stage, the questionnaire was further evaluated by a psychologist and a pilot study was conducted among older people on its readability. At the third, it received expert approval. The final stage was the positive approval of the questionnaire by the Research Ethics Committee for Studies Involving Humans at Poznan University of Technology. The survey was anonymous and took place in stationary and online forms. Ultimately, 198 questionnaires with responses from seniors were taken for the survey. Seniors were qualified for the survey on the basis of the age criterion: 60 years and over.

The final stage of verification was the generation of the final ranking of neighbourhoods based on expert and senior citizen assessments. It should be noted that in the present study, the stage characteristic of the AHP method, involving pairwise comparison of options, was abandoned, as in the case of the publication by Edmundas K. Zavadskas et al. (2014) and the work of Helder Costa (2017). The motivation for this decision was the need to combine expert and perceptual evaluation. In the survey, the senior citizens commented only on the neighbourhoods they lived in, while the experts evaluated all five locations. In addition, two different ordinal scales were included in the survey. A Likert scale (ratings 1–5), more readable for older respondents, and a broader scale (ratings 0–10) giving the experts more freedom of expression. Although it would have been permissible to translate the aggregated and standardised scores into pairwise comparisons on Saaty's (1986) scale, due to the subjectivity of such a translation related to the establishment of a class range, the scores were left as scores.

[5] The global priority presents the average dominance of each of the (smallest) elements (sub-criteria) over the others in relation to the objective of the hierarchy; it is the product of the weights for criterion and sub-criterion.

Hierarchical Structure							
Level 0		Level 1	weight		Level 2	weight	Glob. Prior.
Assessment of neighborhood architectural quality, which impacts the quality of life of seniors	K1	Accessibility of urban area for ageing population	0.202	K1.1	Inclusiveness of architecture and urban space	0.262	5.30%
				K1.2	Neighborhood spatial proximity	0.287	5.80%
				K1.3	Neighborhoods accessibility for pedestrian and cyclist	0.188	3.80%
				K1.4	Neighborhood permeability	0.114	2.30%
				K1.5	Perception (of older inhabitants) on urban area accessibility	0.148	3.00%
	K2	Age-friendliness of the urban function	0.111	K2.1	Neighborhood mixed-use, robustness and space efficiency	0.120	1.30%
				K2.2	Open space provision	0.058	0.70%
				K2.3	Availability of diverse urban equipment improving comfort of using the space	0.100	1.10%
				K2.4	Availability of socializing space (housing)	0.132	1.50%
				K2.5	Availability of housing choice for elderly	0.151	1.70%
				K2.6	Neighborhood natural surveillance and protection	0.081	0.90%
				K2.7	Functional division for public, semi public and private realm	0.086	1.00%
				K2.8	Availability of equipment and installations	0.166	1.80%
				K2.9	Perception (of older inhabitants) on urban function age-friendliness	0.106	1.20%
	K3	Age-friendliness of the urban form	0.082	K3.1	Quality of housing architecture, materials and structure	0.275	2.20%
				K3.2	Neighborhood human scale and density	0.38	3.10%
				K3.3	Quality of urban landscape	0.171	1.40%
				K3.4	Perception (of older inhabitants) on urban form age-friendliness	0.174	1.40%
	K4	Environmental friendliness of urban area	0.081	K4.1	Share of blue-green infrastructure	0.296	2.40%
				K4.2	Emission level of harmful substances	0.387	3.10%
				K4.3	Share of environmentally friendly design and technology solutions	0.166	1.30%
				K4.4	Perception (of older inhabitants) on environmental friendliness of urban area	0.151	1.20%
	K5	Urban area legibility for older inhabitants	0.122	K5.1	Visual permeability	0.359	4.40%
				K5.2	Different spaces explicitly defined	0.301	3.70%
				K5.3	Perception (of older inhabitants) on urban area legibility	0.340	4.10%
	K6	Adaptability for seniors aging in place	0.150	K6.1	Availability of housing and areas modifications for seniors ageing in place	0.370	5.60%
				K6.2	Availability of personalization	0.395	5.90%
				K6.3	Perception (of older inhabitants) on housing adaptability	0.235	3.50%
	K7	Affordability of housing for older people	0.193	K7.1	Affordability of property	0.263	5.10%
				K7.2	Affordability of maintenance	0.417	8.00%
				K7.3	Affordability of housing modifications and repair	0.192	3.70%
				K7.4	Perception (of older inhabitants) on housing affordability	0.127	2.50%
	K8	Quality of multisensory experience of the built environment	0.059	K8.1	Adequate illumination	0.070	0.40%
				K8.2	Adequate natural light	0.228	1.30%
				K8.3	Noise quality	0.189	1.10%
				K8.4	Sensual experience of space	0.076	0.50%
				K8.5	Adequate insulation and aeration	0.191	1.10%
				K8.6	Adequate temperature	0.150	0.90%
				K8.7	Perception (of older inhabitants) on multisensory experience of the built environment	0.096	0.60%

Fig. 7. View after the weights have been completed by experts in the AHP-OS programme (elaborated by A. Ptak-Wojciechowska)

Il. 7. Widok po uzupełnieniu wag przez ekspertów w programie AHP-OS (oprac. A. Ptak-Wojciechowska)

Fig. 8. Selected variants, i.e., the neighbourhoods in Poznań most populated by senior citizens (elaborated by A. Ptak-Wojciechowska)

Il. 8. Wybrane warianty, czyli osiedla Poznania najliczniej zamieszkane przez seniorów (oprac. A. Ptak-Wojciechowska)

In order to finally rank the variants (neighbourhoods), a matrix was created consisting of the scores assigned to each sub-criterion C_j in the rows and the variants A_i (*alternatives*) in the columns.

The ratings were then normalised according to the formula (Mathew, Sahu and Upadhyay 2017):

$$\bar{x}_{ij} = \frac{x_{ij}}{x_j^{\max}} \tag{8}$$

where: $x_j^{\max}$ = the maximum possible value of the variant assessment in a given line (in the case of expert assessments, the maximum value of the rating is 10, and in the case of senior ratings – 5).

The next stage was to calculate the sum of the products of weights (global priorities) of the sub-criteria and their individual normalized values for each neighbourhood, as well as to rank the preferences in order to obtain the final ranking of areas. The final ranking of preference (P_i) is created on the basis of the weighted sum model according to the formula:

$$P_i = \sum_{j=1}^{n} w_j \, \bar{x}_{ij} \tag{9}$$

where:

w_j – weight of the sub-criterion C_j,

$\bar{x}_{ij}$ – normalized variant evaluation A_i for a given sub-criterion C_j.

Based on the results obtained during the study of the efficiency of the author's tool for assessing spatial aspects affecting the quality of life of seniors, it turned out that the highest position in the ranking was given to the Grunwald Południe neighbourhood, and the lowest – to Chartowo (Fig. 9).

The Grunwald Południe neighbourhood received the best rating among all the surveyed areas only in terms of adaptability for seniors aging in place and environmental friendliness of space. It also scored high in terms of accessibility of space, friendliness of function and urban form, and legibility of space, which ultimately contributed to taking first place in the ranking. But this neighbourhood fared worst in terms of affordability (cf. Fig. 10).

Conclusions and summary

Based on research, it has been shown that current tools for assessing urban quality of life are not sufficiently adapted to global challenges such as ageing populations, urbanisation and climate change, and their assessment is not comprehensive enough. The author's set of criteria and sub-criteria proposed in this paper makes it possible to fill this gap. Current assessment instruments do not take into account the importance of spatial scale, even though quality of life can vary within the boundaries of a single city. The method described in this paper therefore covers a smaller spatial scale, close to the area of the auxiliary units – known as neighbourhoods. The research results obtained allowed the research hypothesis to be confirmed. Significant results include assigning weight to criteria according to experts' opinions, determining the perceptual quality of spatial aspects by older people and spatial quality by experts for five neighbourhoods in Poznań, and formulating guidelines for a tool for assessing the spatial quality of cities, including defining the decision problem and variants, defining a coherent family of criteria and the way they are measured, selecting a transparent method, and verifying efficiency through pilot studies. The method proposed in this article complements existing scientific tools and models. This is because it makes it possible to take into account both the global context (universal criteria created on the basis of international quality of life studies) and local conditions (measurement of sub-areas instead of the entire city), and furthermore includes an evaluation of the quality of space in the expert assessment and the level of satisfaction with it in the seniors' perceptual assessment.

Based on the process of verifying the efficiency of the tool, several potential limitations can be diagnosed, such as: the choice of urban areas of the city (some of the selected areas turned out to be so heterogeneous in their boundaries that they made it significantly difficult for the experts to assess them reliably), the detail of the questions in the neighbourhood assessment questionnaire for the experts (the characterisation of the individual sub-criteria developed on the basis of indicators from the current assessment tools analysed earlier turned out to be too general for the experts), and the fact that the expert surveys were conducted individually instead of in the form of a group discussion

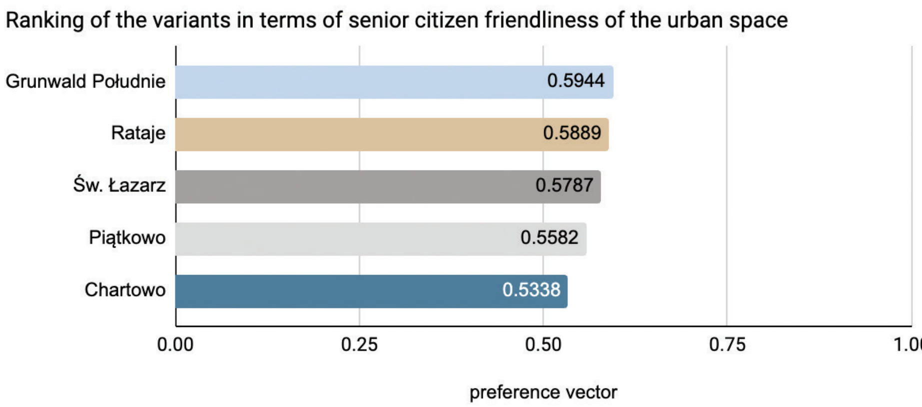

Fig. 9. Ranking of neighbourhoods in terms of the friendliness of architectural and urban spaces for seniors (elaborated by A. Ptak-Wojciechowska)

Il. 9. Ranking osiedli Poznania pod względem przyjazności przestrzeni architektoniczno-urbanistycznej seniorom (oprac. A. Ptak-Wojciechowska)

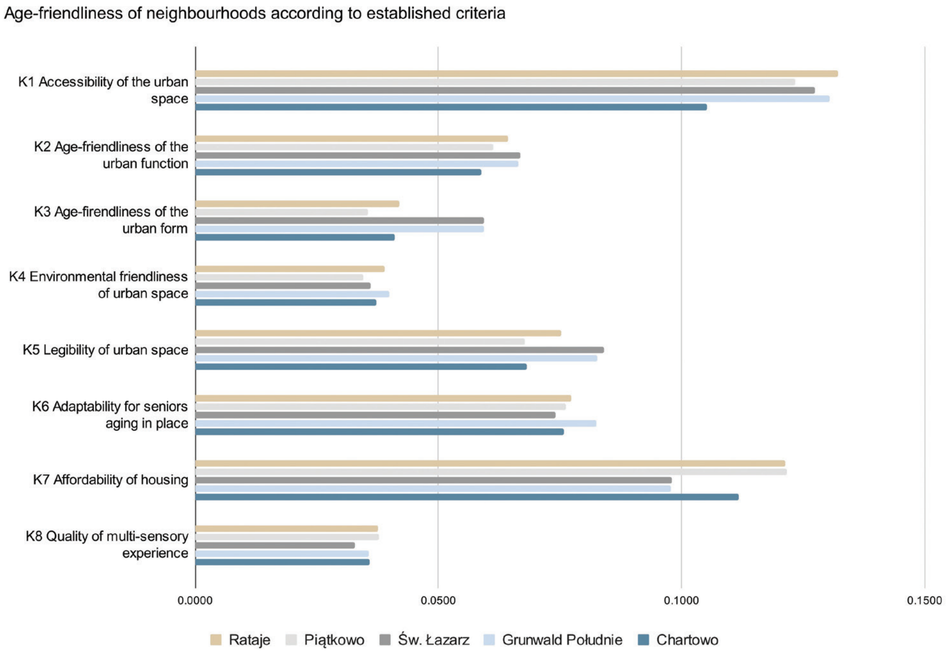

Fig. 10. Rankings of neighbourhoods in terms of their senior citizen-friendliness in various aspects (elaborated by A. Ptak-Wojciechowska)

Il. 10. Rankingi osiedli Poznania pod względem ich przyjazności seniorom z uwzględnieniem poszczególnych aspektów (oprac. A. Ptak-Wojciechowska)

(due to the interdisciplinary nature and diversity of the questions, the assessment could have been conducted in a working group and the result worked out in the form of a discussion between the experts).

The data obtained from the seniors' perception survey not only served to supplement the perception sub-criteria for the assessment tool under development. The ways in which they were used and visualised are shown in the dissertation; the statistical analysis and visualisation of the survey results were performed using Microsoft Excel and the statistical package Statistica (Ptak-Wojciechowska 2023).

An interesting alternative to statistical testing is artificial intelligence. The author is currently working on the use of machine learning (decision trees and rules) to analyse the results obtained from perceptual surveys conducted among seniors and questionnaire surveys of expert assessment. Analyses are performed using the WEKA programme, among others. In addition, research into the quality of life in cities is being continued through ongoing projects using data mining. Their aim is to automate the extraction of objective information from available data sources (e.g., Open Street Map) to supplement expert and perceptual evaluations. These concern the distance of important functions from the place of residence of seniors and the location of small architecture in the context of the needs and mobility of older people.

Translated by
Agnieszka Ptak-Wojciechowska

Acknowledgements

The described research was carried out as part of the doctoral dissertation conducted under the supervision of Prof. Agata Gawlak. I would like to thank the Supervisor, the experts who shared their specialist knowledge, and all the Seniors involved and their Representatives for their participation in the research.

References

Abousaeidi, Monammad, and Pantea Hakimian. "Developing a Checklist for Assessing Urban Design Qualities of Residential Complexes in New Peripheral Parts of Iranian Cities: A Case Study of Kerman, Iran." *Sustainable Cities and Society* 60, (2020). https://doi.org/10.1016/j.scs.2020.10225 .

Abusaada, Hisham, and Abeer Elshater. "Urban design assessment tools: A model for exploring atmospheres and situations." *Urban Design and Planning* 173, no. 6 (2020): 238–55. https://doi.org/10.1680/jurdp.20.00025.

Afshari, Ali, Mahdi Vatanparast, and Dragan Ćoćkalo. "Application of multi criteria decision making to urban planning. A review." *Journal of Engineering Management and Competitiveness* 6, no. 1 (2016): 46–53. https://doi.org/10.5937/jemc1601046A.

Bendowska, Marta, Anna Bieńkuńska, Paweł Ciecieląg, Paweł Luty, Karol Sobesjański, and Joanna Wójcik. "Jakość życia w Polsce. Edycja 2017." Główny Urząd Statystyczny, 2017. Accessed May 2023, at https://stat.gov.pl/files/gfx/portalinformacyjny/pl/defaultaktualnosci/5486/16/4/1/jakosc_zycia_w_polsce_2017.pdf.

Bentley, Ian, Sue McGlynn, Graham Smith, Alan Alcock, and Paul Murrain (eds.). *Responsive environments: A manual for designers*. MPG Books, 2005.

Björnberg, Arne, and Ann Yung Phang. "Euro Health Consumer Index 2018." Health Consumer Powerhouse, 2019. Accessed May 2023, at https://sante.public.lu/dam-assets/fr/publications/e/euro-health-consumer-index-2018/euro-health-consumer-index-2018.pdf.

Blečić, Ivan, Arnaldo Cecchini, Tanja Congiu, Giovanna Fancello, and Giuseppe Trunfio. "Evaluating walkability: a capability-wise planning and design support system." *International Journal of Geographical Information Science* 29, no. 8 (2015): 1350–74. https://doi.org/10.1080/13658816.2015.1026824.

Błędowski, Piotr, Barbara Szatur-Jaworska, Rafał Bakalarczyk, Paweł Łuczak, Zofia Szweda-Lewandowska, Maria Zrałek, et al. *System wsparcia osób starszych w środowisku zamieszkania: przegląd sytuacji, propozycja modelu*. Biuro Rzecznika Praw Obywatelskich, 2016.

Brewer, Graham, Lynne Parkinson, Chris Tucker, and Chris Landorf. "Socially sustainable suburbia: Linking neighbourhood characteristics to health outcomes in an ageing population." *International Journal of Interdisciplinary Social and Community Studies* 8, no. 4 (2014): 1–18. https://doi.org/10.18848/2324-7576/CGP/v08i04/53522.

Cabała, Paweł. "Proces analitycznej hierarchizacji w ocenie wariantów rozwiązań projektowych." *Przedsiębiorstwo we współczesnej gospodarce – teoria i praktyka* 1 (2018): 23–33. https://doi.org/10.19253/reme.2018.01.002.

Centrum Badania Opinii Społecznej. "Zadowolenie z życia (Life satisfaction)." Komunikat z badań 2, 2020. Accessed May 2023, at https://cbos.pl/SPISKOM.POL/2020/K_002_20.PDF.

Cinelli, Marco, Miłosz Kadziński, Grzegorz Miebs, Michael Gonzalez, and Roman Słowiński. "Recommending Multiple Criteria Decision Analysis Methods with A New Taxonomy-based Decision Support System." arXiv (2021). https://doi.org/10.48550/arXiv.2106.07378.

Costa, Helder Gomes. "AHP-De Borda: A hybrid multicriteria ranking method." *Brazilian Journal of Operations & Production Management* 14, no. 3 (September 2017): 281–87. https://doi.org/10.14488/BJOPM.2017.v14.n3.a1.

Czapiński Janusz, and Tomasz Panek, eds. *Diagnoza społeczna 2015. Warunki i jakość życia Polaków. Raport.* Rada Monitoringu Społecznego, 2015. Accessed May 2023, at www.diagnoza.com/pliki/raporty/Diagnoza_raport_2015.pdf.

Czepkiewicz, Michał, and Piotr Jankowski. "Analizy przestrzenne w badaniach nad jakością życia w miastach." *Ruch Prawniczy, Ekonomiczny i Socjologiczny* 77, no. 1 (2015): 101–17. https://doi.org/10.14746/rpeis.2015.77.1.6.

Donder, Liesbeth, Tine Buffel, Sarah Dury, Nico De Witte, and Dominique Verté. "Perceptual quality of neighbourhood design and feelings of unsafety." *Ageing and Society* 33, no. 6 (2013): 917–37. https://doi.org/10.1017/S0144686X12000207.

The Economist Intelligence Unit. *The Global Liveability Index 2019*. (2019). Accessed May 2023, at https://www.cbeinternational.ca/pdf/Liveability-Free-report-2019.pdf.

Esmaeilpoorarabi, Niusha, Tan Yigitcanlar, and Mirko Guaralda. "Towards an urban quality framework: determining critical measures for different geographical scales to attract and retain talent in cities." *International Journal of Knowledge-Based Development* 7, no. 3 (2016): 290–312. https://doi.org/10.1504/IJKBD.2016.078556.

Eurofound. *European Quality of Life Survey 2016: Quality of life, quality of public services, and quality of society*. Publications Office of the European Union, 2017. https://doi.org/10.2806/964014.

European Commission. Directorate General for Regional Policy. *Quality of Life in Cities: Perception Survey in 79 European Cities*. Publications Office, 2013. Accessed May 2023, at https://data.europa.eu/doi/10.2776/79403.

Eurostat (European Commission). *Final Report of the Expert Group on Quality of Life Indicators: 2017 Edition*. Publications Office of the European Union, 2017. Accessed May 2023, at https://data.europa.eu/doi/10.2785/021270.

Federal/Provincial/Territorial Ministers Responsible for Seniors. *Age-friendly rural and remote communities: A guide*, 2007. Accessed May 2023, at https://www.phac-aspc.gc.ca/seniors-aines/alt-formats/pdf/publications/public/healthy-sante/age_friendly_rural/AFRRC_en.pdf.

Feng, I-Ming, Jun-Hong Chen, Bo-Wei Zhu, and Lei Xiong. "Assessment of and Improvement Strategies for the Housing of Healthy Elderly: Improving Quality of Life." *Sustainability* 10, no. 3 (2018): 722. https://doi.org/10.3390/su10030722.

Garau, Chiara, and Valentina Maria Pavan. "Evaluating Urban Quality: Indicators and Assessment Tools for Smart Sustainable Cities." *Sustainability* 10, no. 3 (2018): 575. https://doi.org/10.3390/su10030575.

Garcia, Davide Astiaso, Fabrizio Cumo, Elisa Pennacchia, Valentina Stefanini Pennucci, Giuseppe Piras, V. De Notti, and Rossella Roversi. "Assessment of a urban sustainability and life quality index for elderly." *International Journal of Sustainable Development and Planning* 12, no. 5 (2017): 908–21. https://doi.org/10.2495/SDP-V12-N5-908-921.

Gawlak, Agata, Magda Matuszewska, and Agnieszka Ptak. "Inclusiveness of Urban Space and Tools for the Assessment of the Quality of Urban Life. A Critical Approach." *International Journal of Environmental Research and Public Health* 18, no. 9 (2021): 4519. https://doi.org/10.3390/ijerph18094519.

Giles-Corti, Billie, Anne Vernez-Moudon, Rodrigo Reis, Gavin Turrell, Andrew L. Dannenberg, Hannah Badland, et al. "City Planning and Population Health: A Global Challenge." *The Lancet* 388, no. 10062 (2016): 2912–24. https://doi.org/10.1016/S0140-6736(16)30066-6.

Główny Urząd Statystyczny. "Jak się żyje osobom starszym w Polsce." 2012. Accessed May 2023, at https://stat.gov.pl/obszary-tematyczne/warunki-zycia/dochody-wydatki-i-warunki-zycia-ludnosci/jak-sie-zyje-osobom-starszym-w-polsce-,8,1.html.

Goepel, Klaus. "Implementation of an Online Software Tool for the Analytic Hierarchy Process (AHP-OS)." *International Journal of the Analytic Hierarchy Process* 10, no. 3 (2018): 469–87. https://doi.org/10.13033/ijahp.v10i3.590.

Hoornweg, Daniel, Lorraine Sugar, and Claudia Lorena Trejos Gómez. "Cities and Greenhouse Gas Emissions: Moving Forward." *Environment and Urbanization* 23, no. 1 (2011): 207–27. https://doi.org/10.1177/0956247810392270.

IMD World Competitiveness Center's Smart City Observatory, Singapore University of Technology and Design. "IMD Smart City Index". The IMD World Competitiveness Center, 2019. Accessed May 2023, at https://www.imd.org/research-knowledge/reports/imd-smart-city-index-2019/.

Kobryń, Andrzej. *Wielokryterialne wspomaganie decyzji w gospodarowaniu przestrzenią*. Difin, 2014.

Kubendran, Sindhu, Liana Soll, and Paul Irving. "Best Cities for Successful Aging 2017." Milken Institute, 2017. Accessed May 2023, at https://milkeninstitute.org/reports/best-cities-successful-aging-2017.

Lamura, Giovanni, and Andrea Principi. "2018 Active Ageing Index. Analytical Report." UNECE/ European Commission, 2019. Accessed May 2023, at https://unece.org/population/active-ageing-index.

Lowe, Melanie, Carolyn Whitzman, Hannah Badland, Melanie Davern, Lu Aye, Dominique Hes, et al. "Planning Healthy, Liveable and Sustainable Cities: How Can Indicators Inform Policy?" *Urban Policy and Research* 33, no. 2 (2015): 131–44. https://doi.org/doi:10.1080/08111146.2014.1002606.

Maleki, Saeid, Simon Bell, Seyedbagher Hosseini, Mohsen Faizi. "Developing and testing a framework for the assessment of neighbourhood liveability in two contrasting countries: Iran and Estonia." *Ecological Indicators* 48 (2015): 263–71. https://doi.org/10.1016/j.ecolind.2014.07.033.

Mathew, Manoj, Sahar Sahu, and Ashis Kumar Upadhyay. "Effect of Normalization Techniques in Robot Selection Using Weighted Aggregated Sum Product Assessment." *International Journal of Innovative Research and Advanced Studies* 4, no. 2 (2017): 59–63.

Mercer. "Quality of living – location reports." 2019. Accessed May 2023, at https://mobilityexchange.mercer.com/Insights/quality-of-living-rankings.

Miller, George A. "The magical number seven, plus or minus two: Some limits on our capacity for processing information." *Psychological Review* 63 (1956): 81–97. https://doi.org/10.1037/h0043158.

Monocle. *Quality of Life Survey*, 2019. Accessed May 2023, at https://monocle.com/film/affairs/quality-of-life-survey-top-25-cities-2019/.

Okulicz-Kozaryn, Adam. "City Life: Rankings (Livability) Versus Perceptions (Satisfaction)." *Social Indicators Research* 110 (2013): 433–51. https://doi.org/10.1007/s11205-011-9939-x.

Oppio, Alessandra, Marta Bottero, and Andrea Arcidiacono. "Assessing urban quality: a proposal for a MCDA evaluation framework." *Annals of Operations Research* 312 (2022): 1427–44. https://doi.org/10.1007/s10479-017-2738-2.

Oppio, Alessandra, Luca Forestiero, Loris Sciacchitano, and Marta Dell'Ovo. "How to assess urban quality: a spatial multicriteria decision analysis approach [Come valutare la qualità urbana: un approccio di analisi decisionale spaziale multi-criteriale per gli spazi aperti pubblici].” *Valori e Valutazioni* 28 (2021): 21–30. https://doi.org/10.48264/VVSIEV-20212803.

Organisation for Economic Cooperation and Development. “How’s Life? 2020: Measuring Well-being.” 2020. https://doi.org/10.1787/9870c-393-en.

Polityka and Akademia Górniczo-Hutnicza. “Ranking jakości życia. Wymiary szczęścia (Quality of life ranking. Dimensions of happiness).” 2018. Accessed May 2023, at https://prod-zmp.s3.pl-waw.scw.cloud/uploads/attachment/file/2367/RANKING_MIAST-Polityka.pdf?X-Amz-Expires=600&X-Amz-Date=20241028T103504Z&X-Amz-Algorithm=AWS4-HMAC-SHA256&X-Amz-Credential=SCWNS07DYNDXX7TN9XNZ%2F20241028%2F-pl-waw%2Fs3%2Faws4_request&X-Amz-SignedHeaders=host-&X-Amz-Signature=1d3f4e4017819275e26dbfa1b9fc78ca47c5895e2da9da16f24b5688531712e4.

Pörtner, Hans-Otto, Debra Cynthia Roberts, Melinda M.B. Tignor, Elvira S. Poloczanska, Katja Mintenbeck, Andrès Alegría, et al., eds. “Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change.” Cambridge University Press, 2022. Accessed May 2023, at https://www.ipcc.ch/report/ar6/wg2/downloads/report/IPCC_AR6_WGII_FrontMatter.pdf.

Ptak-Wojciechowska, Agnieszka. “Analiza wybranych narzędzi do ewaluacji jakości życia w mieście w kontekście zmian społeczno-demograficznych.” PhD thesis, Politechnika Poznańska, 2023.

Reid, Jim, Craig Nicol, and Henry Allen. “Mapping the World’s Prices 2019. Thematic Research.” Deutsche Bank AG, 2019. Accessed May 2023, at https://www.dbresearch.com/PROD/RPS_EN-PROD/PROD0000000000494405/Mapping_the_world%27s_prices_2019.pdf?undefined&realload=3Chhg5~gLR7mqW1YPu6b/QkVW2dz2c3l8UwI3sIOswl8TPRB07K7FDIulbgAewd~.

Rokicka, Ewa (red.). *Jakość życia mieszkańców Łodzi i jej przestrzenne zróżnicowanie*. Wydawnictwo Uniwersytetu Łódzkiego, 2013.

Saaty, Thomas L. “Absolute and Relative Measurement with the AHP. The Most Livable Cities in the United States.” *Socio-Economic Planning Sciences* 20, no. 6 (1986): 327–31. https://doi.org/10.1016/0038-0121(86)90043-1.

Stefanów, Piotr, and Anna Prusak. “Badania nad właściwościami operacyjnymi metody AHP”. *Folia Oeconomica Cracoviensia* 52 (2011): 87–104.

Trzaskalik, Tadeusz. “Wielokryterialne wspomaganie decyzji. Przegląd metod i zastosowań.” *Zeszyty Naukowe Politechniki Śląskiej. Organizacja i Zarządzanie* 74 (2014): 239–63.

United Nations. Department of Economic and Social Affairs, Population Division. “World Population Prospects 2020.” Accessed May 2023, at https://population.un.org/wpp/

United Nations. Department of Economic and Social Affairs. “World Population Prospects 2022: Summary of Results.” 2022. Accessed May 2023, at https://www.un.org/development/desa/pd/content/World-Population-Prospects-2022.

United Nations Development Programme. “Human Development Report 2019. Beyond income, beyond averages, beyond today: Inequalities in human development in the 21st century.” 2019. Accessed May 2023, at https://hdr.undp.org/content/human-development-report-2019.

Vitman Schorr, Adi, and Rabia Khalaila. “Aging in Place and Quality of Life among the Elderly in Europe: A Moderated Mediation Model.” *Archives of Gerontology and Geriatrics* 77 (2018): 196–204. https://doi.org/10.1016/j.archger.2018.04.009.

Wałachowski, Karol, and Sebastian Król. *Uciekające metropolie. Ranking 100 polskich miast*. Klub Jagielloński, 2019. Accessed May 2023, at https://klubjagiellonski.pl/publikacje/uciekajace-metropolie-ranking-100-polskich-miast/.

Wojnarowska, Anna. “Model for Assessment of Public Space Quality in Town Centers.” *European Spatial Research and Policy* 23, no. 1 (2016): 81–109. https://doi.org/10.1515/esrp-2016-0005.

World Health Organization. “Global Age-Friendly Cities: A Guide.” 2007. Accessed May 2023, at https://iris.who.int/bitstream/handle/10665/43755/9789241547307_eng.pdf?sequence=1.

World Health Organisation. “Measuring the age-friendliness of cities: a guide to using core indicators.” 2015. Accessed May 2023, at http://www.who.int/ageing/publications/measuring-cities-age-friendliness/en/.

Yigitcanlar, Tan, Md. Kamruzzaman, and Suharto Teriman. “Neighborhood Sustainability Assessment: Evaluating Residential Development Sustainability in a Developing Country Context.” *Sustainability* 7, no. 3 (2015): 2570–602. https://doi.org/10.3390/su7032570.

Zavadskas, Edmundas Kazimieras, Tatjana Vilutienė, Zenonas Turskis, and Jonas Šaparauskas. “Multi-Criteria Analysis of Projects’ Performance in Construction.” *Archives of Civil and Mechanical Engineering* 14, no. 1 (2014): 114–21. https://doi.org/10.1016/j.acme.2013.07.006.

Streszczenie

Wykorzystanie metody Analytic Hierarchy Process (AHP) do oceny jakości życia osób starszych w miastach pod względem aspektów architektoniczno-urbanistycznych

Miasta powinny zapewniać wysoką jakość życia wszystkim mieszkańcom. Mimo zachodzących zmian demograficznych tkanka urbanistyczna odpowiada w sposób niewystarczający na potrzeby przestrzenne seniorów. Brakuje ponadto naukowych instrumentów oceny, które mogłyby posłużyć za wsparcie w ocenie aspektów architektoniczno-urbanistycznych miasta, a w konsekwencji także w ich poprawie. Chociaż popularne rankingi miejskie mogą być wykorzystywane w rozwoju polityki miejskiej, ich wyniki są często nieprawidłowo interpretowane przez odbiorców. Zastosowanie metod wielokryterialnego wspomagania decyzji może ułatwić proces porównywania obszarów miasta, zwiększyć transparentność ewaluacji oraz zaangażować różnych interesariuszy w proces oceny. Uczenie maszynowe natomiast może stanowić interesujące rozszerzenie dla stosowanych powszechnie metod statystycznych. W artykule zaprezentowano najnowsze metody w badaniach nad miejską jakością życia seniorów na przykładzie wielokryterialnej analizy pięciu osiedli miasta Poznania. Omówiono wykorzystanie metody analytic hierarchy process (AHP) jako części autorskiego narzędzia do oceny percepcyjnej przez starszych mieszkańców, a także oceny eksperckiej przez architektów i urbanistów pod względem aspektów funkcjonalno-przestrzennych. Dowiedziono skuteczności metody AHP – rezultaty mogą stanowić wsparcie dla władz miasta, projektantów i badaczy. Przedstawiono ponadto kierunki rozwoju niniejszych badań z zastosowaniem metod uczenia maszynowego.

Słowa kluczowe: metody partycypacyjne, metody wielokryterialne, jakość życia w miastach, uczelnie maszynowe, starzejące się społeczeństwo