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Housing and neighbourhood diagnosis for ageing in place: Multidimensional Assessment System of the Built Environment (MASBE)

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ABSTRACT

Current urban, health and social challenges demand new multidisciplinary assessment systems for decision-making in the built environment from the perspective of the elderly, as an even more vulnerable population. This research contributes with a Multidimensional Assessment System of the Built Environment (MASBE) that provides an integral diagnosis on the perceived suitability of urban and housing environments for an ageing population, whose novel approach is structured and weighted through 35 multidisciplinary variables that are organised in seven dimensions: design, accessibility, comfort, maintenance, security and health, use and control, and stimulus. The system is applied and tested in reference case studies from Spain and Mexico, in order to demonstrate its operation and replicability. The weighted and displayed results help to identify the weaknesses and strengths of each application scale, obtaining average values far from 7.50, as the ideal value for ageing in place, and certain dimensions below 5.00, discussing through a sensitivity analysis the main influencing factors, health risks and major demands of elderly residents before deciding action strategies. The key outcomes incorporate useful implications for policy-makers, promoters and construction firms by enabling assessment procedures to adapt urban and housing spaces for the elderly, thereby ensuring satisfactory proposals in the built environment.

1. Introduction

The United Nations (2019) has recently set as one of the main urban and social targets of the 21st century the design and development of appropriate technical, social and economic tools and procedures to carry out an integrated urban regeneration that guarantees the sustainable development of existing cities. World reports warn of urban obsolescence stating that more than 40% of the building stock was built more than 50 years ago, and around 85% from Europe is currently over 20 years old (United Nations, 2018), which involves important regulatory non-compliances and daily inconveniences for users in existing urban environments that should be solved from multiple approaches (European Parliament, 2016; IEA, 2017).

Furthermore, the World Health Organization describes the global population ageing as an emerging process whose proportion of people over 65 years old could double from 20 to 40% between 2020 and 2050 (WHO, 2015). Regarding the built environment, lack of access to basic services or isolation caused by urban constraints strongly affect the physical and emotional wellbeing for the elderly (Ibarloza, Malles, Ibarloza, & Heras-Saizarbitoria, 2018). In fact, if renovating buildings instead of making new constructions was already necessary in order to reduce the use of natural resources, energy and CO₂ emissions, it has now become even more important to adapt living conditions in urban and housing spaces for the elderly to keep them from having to move to other spaces such as nursing homes. This is now a key challenge, not only in the environmental and economic sense but also in the social sense (European Commission, 2017).

Aiming to measure how the age-friendly existing urban and housing environments already are (WHO, 2016), the literature review developed for this paper highlights that there is currently a lack of research that fully assesses the set of urban and social qualities and attributes of the built environment for the ageing population, so extensive research and new assessment models are required to gather, organise and quantify the diverse qualitative and quantitative dimensions related to the needs of the elderly, offering policy-makers, promoters and users a broad diagnosis that would identify the strengths and weaknesses of each urban scale to promote appropriate renovation strategies for ageing in place and improve their quality of life.

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This paper fulfils this research gap by designing, adjusting, and testing a Multidimensional Assessment System of the Built Environment (MASBE), a new assessment model that provides multidisciplinary information of the acceptance and perceived suitability of the elderly with respect to their housing and neighbourhood scales. The proposed system aims to define and organise the way of quantifying multiple urban, environmental and social attributes related to housing and urban environments based on data obtained from participatory questionnaires, testing its operation in three case studies that belong to different urban models from Spain and Mexico, whose results discuss demonstrate its replicability in every geographical context.

The novelty of the MASBE system is that it establishes the mechanisms to consider a complete diagnosis from the elderly regarding their built environment, as a support system for selecting satisfactory regeneration and renovation strategies that promote ageing in place, and also addresses the complexity of adjusting diverse relevant factors by defining an innovative way of quantifying 35 multidisciplinary variables, both quantitative and qualitative, structured in 7 relevant dimensions: 1. Design, 2. Accessibility, 3. Comfort, 4. Maintenance, 5. Health and safety, 6. Use and control and 7. Stimulus.

As its main contribution, the MASBE system offers a multidimensional diagnosis to policy-makers, promoters and construction firms for designing specific guidelines and renovation works to reduce the vulnerability of the elderly in the built environment. Besides, the advantages of using the MASBE system are based on identifying the main influencing factors, health risks and the major demands of the residents before determining urban regeneration and renovation proposals, offering new theoretical perspectives on the usefulness of combining urban and social dimensions when evaluating public spaces and buildings concerning the elderly, and finally introducing policy contributions for the design and establishment of urban strategies and regulations specifically adapted for the ageing population.

The following sections present related research in a literature review, define the operation of the MASBE model, the selected variables and dimensions, and its application on three case studies. The key outcomes and the main conclusions and contributions will be finally discussed.

2. Literature review

Table 1 organises and classifies the main literature review, defining the advantages and disadvantages of different past studies based on their research topics. The selected works represent novel insights, approaches and advances from different past studies that are going to be discussed to justify and demonstrate the need to carry out this research paper.

Carrying out further analysis of the addressed topics, demographic trends and social challenges lead to incorporating new concepts in the urban regeneration guidelines, such as the “ageing in place” (European Commission, 2012), which involve analysing physical, social and emotional dimensions of the housing stock, aiming to promote active ageing through age-friendly interventions (IMSESO, 2011). Although the elderly population were already considered vulnerable, the recent COVID-19 health crisis has affected to this demographic sector further, so the management of the built environment for the elderly will play a key role in the coming development of cities and society (WHO, 2020). Thus, all the referenced studies on ageing in place agree that population ageing is connected to the deterioration of urban spaces and buildings, so this situation generates new procedural demands to supply the main needs of the elderly (European Commission, 2015).

Aiming to carry out an effective and sustainable urban regeneration in the built environment, most referenced works in Table 1 state that proposals for action need to be considered after a multidisciplinary assessment of technical, social, economic and environmental impact for each strategy through decision support systems, as claimed in Femenías, Mjornell, and Thuvander (2018); Kumar, Ramkumar, and Samanta (2018) or Pombo, Rivela, and Neila (2016), but a higher influence from users’ demands regarding urban regeneration and housing

| Table 1 Classification of related research regarding their advantages and disadvantages based on their topics. |
|-------------------------------|-----------------------------------------------|
| **Topic**                      | **Research paper**                          | **Advantages/Disadvantages**                                      |
| Ageing in place                | Pani-harreman, Bours, and Zander (2020)     | Highlights the multidisciplinary complexity that entails ageing in place. |
|                               | Stafford and Gulwadi (2020)                 | Might have provided more practical support on ageing for policy-makers. |
|                               | Weil (2019)                                 | State that habitacional resilience links ageing and the built environment. |
|                               | Fang et al. (2016)                          | The concept requires formalising a strategy to improve ageing in place. |
|                               | Rodríguez-Rodríguez and Sánchez-González (2016) | Incorporate gentrification of cities into the complexity of ageing in place. |
|                               | Femenías et al. (2018)                      | Highlights the value of designing sustainable environments for the elderly. |
|                               | Kumar et al. (2018)                         | Incorporate community-based participatory research for ageing in place. |
|                               | Garrido-pinto and Mercader-moyano (2017)    | Initiatives for policy and practice on ageing to improve quality of life. |
|                               | Camporeale, Mercader-Moyano, and Czajkowski (2017) | Demand specific methodological tools in Mediterranean Europe and Latin America housing environments for the elderly. |
|                               | Pombo et al. (2016)                         | Environmental, social and cultural aims from owners for housing renovation. |
|                               | Tao, Gou, Yu, Fu, and Chen (2020)           | Theoretical reflection on deep renovation works, introducing different levels. |
|                               | Serrano-Jiménez et al. (2019)               | Identify 7 criteria and 27 variables related to socio-technical perspectives. |

Research framework uniquely focused on building renovation in India. Multidisciplinary assessment of eco-efficient actions in social housing. Users’ demands are not included in the design of renovation interventions. Multi-objective optimisation method for decision-making applied in Spain. Absence of social patterns for assessing certain renovation works. Key methodological aspects of assessment methods in housing renovation. Multidisciplinary criteria and future prospects on building renovation. Address the aim of designing liveable indoor environments for the elderly. Occupancy survey to assess just thermal, lighting and noise conditions. Combine technical diagnosis and residents’ perceptions of decision-making.

(continued on next page)
3. Methodology

This section presents the MASBE method, defining the set of dimensions and their weighting expressions for their correspondent group of variables. Fig. 1 represents a general outline of the proposed system, defining a background that meets the starting conditions of the built environment and the demographic trends (Step 0), the operation of the system based on 35 urban and social variables organised in seven dimensions (Step 1.A.), the definition of two urban application scales along with a participatory questionnaire (Step 1.B.), and finally the application and testing procedure of the MASBE system (Step 2) as well as the contribution as decision support of the obtained results (Step 3). The following subsections define the scope of application, the selected case studies and the application procedure for obtaining the multidisciplinary results.

3.1. Multidimensional assessment system for the built environment (MASBE)

This new assessment system for public spaces and housing environments incorporates a novel approach with multiple variables that have been organised into seven key dimensions. The dimension is a novel concept whose aim is to organise the diversity of disciplines (technical, economic, social, gerontological...) that influence elderly people to manage the built environment and face urban regeneration through an integrated and cross-disciplinary approach.

The selected dimensions are design, accessibility and mobility, comfort, maintenance, security and health, use and control, and stimulation. A comprehensive assessment model, as a decision support system, that would gather a broad multidimensional perspective to understand the performance of the built environment, both in public space and building scales, with respect to current needs and the demands of the elderly.

Table 2 defines all the variables considered for each dimension, and subsequently presents the procedure for quantifying the responses obtained from the participants, using a Likert scale between 1–5, whose values are adjusted to the degrees of satisfaction exposed in the questionnaire, and weighting all these dimensions to obtain a standardised

| Topic | Research paper | Advantages/Disadvantages |
|-------|----------------|--------------------------|
| Indicators - Decision support systems | Jiao et al. (2017) | Study focused on a single country and only on thermal comfort. Includes users’ perceptions and feelings in outdoor spaces with indicators. |
| | Shooshtarian and Ridley (2016) | Application study in the educational field but with flexible patterns. Review of decision support tools in building renovation based on six areas. |
| | Nielsen et al. (2016) | Demand for new tools with social issues in renovation projects. Renovation strategies considering social aspects and cultural heritage factors. Particular study in Vienna, not an assessment model that could be replicated. |
| | Kovacic et al. (2015) | |
| | Monzón and López-Mesa (2018) | Applied in a single study without including social or economic issues. Assess and compare the influence of maintenance on building performance. Unique approach to cost-optimal from a technical point of view. Thermal comfort and occupant behaviour of the elderly are quantified. |
| | Farahani et al. (2018) | Survey conducted in a city and using a Likert scale to assess the subjective approach to the built environment. |
| | Ruza et al. (2014) | Application in a case study with users, academics and professional experts. Overview of indicator categories that can quantify the building performance. |
| | Maslesa, Jensen, and Birkved (2018) | There are no specific approaches to the built environment and the elderly. Different indicators to measure the obsolescence of residential buildings. |
| | Serrano-Jiménez et al. (2018) | Absence of certain social parameters and attributes for ageing in place. Quantify the "age-friendliness" of cities based on the results of a survey. |
| | Mujan, Andelković, Munican, Kljašić, and Ruzić (2019) | Reviews numerous works and affirm the need to carry out participatory surveys to assess indoor environmental quality for health and productivity. Base the diagnosis according to technical and social results in a survey. |
| | Kovacic et al. (2015) | Reduced approach on social indexes for the complex building renovation. |
| | Nielsen et al. (2016) | |
scale between 0 and 10. The calculations are obtained by assigning a score for each variable ($w_i$) with respect to each maximum score and then weighting all of them ($w_j$). The dimensions are defined as follows:

**Design ($w_{D1}$)** evaluates urban attributes related to the morphology and building typology and includes an assessment of diverse layout patterns related to the location, urban space, size and also the assessment of the indoor distribution, furniture and devices.

**Accessibility & mobility ($w_{D2}$)** is considered a dimension that is focused on rating daily success or inconveniences in daily journeys, regulatory non-compliances and deficiencies regarding these technical conditions from the elderly perspective, by assessing the absence of barriers, the topography, as well as quantifying their perceived quality of pathways and routes.

**Comfort ($w_{D3}$)** is a dimension that values quantitative and qualitative aspects of comfort in urban and housing environments in terms of temperature levels, air renovation rates, lighting, noise and also indoor or outdoor environmental quality.

**Maintenance ($w_{D4}$)** gathers technical and architectural factors that qualify the conservation status, maintenance and repair works required in public spaces, buildings and dwellings.

**Security & health ($w_{D5}$)** assesses the perceived security and health of the elderly regarding urban and housing environments, taking into account variables related to safety, privacy, avoiding conditions to prevent falls, green spaces or sanitary services which lead to higher well-being.

**Use & control ($w_{D6}$)** quantifies the management in the daily use and control of the public space and dwellings, quantifying the perceived quality of life in their usual housing environments, the correct development of frequent activities, support elements, basic services or the sense of independence and control that elderly people feel in both urban scales.

**Stimulus ($w_{D7}$)** is considered a sensory attribute of the elderly with respect to the built environment that is usually determined by environmental feelings, including materials, textures, visual aesthetics, as well as the place attachment and their social relationships, that lead them to stimulate their living emotions regarding the built environment.

### 3.2. Case studies of application

In order to test the operation of the MASBE system, three case studies have been selected from Spain and Mexico that incorporate representative patterns of social housing in the built environment (United Nations, 2018), which were built at least 40 years ago and involve obsolete environments with difficulties in achieving adequate living conditions for the elderly. Seville and Mexicapan are cities of great architectural, urban and historical value, which implies a high level of tourist activity that impacts the elderly inhabitants in many dimensions (CONAPO, 2016; IECA, 2016). Furthermore, there are also similarities in the cultural background and a large percentage of an ageing population are represented in both countries (García-Valdez, Sánchez-González, & Román-Pérez, 2019), and the vulnerability of this population group in housing and urban environments has increased recently (Government of Mexico, 2018), even more after the huge impact of the global health crisis.

The aim to check the procedure and the weighted results in diverse urban typologies and socioeconomic contexts has led to extend the scope of application and select a historical neighbourhood, where the lack of renovation works and the percentage of ageing population are significant, and two recent urban extensions from Spain and Mexico that were
Table 2
Dimensions, variables and weighting expressions of the MASBE system.

| Dimension | Variables | Neighbourhood-Public space | Housing-Dwelling |
|-----------|-----------|-----------------------------|------------------|
| 1. Design | w_01 = \sum (w_i)_{2,4,5} / \sum w_i \times 10 | 1) Urban composition and design | 1) Architectural typology |
|           |           | 2) Location and orientation | 2) Location and orientation |
|           |           | 3) Size and scale | 3) Size and number of apartments |
|           |           | 4) Infrastructures and facilities | 4) Indoor distribution |
|           |           | 5) Urban furniture | 5) Furniture and devices |
| 2. Accessibility & Mobility | w_{02} = \sum (w_i)_{7,8,9,10} / \sum w_i \times 10 | 6) Access to Neighbourhood | 6) Access to the dwelling |
|           |           | 7) Absence of physical barriers | 7) Absence of physical barriers |
|           |           | 8) Topography | 8) Unevenness/slopes |
|           |           | 9) Urban mobility and transport | 9) Indoor mobility |
|           |           | 10) Pathways and routes | 10) Useful space and widths |
|           |           | 11) Sun/Shadow spaces | 11) Temperature |
| 3. Comfort | w_{03} = \sum (w_i)_{12,13,14,15} / \sum w_i \times 10 | 12) Relative Humidity | 12) Air renewal |
|           |           | 13) Natural/Artificial lighting | 13) Natural/artificial lighting |
|           |           | 14) Silence/Disturbance | 14) Silence/Disturbance |
|           |           | 15) Outdoor air quality | 15) Indoor air quality |
|           |           | 16) Basic maintenance and care | 16) Basic maintenance and care |
|           |           | 17) Conservation status | 17) Conservation status |
|           |           | 18) Repair works | 18) Repair works |
|           |           | 19) Adaptation works | 19) Adaptation works |
|           |           | 20) Needs for services and equip. | 20) Heating-Cooling devices |
|           |           | 21) Urban security | 21) Housing security |
| 4. Maintenance | w_{04} = \sum (w_i)_{15,16,17,18,19,20} / \sum w_i \times 10 | 22) Privacy | 22) Privacy |
|           |           | 23) Accident/fall avoiding condit. | 23) Accident/fall avoiding condit. |
|           |           | 24) Vegetation-Green areas | 24) Vegetation and open spaces |
|           |           | 25) Health care services | 25) Space for emergency access |
|           |           | 26) Self-perceived quality of life | 26) Self-perceived quality of life |
| 5. Security & Health | w_{05} = \sum (w_i)_{22,23,24,25} / \sum w_i \times 10 | 27) Development of daily use | 27) Development of daily use |
|           |           | 28) Use of basic services | 28) Use of basic services |
|           |           | 29) Support and control elements | 29) Support and control elements |
|           |           | 30) Cleaning | 30) Cleaning |
|           |           | 31) Place attachment | 31) Housing attachment |
| 6. Use & Control | w_{06} = \sum (w_i)_{26,27,28,29,30} / \sum w_i \times 10 | 32) Visual aesthetics | 32) Visual aesthetics |
|           |           | 33) Materials | 33) Materials |
| 7. Stimulus | w_{07} = \sum (w_i)_{32,33,34,35} / \sum w_i \times 10 | 34] Textures and colours | 34] Textures and colours |
|           |           | 35] Social relationships | 35] Neighbourhood communities |

Table 2 (continued)

| Dimension | Variables | Neighbourhood-Public space | Housing-Dwelling |
|-----------|-----------|-----------------------------|------------------|
| 3.3. Participatory survey and data collection | | | |

The survey was made up of selected questions that correspond to a detailed evaluation of each of the variables fixed in Table 2, regarding their degree of satisfaction or perceived quality on a 5-point Likert scale, for subsequent correlation and weighting on a final scale of each dimension between 0 and 10. For its confirmation, the survey was assessed and checked in a pre-test on 10 elderly residents to make it as understandable and readable as possible.

The survey, which is divided into two main scales and is attached as supplementary material, contains the parameters previously established as variables in Table 2 to assess the suitability of public space and housing environments, also taking into account sociodemographic, health and dependency variables. The application of the final questionnaire was carried out physically with visits and interviews, as well as using virtual platforms through Google Forms to facilitate the percentage of participation and concentration of data. The number of responses exceeded at least 60 participants over 65 years old in the three cases, obtaining in Case 2 “Bermejales” more than 100 responses. The proportion of participants has been established in the three case studies built during the second half of the 20th century (Fig. 2), allowing for a comparison and discussion between them regarding the obtained multidimensional performance. Each case study is further defined below:

a) Encarnación. Representative urban district located in Seville, in one of the largest historical centres in Europe. The urban morphology corresponds to the Islamic urban patterns, with massive occupation levels that correspond to narrow streets, irregular blocks and the existence of small open spaces and squares. Most buildings have not had renovation works performed in them for at least 50 years, and most of them present more than 3 storeys. The elderly population is over 20% and the average age is 46 years old (INE, 2013). It is one of the most touristic and commercial areas of Seville, with few green areas and generally big congestion for the elderly.

b) Bermejales. Residential neighbourhood located in the south of Seville that was built during the 80 s. The urban morphology presents much more regular blocks, uniform distribution and a wide provision of services, green areas and infrastructures. The buildings are generally around 40 years old and the elderly population is important (15%) but does not reach the levels of historical districts. The remote situation with respect to the city centre and tourist areas makes it mainly residential, without contributing to gentrification.

c) Mexicapan. Residential area located in the north of the state of Zacatecas, in Mexico, that was designed and built in the 50 s and 60 s. Its urban morphology corresponds to the commonly known as “broken plate”, a high-density settlement in its occupation, irregularly shaped blocks, irregular topography, narrow streets and few urban empty spaces. This neighbourhood combines historical patterns with a peripheral belt, where there is a considerable concentration of elderly residents in conditions of vulnerability. The buildings are generally two or three storeys tall and the elderly represent between 12 and 18% of the residents. The neighbourhood is one of the oldest of this city, purely residential, close to the historical and commercial areas of the city.
around 20% concerning the total sample size of the elderly population in the selected area, which is considered a representative sample in the ageing population to obtain an integral diagnosis. It should be noted that the physical surveys were collected from people on the streets or public places that were near their homes, in the same neighbourhood, at different times of the day.

Once the data were collected both physically and online via Google Forms, a multi-criteria analysis of up to 140 parameters of the questionnaire applied in the SPSS statistical analysis tool was obtained, developing multiple correlations that provided certain new factors that have been included into the group of selected variables. Finally, by counting surveys a complete diagnosis is obtained from the perspective of the elderly, which provides useful information from multiple disciplines that allows to identify particularities of the area not detected by technicians or construction firms to decide on renovation strategies.

4. Results and discussion

This section presents the results of testing the system in the selected three case studies. Based on the organisation of the MASBE model, Table 3 details the results for each case study, which are structured according to both application scales for each variable and dimension. The results show the rating values on a weighted scale between 0 and 10, considering that for appropriate ageing in the place it would have to

Table 3
Main results of each urban scale and case study using the MASBE system.

| Dimension | Variables                                      | Case study | Variables                                      | Case study |
|-----------|------------------------------------------------|------------|------------------------------------------------|------------|
|           | Neighbourhood-Public space                      | A)Enc. B) Ber. C)Mex. | Building-Dwelling                               | A)Enc. B) Ber. C)Mex. |
| 1. Design | 1) Urban composition and design                 | 7.30 5.76 5.10 | 1) Architectural typology                      | 5.86 5.62 5.57 |
|           | 2) Location and orientation                     | 6.82 5.72 4.37 | 2) Location and orientation                    | 6.72 5.43 4.39 |
|           | 3) Size and scale                              | 7.21 6.40 4.83 | 3) Size and number of apartments               | 5.03 6.54 4.83 |
|           | 4) Infrastructures and facilities               | 6.43 5.05 5.38 | 4) Indoor distribution                         | 6.14 6.87 6.47 |
|           | 5) Urban furniture                             | 7.11 6.62 6.88 | 5) Furniture and devices                       | 5.17 5.37 3.71 |
|           | 6) Access to neighbourhood                     | 5.01 5.05 4.88 | 6) Access to the dwelling                      | 1.29 3.17 5.10 |
|           | 7) Absence of physical barriers                | 5.14 6.30 4.88 | 7) Absence of physical barriers                | 5.38 6.22 5.00 |
| 2. Accessibility & Mobility | 8) Topography                   | 1.29 3.17 5.10 | 8) Unevenness/slopes                           | 5.84 6.86 4.20 |
|           | 9) Urban mobility and transport                 | 3.74 5.76 6.31 | 9) Indoor mobility                             | 4.89 6.32 5.31 |
|           | 10) Pathways and routes                        | 7.19 6.55 7.02 | 10) Useful space and widths                    | 6.87 6.15 6.27 |
|           | 11) Sun/Shadow spaces                          | 6.24 6.52 7.18 | 11) Temperature                                | 7.66 6.04 4.91 |
|           | 12) Relative Humidity                          | 6.92 5.00 6.25 | 12) Air renewal                                | 4.44 5.69 6.02 |
| 3. Comfort | 13) Natural/Artificial lighting                | 5.97 6.40 7.13 | 13) Natural/Artificial lighting                | 6.91 6.79 6.08 |
|           | 14) Silence/Disturbance                        | 6.22 5.05 6.35 | 14) Silence/Disturbance                       | 6.29 7.42 4.58 |
|           | 15) Outdoor air quality                        | 6.29 5.76 6.31 | 15) Indoor environmental quality               | 5.12 6.44 4.73 |
|           | 16) Basic maintenance and care                 | 4.92 6.54 4.36 | 16) Basic maintenance and care                 | 6.28 6.94 6.52 |
|           | 17) Conservation status                        | 4.29 6.18 5.45 | 17) Conservation status                       | 4.58 5.84 4.57 |
| 4. Maintenance | 18) Repair works                     | 4.11 5.30 4.48 | 18) Repair works                              | 3.84 4.45 4.81 |
|           | 19) Adaptation works                           | 3.74 5.62 4.32 | 19) Adaptation works                          | 4.16 5.20 3.54 |
|           | 20) Needs for services and equip.              | 4.58 6.03 4.15 | 20) Heating-Cooling devices                   | 1.26 1.99 2.53 |
| 5. Security & Health | 21) Urban security                           | 6.02 5.95 6.19 | 21) Building security                         | 5.64 6.66 5.85 |
|           | 22) Privacy                                   | 5.69 6.11 5.90 | 22) Privacy                                   | 7.37 7.69 7.23 |
|           | 23) Accident/fall avoiding condit.             | 4.33 5.95 5.62 | 23) Accident/fall avoiding condit.             | 5.29 5.59 5.37 |
|           | 24) Vegetation-Green areas                    | 5.20 6.31 6.24 | 24) Vegetation and open spaces                 | 5.48 5.51 6.31 |
|           | 25) Health care services                       | 6.74 7.15 5.05 | 25) Space for emergency access                 | 5.12 6.81 6.92 |
|           | 26) Self-perceived quality of life             | 8.04 6.89 3.86 | 26) Self-perceived quality of life             | 5.23 6.83 4.51 |
|           | 27) Development of daily use                  | 6.56 5.42 6.58 | 27) Development of daily use                  | 6.05 7.04 5.25 |
| 6. Use & Control | 28) Use of basic services                    | 6.72 5.55 4.87 | 28) Use of basic services                     | 6.27 6.79 6.56 |
|           | 29) Support and control elements              | 4.14 3.30 4.25 | 29) Support and control elements              | 3.46 4.48 3.16 |
|           | 30) Cleaning                                  | 6.29 5.55 5.97 | 30) Cleaning                                  | 6.21 7.01 4.73 |
|           | 31) Place attachment                          | 4.57 6.36 6.59 | 31) Building attachment                       | 7.60 5.56 7.00 |
|           | 32) Visual aesthetics                          | 6.11 7.38 6.08 | 32) Visual aesthetics                         | 5.78 5.17 6.59 |
| 7. Stimulus | 33) Materials                                 | 5.86 4.98 6.85 | 33) Materials                                 | 6.69 5.03 6.51 |
|           | 34) Textures and colours                      | 5.99 6.31 6.29 | 34) Textures and colours                      | 6.61 3.83 6.46 |
|           | 35) Social relationships                      | 5.32 6.65 7.20 | 35) Neighbour communities                     | 7.14 5.29 7.21 |

Fig. 2. Aerial images of the three selected case studies in Spain and Mexico.
which it is located (specific guidelines for the elderly, improving the sustainable management of urban regeneration strategies in each case study and adopt the key outcomes of the methodology since it allows to detect the points main dimensions has been designed. Subsequent Figs. 3-5 represent the following sensitivity analysis in each application scale and case study.

As a way to offer a better understanding of the results obtained in this MASBE system, a graphical display of results according to the seven main dimensions has been designed. Subsequent Figs. 3-5 represent the ratings obtained for each scale in the three selected cases. This graphical display of results is already considered a novel contribution and one of the key outcomes of the methodology since it allows to detect the points of weakness or strength each case and dimension, which conditions the planning of urban regeneration strategies in each case study and adopt specific guidelines for the elderly, improving the sustainable management of cities.

According to the results obtained in the neighbourhood scale of Case A "Encarnación" (Fig. 3a), there is an important variation between dimensions, with a great valuation in the design of the urban context in which it is located (w_1 = 7.0) and the perceived quality of life in the use & control dimension (w_5 = 6.4), mainly due to the central and historical situation of one of the most important neighbourhoods in Seville. However, there is a significant deficiency related to the maintenance of urban space (w_4 = 4.5), due to the deteriorated state of many elements and the adaptation needs of a historic district for the correct mobility of the ageing population. The assessment of safety and health (w_6 = 5.6) and the stimulus (w_7 = 5.6) are also reduced due to the tourist occupation, where the feeling of belonging and identity are diluted in elderly residents.

As for the housing scale in case A (Fig. 3b), the results are highly differentiated with respect to the neighbourhood scale, with an average assessment very far from the 7.50 value estimated as ideal value for ageing in place. There are dimensions with remarkable low scores, such as accessibility and mobility (w_2 = 4.9), since these old buildings present important physical barriers which evolve into daily problems for indoor mobility and access to buildings. The maintenance valuation is also outstanding (w_4 = 4.0) in buildings that need major repairs and renovations, as well as specific adaptation measures according to the demands of users. On the other hand, the stimulus level of the elderly is positive (w_7 = 6.8), having a high place attachment and close emotional feelings to their housing environment. The elderly also highlight other dimensions such as comfort (w_3 = 6.1), safety and health (w_8 = 5.8) and design (w_5 = 5.8), whose historic buildings were built with good features, large spaces in indoor distribution, and quality materials, although their current conservation status is deteriorated and obsolete.

Regarding Case B "Bermejales" (Fig. 3a), the results obtained in the set of dimensions are homogeneous, with a low-medium performance that corresponds to an ordered urban model and with higher benefits in the existing services but without recognising other favourable qualities that a historical district would have. The dimensions of comfort (w_3 = 6.0), safety and health (w_5 = 6.3) and stimulus (w_7 = 6.3) are highlighted, representing positive perceptions of the elderly population regarding the design of urban space, green areas, materials or visual aesthetics. In contrast, there are important reluctances with lower values regarding the design (w_3 = 5.6), mainly due to the location with respect to the city centre, or the use and control (w_6 = 5.3) with deficient support elements for the ageing residents and a lower perceived satisfaction compared with case A despite having better services, quality and benefits in public space.

Concerning the housing scale in case B (Fig. 3b), the results are more favourable than for the public space, with buildings that were built around 30 years ago and present higher levels in their design patterns (w_3 = 6.3), adequate features related to comfort (w_5 = 6.5) and regarding safety and health (w_5 = 6.5). There are also certain reluctances regarding the accessibility and mobility of the elderly (w_2 = 5.7), although with a better assessment in comparison with historical buildings. There are also negative values related to maintenance (w_4 = 4.9), with significant repair and adaptation demands in housing spaces, and lower stimulus levels (w_7 = 5.0) regarding materials, the visual aesthetics and the textures and colours in the respective buildings.

Finally, results obtained in Case C "Mexicapan" on the neighbourhood scale show significant differences between the selected dimensions, with obtained values in a range between 6.8 and 4.7 and whose mean value is lower than the rest of the cases and quite far from the ideal standard for ageing in place. There are unfavourable values in the assessment of the urban morphology, the location and the urban space design (w_1 = 4.9) and also regarding the conservation status, repair needs and maintenance (w_4 = 4.7). The ageing population shows higher values regarding comfort (w_3 = 6.8) and stimulus (w_7 = 6.6) dimensions, which evidence the beneficial perception of outdoor environmental conditions for the elderly in the Mexican urban morphology which is characterized by narrow streets, with important social relationships and identity and with a remarkable place attachment as remarked from the elderly responses.

Regarding the housing scale in Case C, the elderly participants
expose a lower valuation regarding design ($w_{D1} = 5.0$), accessibility and mobility ($w_{D2} = 5.2$), comfort ($w_{D3} = 5.3$), maintenance ($w_{D4} = 4.4$) and use and control ($w_{D6} = 4.8$), admitting worse architectural and environmental features of the dwellings for their wellbeing and the correct development of the daily activities. Despite these results, better values are obtained in social and perceptual dimensions, such as safety and health ($w_{D5} = 6.3$), and mainly regarding the stimulus ($w_{D7} = 6.8$), obtaining high ratings regarding place attachment and social relationship in neighbourhood communities.

The application of the system in neighbourhoods from Spain and Mexico demonstrates the operation of the system and shows certain variations between dimensions for each urban and socioeconomic context, fulfilling the demands of a new decision support system for the built environment as launched by Nielsen, Jensen, Larsen, and Nissen (2016). Although the age of participants is similar, there are important differences between those who live in the city centre and those who live on the outskirts. The results of this study go beyond the insights developed in studies such as Monzon & Lopez-Mesa (2018) or Maslesa et. al (2018), offering information that pertains to the performance that considers the specific conditions of the built environment and elderly users, and also evidenced that the final diagnosis is linked to the particular demands, sensory feelings and behaviour of the ageing population from each context, as Santangelo and Tondelli (2017) pointed out in their work.

Lastly, the main results have validated what mentioned research studies like Kumar et al. (2018) and Shooshtarian and Ridley (2016), that certain parameters greatly influence on the building performance, based on variables and dimensions. On the one hand, this system demonstrates that technical parameters, such as the year of construction, the location, the architectural patterns and the urban model condition the design, accessibility and mobility, comfort or maintenance, which are fundamental dimensions for the daily use of this vulnerable population (Ibarloza et al., 2018; Kovacic, Summer, & Ahammer, 2015). On the other hand, those sensory feelings from the elderly are also combined with technical factors through different variables related to use and control, safety and health or stimulus dimensions, being considered essential perceptions to guarantee the wellbeing and the development of daily activities for the elderly and following the expectations pointed out in their models Ruza et al. (2014) or Serrano-Jiménez, Lima, Molina-Huelva, and Barrios-Padura (2019). Thus, the combination of physical and emotional diagnosis, through the weighted responses of elderly residents in different contexts, provide key outcomes of this MASBE system for adjusting urban regeneration strategies to adequately ageing in place, as Stafford and Gulwadi (2020) claimed and concluded in their work.

5. Conclusions

The Multidimensional Assessment System of the Built Environment (MASBE) provides multidisciplinary information regarding the
conformity and perceived suitability for the elderly concerning their built environment. This research paper addresses current urban and social challenges that demand new assessment models for existing housing and neighbourhood scales and consider the ageing context in the demographic trend, aiming to promote a sustainable and satisfactory regeneration of cities.

The research contributes to establishing required participatory models and weighting procedures for obtaining a multidimensional diagnosis in the built environment from the needs of the elderly, which introduces theoretical and practical insights for policy-makers, promoters and construction firms to be combined with technical reports in order to facilitate the decision-making process. The provided diagnosis enables the promotion of sustainable development in the regeneration of urban and housing spaces by identifying the main influencing factors, health risks and major demands of elderly residents prior to the design of urban regeneration and renovation proposals.

The innovative aspect of this assessment system is that it considers a novel organisation and rating procedure from multiple approaches, assessing and quantifying 35 urban, social and environmental variables, both qualitative and quantitative, that are organised into seven key independent dimensions, which correspond to the physical and sensory perceptions of the elderly in their housing and neighbourhood scales.

This research introduces, as its main novelty, new sensorial attributes of the elderly population that complement technical disciplines of urban and housing environments. The multidisciplinary nature of all these variables demonstrates the complexity of proper management in existing urban environments, which extends the analysis from variables that attend technical needs to perceptions related to visual aesthetics, cleaning, social relationships, perceived quality in pathways and routes for the elderly residents.

The paper goes beyond other related research since it perceives that, in order to adequately analyse ageing in place in existing urban settlements, new arising demands and perceptions from the elderly need to be addressed from a design and architecture point of view, which is a reason why obtaining a complete diagnosis that gathers physical and emotional variables of each urban scale from an analytical perspective is needed.

The application and test of the proposed method in three case studies from Spain and Mexico have demonstrated the operation and replicability of the MASBE system to be applied in different countries and obtain different ratings according to each urban and housing patterns. The results obtained for these cases are far from average scores around 7.50, which would be ideal for ageing in place, and there are even valuations below 5.00, which show important needs to implement urban regeneration and renovation strategies. The weighted values and the graphical display of the results provide useful information about particular variables and dimensions as well as a comprehensive report on the perceptions of the elderly regarding their environment. The key outcomes obtained from applying the MASBE system mean important contributions for decision-making, so policy-makers and promoters can put into place measures to ensure an appropriate management of cities.

This model is an opportunity to guarantee better living conditions for the elderly in their residential environments and prevent this segment of population from overcrowding nursing homes, thus creating situations of Seville and other cities. The results obtained for these cases are far from average scores around 7.50, which would be ideal for ageing in place, and there are even valuations below 5.00, which show important needs to implement urban regeneration and renovation strategies. The weighted values and the graphical display of the results provide useful information about particular variables and dimensions as well as a comprehensive report on the perceptions of the elderly regarding their environment. The key outcomes obtained from applying the MASBE system mean important contributions for decision-making, so policy-makers and promoters can put into place measures to ensure an appropriate management of cities.

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