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Smart Housing Adaptations Register with User Matching Functionalities for different mobility categories for the social housing sector

Abstract

Purpose: The lack of a proper register to store, match and display information on the adapted property has led to a waste of resources and prolonged delays in matching the disabled and elderly people with appropriate properties. This paper presents the development of a Housing Adaptations Register with user-matching functionalities for different mobility categories. The developed system accurately captures and documents adapted home information to facilitate the automated matching of disabled/aged applicants needing an adapted home with suitable property using banding, mobility, and suitability index.

Design/methodology/approach: A theoretical review was conducted to identify parameters and develop adaptations register construct. A survey questionnaire approach to rate the 111 parameters in the register as either moderate, desirable, or essential before system development and application. The system development relied on DSS Modelling to Support Data-Driven Decision-Making based on the decision table method to represent property information for implementing the decision process. The system is validated through a workshop, four brainstorming sessions, and three focus group exercises.

Findings: Development of a choice-based system that enables the housing officers or the Housing Adaptations Register coordinators to know the level of adaptation to properties and match properties quickly with the applicants based on their mobility status. The merits of the automated system include the development of a register to capture in real-time adapted home information to facilitate the automated matching of disabled/aged applicants. A 'choice-based' system that can map and suggest a property that can easily be adapted and upgraded from one mobility band to the other.

Implications: The development of a housing adaptation register helps social housing landlords to have a real-time register to match, map, and upgrade properties for the most vulnerable people in our society. It saves time and money for the housing associations and the local authorities through stable tenancy for adapted homes. Potentially, it will promote the independence of aged and disabled people and can reduce their dependence on social and healthcare services. **Impacts/originality:** This system provides the local authorities with objective and practical tools that may be used to assess, score, prioritise, and select qualified people for appropriate accommodation based on their needs and mobility status. It will provide a record of properties adapted with their features and ensure that matching and eligibility decisions are consistent and uniform.

INTRODUCTION

According to Roy et al. (2018), older adults are more likely to experience disability due to age-related conditions that affect their physical and cognitive capabilities and independence. There is a correlation between ageing and long-term illness and disability (Miller et al., 2014). 9.7 million, or 18% of the population in the UK, have a health condition or disability that limits their day-to-day activities (The DFG Crisis & the Better Care Fund 2020). The life-limiting illnesses create environmental barriers that prevent most daily living activities (Gitlin, 2003; Golant, 2008). With these barriers, older adults are forced to either adapt their existing homes or move to more accessible housing. Accessibility is the absence of physical obstacles that prevent individuals or groups from fully participating in society or social life (Lid & Solvang, 2016). According to Farber and Lynott (2011), with these limitations, over 85% of older people strongly desire to remain in their own homes and communities to uplift their physical and mental health, provided their house could be adapted (Heywood, 2004). Such homes typically have wider doors, main-level bathrooms, and a level or ramped approach to the house (Morrison & Burgess, 2016). Housing adaptations are defined as modifying permanent physical features, indoors and immediate outdoors to reduce environmental barriers and restore independent living (Zhou et al., 2019).

There are different funding sources for housing adaptations. However, the objective is to support people of all ages to live in suitable housing to improve their quality of life and enable them to stay independent at home. According to EHS (2016), the broader objectives include the prevention of unnecessary hospital stays following falls in the home and promoting the social inclusion and independence of people with long-term illnesses or disabilities. Major adaptations will include widening doors and installing ramps, improving access to rooms and facilities, providing a heating system suitable for the occupant's needs, and adapting heating or lighting controls to make them easier to use (Oyegoke et al., 2022). Housing adaptation is not only applicable to private homes but is also applicable to local authorities' houses. Local authorities differ when it comes to social housing and accessible homes. Some local authorities act as a facilitator of the provision of social housing, and some as direct providers of council housing.

According to Adams et al. (2018), council housing is allocated based on a need basis and let at regulated rent levels set by the Homes and Communities Agency (HCA). The council housing is usually managed and maintained by the local authority; however, in some cases, the responsibility can be subcontracted to an Arms' Length Management Organisation (ALMO). Adams et al. (2018) maintained that not all the local authorities provide council housing in the UK; in England, for instance, 58% of local authorities own housing, 79% in Scotland, 52% in Wales, and about 60% in average around Britain. Where local authorities are not providing council housing, social landlords and charitable Housing Associations provide housing at HCA-regulated rent levels. These charitable Housing Associations are known as Private Registered Providers (PRP) in England or Registered Social Landlords (RSL) in Scotland or Wales. Based on national studies in England and Scotland, Pawson and Kintrea (2002) postulate that housing allocation policies contribute to social exclusion through social landlords' restriction on eligibility for social housing, and the mechanisms within allocation systems continue to segregate the most excluded. Also, allocation policies became increasingly coercive, reducing (in some cases eliminating) tenant choice over their housing in contrast to the choice available in the private market.

The Equality and Human Rights Commission Research report on the role of local authorities in housing for disabled people (Adams et al., 2018). The report indicates that the local authorities lack information on suitable houses for disabled people. About 22% of the local authorities have accessible

housing, which hinders the appropriate housing allocation to disabled people with specific impairments. Authorities with larger populations were also more likely to hold accessible housing registers (35% compared with 12%). Apart from the shortage of accessible homes, there is also a lack of a register for adapted homes. To provide housing that matches disabled peoples' needs, local authorities must understand the proportion of disabled residents and their existing circumstances and needs. Local authorities also need a level of knowledge of the extent to which the housing stock in place already caters to disabled people's needs (Adams et al., 2018). The housing adaptations register vital to allocating and matching disabled properties is unavailable in most local authorities. The information is scanty and not comprehensive when available (Oyegoke et al., 2022).

Boyle and Thomson (2016) indicated that part of the problem facing social housing providers is an alarming information gap within housing data sets, exposing an imbalance between the supply and demand and realising the cost implications for adapting the housing stock. The lack of a comprehensive register will affect setting policies and spending priorities and waste money already spent on the adapted property when the property is not put into use or adaptation features are removed for a new tenant.

The initial plan in the Adapt-ABLE project is to use the adaptable register to develop preventative maintenance using a machine learning approach. This is part of the five platforms in the innovative Adapt-ABLE project, four integrated platforms through constructive development of the smart system (Oyegoke et al., 2022). The fifth platform was about using the intelligent system for preventive maintenance. One of the outcomes of the initial project workshop of 76 participants was that the adaptation register was unavailable to the local authorities and could have been used for preventive maintenance through machine learning applications. The participants also preferred developing matching functionalities because it would be more beneficial than preventive maintenance. The project team has to request a change for this project section based on unexpected circumstances changes.

The study aims to develop an online platform that can accurately capture and document adapted home information to facilitate the automated matching of disabled/aged applicants needing an adapted home with suitable property using banding and suitability index. The register contains purpose-built, adapted properties or properties with special features that could benefit someone with a disability. This will promote 'choice-based' approaches to lettings to boost community sustainability, and save money from not using adapted homes or the money used to reconvert adapted homes due to lack of a register. It will also counter the disabling impact of coercive approaches used by some social landlords. The platform is also developed for mapping adapted homes and can suggest to the authority the amount of work needed to convert adapted homes from one mobility band/user to the other.

The housing adaptations register in this paper is not the same as the allocation scheme used by social landlords/local authorities, which sets out the rules used to decide whom to house: a list of people waiting to obtain council houses. Some LAs have the Accessible Housing Register (AHR) that contains the details of people who require special needs housing because their current accommodation is unsuitable for their specific needs. However, this does not solve the problem because of the lack of a register for adapted homes and the lack of matching functionalities to match new and old tenants to properties that meet their special needs. Therefore, the housing adaptations register is the official list containing details of adaptation features in a house.

LITERATURE REVIEW

UK ageing population

Over 9.7 million, 18% of the population, have a health condition or disability that limits their day-to-day activities. It has been estimated that over 4.5 million people's daily activities are limited due to their health conditions and disability. A projection of 6.3 million more people aged 60+, 3.6 million people aged 75+, and an extra 2.8 million people aged 60-74 in 20 years ('AKW 2022). Old age comes with life-limiting illnesses that often create environmental barriers and activities for daily living (Gitlin, 2003; Golant, 2008). According to Savino et al. (2014), the ability to remain mobile in old age measures the quality of life, which is critical for preserving independence. However, the social model of disability places stronger emphasis on the social structures instead of the person. However, it argues that impairments alone at the individual level may not create disability. However, social perceptions, attitudes, institutions, and policies all contribute to the creation of disability, which is "situational and interactive" (Fougeyrollas & Gray, 1998). Disablement, therefore, is perceived less as an attribute of a person and more as a set of circumstances, many of which arise from the external environment. Sociocultural expectations and the built environment are good examples of the external environment that can limit opportunities to carry out daily activities for persons who experience physical or psychological impairments, activity limitations, or participation restrictions (Patel & Brown, 2017).

The English Housing Survey 2018/19 reveals the level of accessibility in English homes. Only 9% of homes have key accessibility features to deem them 'visitable'; 91% of homes do not provide the four main features to be considered even 'visitable'. However, this is 4% over 13 years (an increase from 5% in 2005). Just over 57% of wheelchair users are living in adapted homes. Habinteg estimates that over 400,000 wheelchair users live neither adapted nor accessible (Habinteg, 2020). The report further states that the total proportion of accessible homes are still woefully inadequate. In the 2020/21 English Housing Survey, 4.0 million households (17%) are in the social rented sector, comparable to 2010-11, which accounted for 17%. In 2010-11, 9% (2.0 million) of households in the social rented sector were from housing associations, and 8% (1.8 million) were from local authorities. In 2020-21, 10% (2.4 million) rented from housing associations and 7% (1.6 million) from local authorities (Department for Levelling Up, Housing and Communities 2022).

Housing adaptations

Housing adaptation modifies permanent physical features indoors and outdoors to reduce environmental barriers and restore independent living (Zhou et al. 2019a, b). According to the Ministry of Housing, Communities and Local Government (2021), around 8% of all households in England (1.9 million households) in England had one or more people with a health condition that required adaptations to their home in 2019-20. The importance of housing adaptation is enormous; it can lead to savings in home care, residential care, and hospitalisation. As reported in AKW (2022), for every £1.00 spent on adaptations, savings up to £4.00 can be made (Appleton et al., 2012); a typical home adaptation can delay entry to residential care by up to 4 years, saving up to £73,000 per person (Zokaei, 2010) and reduce the risk of falls by 60% and savings of £28,6659 for hip fracture alone (Heywood, 2007).

The eleven most common adaptations needed inside the home, according to the report by the Ministry of Housing, Communities and Local Government (2021) were: (i) hand or grab rails in the kitchen or bathroom (42%), representing around 819,00 households (ii) hand, grab, or stair rails inside the home (36%); (iii) bath/shower seats or other bathing aids (25%); (iv) a special toilet seat/raised

toilet or other aids to help use the toilet (23%), (v) a graduated or level access floor shower (20%); (vi) a shower replacing a bath (18%), (iiv) a stairlift (16%), (viii) redesigned bathroom (14%), (ix) adjustable bed (13%); (x) new bath or shower room (13%) and (xi) adapted furniture, e.g. specialist lamps (13%). Outside the home, according to the report, external handrails or grab rails constitute (27%) of external adaptation, representing around 527,000 households. This is followed by an external ramp (18%), a rail to external steps (15%), plot wheelchair-accessible parking space (9%), and wide paths (8%) (Ministry of Housing, Communities and Local Government 2021).

Regarding tenure, owner-occupiers (17%) were less likely to report their accommodation as unsuitable than local authority households (25%). A quarter (25%) of private renters and 21% of housing association renters reported unsuitable accommodation. In terms of income, households in the middle-income quintile were more likely not to have the adaptations that they needed (63%) compared with households in lower (first or second) income quintiles (51% or lower) (Ministry of Housing, Communities and Local Government 2021).

The problem is more pronounced with social renters, including households renting from Local Authorities (including Arms' Length Management Organisations (ALMOs) and Housing Action Trusts) and Housing Associations and Local Housing Companies, co-operatives, and charitable trusts. The Royal College of Occupational Therapists (2019) report indicates that housing adaptation continues to be delayed due to waiting time for a social care assessment, especially for those who can self-direct their care and wish to adapt their homes. The delay in providing adaptations potentially reduces the benefits of adaptations as a preventative intervention. Oyegoke et al. (2022) proposed an innovative smart solution to streamline the housing adaptation process to prevent lengthy delays for disabled and elderly people. The lack of a housing adaptation register was identified in the study as one of the impediments to reusing adapted facilities, which often results in waste and long waiting times for those that need similar properties. The development of the housing adaptation register becomes critical to recording adapted homes, with User Matching Functionalities for different mobility categories to match and track properties to a new user.

Adaptations (housing) register vs accessible housing register

According to Vaughan et al. (2021), poor communication about the standards is detrimental to the chance of increasing accessible housing stock. In the EHS report on adaptations and accessibility of homes, the visitability of dwellings is based on four key features: 1. Level access; 2. Flush threshold; 3. Sufficiently wide doors and circulation space; 4. WC at entrance level. These features form the basis for the building regulations part M and are the most important factor in enabling people with mobility difficulties to access a home (Cambridge City Council 2022).

There is also the London Accessible Housing Register (LAHR) category, a system that facilitates the ease and consistency by which accessible housing information is collected. This register focuses primarily on the accessibility for the property's assessment based on national design standards. Accessibility is the absence of physical barriers that prevent individuals or groups from fully participating in society or social life (Lid and Solvang, 2016).

The criteria used to achieve the given category include the gradient of ramps. Number of external and internal steps, door widths (communal front door, property front door, and internal doors), corridor widths, number of toilets, access to a lift and number of lifts, and circulation space (LAHR 2011).

The accessible housing categories are (LAHR 2011):

- A. Wheelchair accessible throughout – based on the Wheelchair Housing Design Guide
- B. Wheelchair-accessible essential rooms - complies with the Wheelchair Housing Design Guidance
- C. Lifetime Homes Meets – based on the space standards of Lifetime Homes developed by the Joseph Rowntree Foundation.
- D. Easy access Compatible – based on the DoE and Housing Corporation Scheme Development Standards (pre-1999) and Part M of Building Regulations (2000).
- E. Step-free – based on general need not published access design guidance
 - E+ Minimal steps No published access design guidance. Properties that do not meet any accessible housing design guidance and have a limited number of steps to enter the property. Properties in this category will have no more than four steps to access the front door and are likely to be ground-floor properties or properties in a block with a lift and a small number of communal or property front doorsteps.
- F. General needs - does not meet any of the above criteria.
- G. Additional information based on the details of major adaptations such as level access showers and stairlifts, parking, private garden or balcony proximity to local shops, and proximity to public transport.

The London Accessible Housing Register (LAHR) categories are complicated therefore, the OASIS (M1860) Ambulation/Locomotion resources for accurate Scoring are used for the mobility status for the adaptation register system development (Centres for Medicare and Medicaid Services 2022):

- the ability to walk
- use the one-handed device
- two-handed device
- required assistance
- self-wheelchair
- wheelchair with assistance, and
- bedfast.

CONCEPTUAL FRAMEWORK

According to Ofori-Boadu (2017), many assessment tools have been developed in various fields to overcome the problem associated with eligibility determination and to ensure a fair selection process. Savino et al. (2014) developed simple self-report and objective measures for assessing a challenging performance-based objective for the age-related disablement process (Firth et al., 2008). Different measurement parameters have been used in developing assessment tools. Janzon (1998) used three categories of need: high, moderate, and low; Straub (2009) uses a six-point condition rating scale ranging from very bad, bad, poor, fair, good, and excellent rating. Caccavelli and Genre (2000) used a four-point scale to characterise the degradation of building components, good condition, slight degradation, medium degradation, and end-of-life span. The ratings used in this study for the property/adaptation features are 0 – Not applicable, 1 – Moderate - beneficial for the mobility status but not essential, 2 - Desirable - could be necessary for the mobility status in the future with adaptation, and – Essential - essential for the mobility status now.

Although there is a housing allocation assessment in local authorities, but not a register that includes the adapted buildings for the disabled and the elderly. The feedback from the initial workshop shows that the majority of the participants acknowledged the lack of the register and supported the development of a register and the use of matching functionalities as a favourable option to the initial plan. The conceptual framework is based on an adaptation register based on the front-end algorithms using adaptation rules, home features, medical and disability variables (including Activities of Daily Living), and allocation factors from the local authorities. Two different property banding options were considered to develop banding algorithms. The mobility status was preferred over the London accessibility register banding. The London accessibility register banding is complicated and only focused on accessibility, but the mobility status is more appropriate as it covers different levels of mobility/disability. The back-end algorithms are matching functionalities that can predict the time and condition-based maintenance, predictions based on the potential failure, and mapping properties with those that require adapted homes. The applicant's matching information that will be required will include basic information, disability, medical, and property requirements. The constructive research approach is used to develop the conceptual framework based on contextual and accumulated theoretical knowledge of the current practice to produce new knowledge in the form of normative applications (Kasanen et al., 1993; Oyegoke, 2011).

Figure 1 presents the conceptual framework of the housing adaption register. It comprises the back-end system of building requirements that form the register database with property banding algorithms and different mobility statuses. The front-end system consists of user-matching functionalities that enable users to be matched with available properties.

Figure 1 conceptual framework of housing adaptation register

METHODOLOGY

Settings

This is an IT research development project which is different from the usual research processes and procedures. This project relies on a constructive research approach through coproduction of knowledge, which is a problem-solving method that relies on different research tools and is also associated with interpretive epistemology, positivist epistemology and empiricism (Oyegoke, 2011). The research strategies relied upon for the study are brainstorming, workshop evaluation, and focus groups. Brainstorming is a creative technique used in many idea-generation research studies (Hender et al. 2001 and Geschka 1996). As part of the more comprehensive study, a single three-part workshop was used to (i) verify if any major DFG problem has been omitted in our construct, (ii) validate the proposed solutions, and (iii) suggest areas that need improvement. According to Thoring et al. (2020), workshops are often used in the information systems (IS) and design fields to evaluate artefacts or co-create innovations.

A non-probability purposive sampling method was used based on the research team's expertise and network to select a sample that is most useful for the purposes of the research. The rationale for inclusion/selection was based on the participants' experience in housing adaptation. This was facilitated by the lead partner in the project. The lead partner in the project oversees a national network of Home Improvement Agencies (HIAs) and handyman providers and works with many local authorities across the country. There were 76 highly experienced practitioners in the workshop. The participants include about 4% of the third sector staff, DFG applicants about 8%, Home Improvement Agencies (HIAs) 18%, equipment suppliers 4%, DFG contractors 5%, local authority staff 51%, occupational therapists 7% and others 3%.

The key project participants did brainstorm exercises with a diverse range of expertise in housing assessment, digital (IT) development, housing adaptation policy and legislation, occupational therapist, and home improvement. The focus group approach is also used to gather diverse experts' perspectives and opinions (Hennink, 2014) on the conceptual framework and evaluate and validate the proposed solution. The workshop and the focus group were facilitated by the lead partner on the project. The focus group exercises were used to validate the implementation framework and improve on the developed platforms. The study is designed in conformity with all ethical issues around anonymity, confidentiality, and informed consent (Oyegoke et al., 2022). The workshop was recorded, transcribed and analysed along themes and subthemes through content analysis. The opinion of the participants was sought on the need for a housing adaptation register. The workshop unanimously agreed that the register is overdue for mapping the local authorities owned and rented properties. A register is also needed to have up-to-date information and for matching properties with users on a timely basis with the possibility of covering a cluster of local authorities. A system that can show the level of adaptation in a property and identify the requirements to adapt or upgrade it to the needs of the new users to suit their mobility status. Cost implications were said to be another driver because of the cost of converting already adapted buildings when they are potential users. One of the participants said, "This sort of register is long overdue. We tried to do this in our local authority but were not successful". It was checked before incorporating it into the study. Three focus group exercise of six DFG experts was held to validate the system.

Stages of data collection and system development

In developing the register, the objective assessment measures of the dwelling by surveyors on the accessibility, visitability, and the subjective assessment of the adaptations based on the occupant's needs (adaptations required) and the suitability of an occupant's home are thoroughly reviewed. These comprise nine accessibility features as assessed by the English Housing Survey in accordance with Part M of building regulations (Building Regulations, 2010). The first four features for a home to be fully visitable are level access to the entrance, a flush threshold, sufficiently wide doorways and circulation space, and a toilet at the entrance level. The other accessibility features are changes in floor level/trip steps at the entrance level, a room at the entrance level suitable for a bedroom, a bathroom at the entrance level, straight stairs with landings >900mm, and a wheelchair-accessible WC at the entrance level. The critical home features identified in the Home Safety Self-Assessment Tool (HSSAT) V.5 (Department of Rehabilitation Science 2017) are also used in developing the register.

In the second stage, three local authorities' home allocation criteria are used to determine the types of applicants' needs to generate the critical factors for the register. The three applicant needs that were identified include the homeless applicants (HWLC), the General Needs applicants (GN), and the Transfer applicants (TL). The housing authority's allocation criteria are merged with the accessibility

and visitability measures, and the HSSAT home features form the main focal points for designing the questionnaire survey. The survey comprises twelve home features used to collect data for the register. These are the twelve home features, **and the breakdown can be found in Appendix 1:**

- 1) Property information covers the property type, number of rooms, floors, toilets, age of the building, and proximity to local schools, shops, and public transport.
- 2) The nature of adaptations in the property, such as a level access/ramp, walk-in shower (not step shower), stairlift, specialist bath, ground floor bathroom, lower kitchen units, etc.
- 3) Pathway and access include the pathway from the street to the front door, front door access to the house (door width), and access to the upstairs.
- 4) Kitchen - the nature of access to the kitchen and the nature of adaptation and condition of the features in the kitchen (e.g. kitchen cupboards height, storage height, clear space in front of the fixed benches, etc.)
- 5) Bedroom - the nature of access to the bedroom (size of the door), the size of the bedroom (single, double, or box room), and if there is clear space around one side of the bed and a clear path to the door.
- 6) Garden - the types and conditions of the garden in terms of size, location, fencing, and nature of maintenance, and access to the garden, e.g. if a ramp or platform lift is installed.
- 7) Bathroom - the nature of access to the bathroom, e.g. door width, showering type and details, e.g. bath, cubicle, or level access, etc., and the nature of access to a shower in terms of the dimension of the shower.
- 8) Parking - the type, availability, and condition of parking. If it is a driveway, layby, hardstanding, chargeable, restricted, permit required, shared driveway, etc.,
- 9) Heating - the type of heating system in the property, e.g. district heating, electric central heating, gas fire, etc. Also, if there is a gas, electric, or water meter.
- 10) Additional information that covers the nature of loft/attic/cellar space, outer building (outhouse or shed), nature of storage, separate dining room
- 11) Pets - information about if pets are permitted, if pets are allowed, but restrictions may apply, and if the existing tenant - has had pets on this property.
- 12) Location - location type, nearest town/village, information on local amenities, approximate distance from the town centre.

In stage three, one hundred and eleven parameters were identified from the twelve focal points for every property in the register. The register was developed with both academic and practitioner groups. It was sent to 6 experts working in the local authority's housing department and HIA staff to evaluate its completeness and if it is fit for purpose.

In stage four, seven mobility statuses were used to evaluate each parameter's importance to different mobility statuses. It includes the ability to walk, use a one-handed device or two-handed device, require assistance, self-wheelchair, wheelchair with assistance, and bedfast. The 111 parameters in the register are rated for each mobility status to know the importance of visitability and accessibility features in different home features. Table 1 presents a format for the rating of 111 parameters. On the vertical axis are the parameters rated based on the mobility status on the horizontal axis. The rating criteria are:

- 0 – Not Applicable: when the home feature is not applicable
- 1 - Moderate: When the home features have a moderate impact, that is, optional - something that is based on users' want
- 2 - Desirable: something desirable in the future

Table 1: A typical example of the rating of the parameters across different mobility statuses.

An experienced practitioner of over 30 years provided the preliminary questionnaire rating. This only provides the basis for the system's initial design, and further improvements are made at different testing stages. The logic enables a different set of users' involvement and contribution in the system development and testing through the co-production of knowledge.

In stage five, the implementation framework with the users' interface is developed before developing algorithms for user Matching Functionalities for different mobility statuses based on the responses in stage four (questionnaire survey). The actual system development was carried out in stage six. This includes technical and managerial inputs and brainstorming by the project team. A series of tests and feedback for further development were carried out in stage seven. Three focus groups by the end-users were organised to validate the data and test the system's functionalities, aligned with Hennink (2014), to gather perspectives. A final workshop was organised to test and validate the platform.

IT DEVELOPMENT AND APPLICATION

A decision support system (DSS) supports the requirements of matching disabled and elderly people with appropriate properties because it requires judgment, determination, and a sequence of actions. There are different types of decision support systems (Dodevska et al., 2020); this study relied on DSS Modelling to Support Data-Driven Decision-Making. This is to achieve two things: remove subjectivity and bias from the decision-making process and the possibility to evaluate numerous alternative scenarios and identify the best option (Hammad et al., 2018). Knowledge is an integral part of any DSS that is gathered and structured in a form that computer systems can process. In this project, the decision table method represents knowledge for implementing the decision process. The reason for the decision table is that it is best suited for situations involving multiple conditions and actions.

Figure 2: High-level software application architecture

Figure 2 shows the high-level architecture of the proposed housing adaptation register and automated matching software system. The decision-making process starts with property registration. All properties with their features information are stored in a database through an interactive user interface. The registration of a large number of property features and the knowledge modelling for the decision table require a user-friendly usability design of the software application. For this case, the property registration process is designed so that the input from the user (local authorities and housing associations) is taken as a selection of values to make the process easy and efficient.

The information of every registered property is then mapped to a central decision table to compute the final property's suitability scores. A decision table is a method to represent all conditions and their

possible alternatives or actions in a tabular structure. The conditions and property features for the present case are represented as rows, and different mobility categories as columns. The intersection of a row and column called the cell is filled with the rating value. Rating values can range from 0 to 3, where 0 is not applicable, 1 for moderate, 2 for desirable, and 3 for essential. By modelling the decision table, the proposed system can derive which property features (conditions) are associated with the mobility category in terms of suitability. This is in advance of the traditional if-then construct. With a decision table, it can be incurred that multiple conditions can invoke a particular action, i.e., multiple property features are associated with a mobility category for a given suitability rating. In a traditional if-then construct, a condition is mapped to a single action only.

Figure 3: System computed suitability scores for two properties

The suitability scores regarding mobility categories are computed by frequency distribution analysis for every property. The system computes the scores by calculating the number of property features suitable at a level (moderate, desirable, or essential) for every mobility category. The backend computed scores of two properties are shown in Figure 3, which is only for the system's internal property ranking process, based on which the system ranks the properties in the user's search according to their search criteria. The suitability scores for a bedfast occupant in Figure 3 show that property A has four essential features, whereas property B has six essential features. A new property can be added using the admin panel in the backend system (housing adaptation register database). Each property has a unique identification code. The system is developed for the housing officers to know the level of adaptation to properties and match properties based on the mobility status of the applicants. Finally, users can search properties based on their mobility and other preferences such as location, number of rooms, etc. The system provides a ranked list of available properties containing the most suitable properties results on the top. Figure 4 presents the user interface that was adopted based on its flexibility.

Figure 4: The system user interface

DISCUSSIONS

The literature review supported by the empirical results from the workshop and focus group indicates the need for a housing adaptation register (AHR) to prevent delays in matching and allocating properties to elderly and disabled people. Some local authorities have an accessible housing register (AHR) that only holds the details of people requiring special needs housing if their accommodation is unsuitable (City of Doncaster Council 2022). This is also referred to as the waiting list based on the priority criteria in the allocations scheme (Scope 2022). The process of matching properties with the elderly and disabled people in the present system is through the AHR coordinator liaising with the housing assessment panel (HAP) of the local authority housing department and the housing association. The AHR coordinator is notified of all properties by the housing assessment panel (HAP) when they meet the criteria and nominate prospective tenants when the properties are available for allocation. The allocation can be choice-based lettings or direct offers by the local authorities (Scope 2022). This

process is fragmented, leads to delay and does not provide the possibility for personalised upgrades to suit the needs of the disabled/elderly tenants. However, the smart housing adaptations register is a one-stop automated system that enables properties to be registered, matched, mapped and upgraded. Properties are registered with their identifiable physical features. The matching users' functionalities enable automated matching with the tenants based on the different mobility statuses of the disabled tenants. Detailed information about every address in the local authority or housing association's tenants' portfolio can be easily mapped. It also enables easy identification of properties that can be upgraded with details of what needs to be upgraded to meet tenants' needs in a timeless manner.

Study implications and limitations

Home accessibility is important to the disabled and elderly people; however, the pool of properties that are accessible is limited, and the lack of a housing adaptation register makes it even more restricted. The housing adaptation register allows elderly and disabled people to search for property that meets their needs. An accessible home will improve their independence and remove the barriers to the challenges they face daily to live an active life and receive good care within a safe and secure environment. The housing adaptation registers ensure that disabled people can find accommodation that suits their needs to improve their independence.

The housing associations and local authorities can maintain a record of their adapted homes and let, maintain, and manage their homes effectively. It provides savings for housing associations for repeated use of the homes due to available registers. By implication, it will improve disabled and elderly people's independence, reduce adult social care and housing adaptation costs and reduce admissions to residential care facilities. It will also reduce the inequalities this group faces in the timely allocation of homes and allow the social landlords to meet disability equality duties. The study focuses on the housing adaptation register and is limited to the elderly and disabled people. The constructive approach that is associated with IT development studies is used in this study.

CONCLUSIONS

Housing adaptation is increasingly becoming more important because of an increasing number of elderly and disabled people. More than 6.3m million people will be over 60 years old in 20 years. Only about 55% of households in England that required adaptations in their home already had them installed (Department for Levelling Up, Housing and Communities 2022). Less than a quarter of the local authorities have accessible housing, which hinders the appropriate housing allocation to disabled people with specific impairments. It has been shown empirically that most local authorities have no adaptation register, which leads to a waste of public funding in renovating the properties when it could have been useful for other tenants in similar conditions.

The project developed a smart system that consists of housing adaptations register with user-matching functionalities for different mobility categories. A conceptual framework was developed, and six stages of data collection were used for the system development process. This also includes a rating system to measure the significance/desirability of different property features with varying mobility statuses. This study uses DSS Modelling to Support Data-Driven Decision-Making models to support managerial decision-making for matching adapted properties with elderly and disabled people. Validation is done through a workshop and a series of focus group exercises. The backend

system consists of a home adaptations database, which enables additional properties to be added and edited. The front end involves the development of matching algorithms, and the user interface allows the Housing Adaptation Register coordinators to match the people with the properties quickly. Housing Adaptation Register is recommended for the local authorities and housing associations to have a real-time adapted home register for mapping their properties and matching adapted homes to disabled and elderly users. People with disabilities experience housing inequalities, and this system will enable them to identify properties that would adequately meet their needs.

FURTHER STUDIES

The system can be expanded by creating a sub-register for preventive maintenance of the properties. A home swapping/mutual exchange platform will allow the tenants to swap homes in and between the local authorities. It might also include an interface for public users and information about the rent regarding cost, duration, deposit, etc. A viewing section can be added to show some pictures and videos of the property with accessibility features for disabled people. There can also be a platform for the tenants, based on priority points and personal criteria, to select appropriate accommodation and apply to the local authority or the housing association. The prospective tenants will also access the system online to match the properties based on their mobility status and need requirements.

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COMPLIANCE WITH ETHICAL STANDARDS

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- **Informed consent** - The study is designed in conformity with all ethical issues around anonymity, confidentiality, and informed consent of the participants in developing the system. For instance, the participants' permission was sought before the virtual workshop was recorded. The recorded workshop was transcribed and analysed along the themes and subthemes. It was checked before incorporating it into the study.

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