# DEVELOPMENT OF ADAPT-ABLE SMART SYSTEM - AN END-TO-END SYSTEM FOR SPEEDING UP DISABLED HOUSING ADAPTATION PROCESS

## Abstract

### Purpose

The problem of long delay and waiting time in Disabled Facilities Grants (DFG) housing adaptation has been ongoing for years. This study aimed at constructing an innovative smart solution to streamline the housing adaptation process to prevent lengthy delays for disabled and elderly people.

### Design/methodology/approach

The Adapt-ABLE approach is suggested based on a constructive research approach, where extensive theoretical development of the Adapt-ABLE concept is developed. It consists of four integrated platforms that undergo theoretical and analogical development and validations through applicable theories, a workshop, four brainstorming sessions and a focus group.

### Findings

The proposed Adapt-ABLE approach utilises process optimisation techniques through an IT system for streamlining the process. The merits of the semi-automated system include the development of a preventive measure that allows measurement of suitability index of homes for the occupants, indicative assessment that shorten the application duration, procurement and contracting platform that utilises principles based on framework agreement and call-off contract, and a platform that standardised performance management for continuous improvement.

### Originality/value

The Adapt-ABLE solution will cut the application journey of non-qualified applicants and suggest where help can be sought. The qualified applicants' application journey will also be shortened through an online indicative assessment regime and early online resources (means) testing. Overall, the proposed system reduces the waiting time, and timely delivery improves the applicant's quality of life by living independently. It will potentially save the NHS billions of pounds used to replace hips and residential care costs due to lengthy delays in the housing adaptations process.

**Keywords:** Housing adaptation, Disabled Facilities Grants, constructive research, independent living, ICT, United Kingdom

**Paper type:** Research paper

**INTRODUCTION**

According to Miller et al. (2014), there is a correlation between ageing and long-term illness and disability. A report sponsored by the UK government titled 'the DFG crisis & the Better Care Fund' indicates that 9.7 million or 18% of the population have a health condition or disability that limits their day-to-day activities. The 'demographic time-bomb', as it was called, has 4.5 million people whose daily activities are limited due to their health conditions and disability. The report categorised disability into two types: major and minor disability. Among those with major disability conditions, 2.2m people are under 65, and 2.3m are over 65 years old. In the minor disability category, 2.8m people are under 65, and 2.4m are over 65. The projection in 20 years shows that there will be 43% more people aged 60+ (6.3million more people), an extra 3.6million people aged 75+ and an extra 2.8million people aged 60-74 (The DFG Crisis & the Better Care Fund 2020).

Life-limiting illnesses create environmental barriers that prevent most daily living activities (Gitlin, 2003; Golant, 2008). According to Farber and Lynott (2011), with these limitations, over 85% of the older people have a strong desire to remain in their own homes and communities to uplift their physical and mental health, provided their house could be adapted (Heywood 2004). The concept of housing adaptations has been defined in different ways (Sanford, 2012); therefore, this paper adopts Zhou et al. (2019) definition as a modification of permanent physical features in the indoor and immediate outdoor to reduce environmental barriers and restore independent living. One of the major home intervention schemes is Disabled Facilities Grants (DFG), a grant obtained from local councils. According to the UK government (2020), DFG is used to widen doors and install ramps, improve access to rooms and facilities, provide a heating system suitable for the occupant needs, and adapt heating or lighting controls to make them easier use.

Mackintosh et al. (2018) suggest that only 7% of homes in England have basic accessibility features; therefore, the majority of disabled people are living in ordinary housing. A survey on English house conditions shows that around 1.9 million households (about 8% of all households in England) had one or more people with a health condition that required adaptations to their home. In 2019-20, 81% of households that needed adaptation to their home due to their health condition felt their home was suitable for their needs. This has not changed since 2014-15 (Department for Communities and Local Government, 2021).

About two-thirds of the people who applied for DFG are older people, followed by nearly a quarter of working-age adults, disabled children, and young people constitute a small but growing minority. Home interventions were reported to prevent falls (Cumming et al., 1999), slow down the deterioration in the quality of life (Bamford, 2000; Watson and Crowther, 2005), and reduce pressure and cost on healthcare. The DFG Crisis & the Better Care Fund (2020) suggests that "for every £1 million reductions in DFG funding, up to 200 vulnerable elderly or disabled people lose the chance to gain vital home adaptations that allow them to live safely and

independently". DFG saves home care cost, residential care home cost, and hospitalisation costs. Every £1.00 spent on adaptations can save up to £4.00. A typical home adaptation can save up to £73,000 per person, and a typical home adaptation can reduce the risk of falls by 60% (The DFG Crisis & the Better Care Fund 2020).

The Disabled Facilities Grants (DFG) is supported by the Local Government and Housing (LCH) Act 1989 and the Housing Grants, Construction and Regeneration (HGCR) Act 1996. Section 24(3) 1996 states that DFG should be awarded when the housing authority is satisfied that an adaptation is necessary and appropriate to meet an applicant's needs, reasonable and practicable to adapt the property. An occupational therapist usually carries out the assessment to determine if adaptation is necessary and appropriate. However, housing authorities will decide whether the works are reasonable and practicable. The eligibility criteria enable only those assessed as having a critical or substantial problem to be eligible for DFG. Section 24(5) also states that the approval can only be given when the local authority is satisfied that the applicant has power or is under a duty to carry out the relevant works.

Mackintosh and Leather (2016) referred to the DFG as a process with fragmented responsibilities and phases with lengthy procedural steps. Zhou et al. (2019) emphasise that the bureaucratic process in DFG delivery caused substantial delays, fragmented responsibilities, and lack of collaboration between different departments. Section 34 of the Housing Grants, Construction and Regeneration Act (1996) states that the local authority should "provide notice in writing, approving or refusing the grant application as soon as reasonably practicable, and not later than six months after the date of the application".

In practice, most DFG is delayed due to long waiting times from referral to installation. Zhou et al. (2019) show the waiting time for category II local authority for each phase of DFG. From referral to assessment, it takes an average of 121days and a maximum of 573 days; for funding approval alone, it takes an average of 118 days and a maximum of 630 days; and for the installation stage, it takes an average of 93 days and maximum of 226 days. The total average days for category II local authority will be 243 days with a maximum of 474 (Zhou et al. 2019). Delays-related problems include insufficient resources, lack of joint work, bureaucratic procedures, the gap between grant and cost, and shortage of reliable contractors through poor selection and management processes. The time spent by the clients in making decisions about when to start the building work or appointing their contractor is another problem (Zhou et al. 2019a).

The funding problem has improved since the DFG became part of the Better Care Fund (BCF). The central government resources have significantly increased from £220 million in 2014/15 to £431 million 2017/18 and £573 million 2020/21 (NHS 2021). Attempts have been made in the past to review the adaptation process to streamline it as lengthy delays in the delivery of housing adaptation were identified as one of the major deficiencies in the process (Audit Scotland 2004, Heywood et al. 2005 and Jones 2005). Many years after, as indicated in Zhou et al.

(2020), the problems persist; therefore, this paper suggests a better management process through the Smart Adapt-ABLE online portal.

The study aims to construct an innovative smart solution to streamline the housing adaptation process to prevent lengthy delays for disabled and elderly people. Therefore, the research question is how the long delays in the delivery of housing adaptation for the disabled and elderly people can be reduced through process optimisation and the development of the intelligent system. The smart Adapt-ABLE has four integrated platforms: the Home Suitability Assessment/Analytics Platform that determines the suitability of homes, the platform for Indicative Assessment to determine if the applicants are qualified for the grants, the Procurement and Tendering Hermeneutics that enable dynamic procurement, and the Performance Management Platform that ensure performance monitoring, tracking, and feedback across the local authorities. However, the study is limited to the process-related issues of all the identified problems that constitute delays in the adaptation process. For instance, the shortage of contractors is due to contractor selection, tendering process, and contract management process.

## METHODOLOGY

The constructive approach has been used in numerous fields, including the development of the Specialist Task Organisation (STO) procurement approach (Oyegoke and Juhani, 2009) and in management accounting (Kasanen et al.,1993). The constructive research approach is an applied study that produces new knowledge in normative applications (Kasanen et al., 1993; Oyegoke, 2011). The problem of long delay and waiting time in DFG housing adaptation is solved by designing a construct based on process optimisation with an IT system for streamlining the process. A new Adapt-ABLE system construct was suggested. The problem and the solution are based on the accumulated theoretical knowledge on the housing adaptation process (Zhou et al. 2017, 2019a, 2019, 2020). Also, on the contextual knowledge of the current practices and opportunities digital technologies offer for system automation. The novelty and actual working of the theoretical construct, new Adapt-ABLE tools, and implementation framework were developed, evaluated, and validated through brainstorming, a single but three-part virtual online stakeholder engagement workshop, and a focus group.

The five steps in constructive approach (Oyegoke 2011) are being relied on to develop the Adapt-ABLE construct and develop the implementation framework. Initially, theoretical connections in the form of analysis of the state-of-the-art review were carried out to define the knowledge gap and specify the research problem. The approach ties the problem and its solution with accumulated theoretical knowledge. The steps are (Oyegoke 2011):

- Finding a practically relevant problem that has research potential
- Obtaining a general and comprehensive understanding of the topic

- Innovate, i.e., construct a solution idea: This phase is heuristic in nature as it involves stricter theoretical justification and testing of solution afterwards,
- Demonstrate that the solution works: validation processes, and
- Show the theoretical connections, research contribution, and examine the scope of applicability of the solution.

The research strategies relied upon are brainstorming, workshop evaluation, and focus group. Brainstorming is a creative technique normally used for idea generation. According to Geschka (1996), brainstorming is the most used by practitioners, studied by researchers and used in a substantial proportion for idea generation research studies (Hender et al. 2001). The four major steps of classical brainstorming were followed to generate and improve on novel solutions:

1. criticism is ruled out in the ideation stage
2. unconventional ideas are welcomed.
3. quantity is wanted
4. combination and improvement are sought.

Four brainstorming sessions were carried out at different stages of the development of the Adapt-ABLE construct by the research group. The aim is to develop further and improve the constructs based on the feedback. The initial construct was designed into a concept map of the Adapt-ABLE platform, consisting of (a) Home Suitability Assessment/Analytics Platform (b) Adapt-ABLE Platform for Indicative Assessment, (c) Adapt-ABLE Procurement, and Tendering Hermeneutics, and (d) Smart Performance Management Platform. 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 single but three-part workshop was used to verify if any major DFG problem has been omitted in our construct, validate the proposed solutions and suggest areas that need improvement. There were 76 highly experienced practitioners in the workshop. It cut across all the major DFG stakeholders, including DFG applicants, Home Improvement Agencies (HIAs), equipment suppliers, DFG contractors, local authority staff, and occupational therapists. The focus group approach is also used to gather diverse experts' perspectives and opinions about the ideas, evaluate and validate the proposed implementation framework. The workshop and the focus group were facilitated by one of the partners on the project. The partner oversees a national network of Home Improvement Agencies (HIAs) and handyperson providers and works with many local authorities across the country. The study is designed in conformity with all ethical issues around anonymity, confidentiality, and informed consent. For instance, the participants' permission was sought before the virtual workshop was recorded. The recorded workshop was transcribed and analysed along each of the themes and subthemes. It was checked before incorporating it into the study. Hennink (2014) states, "the purpose of a focus group is to gather perspectives". A focus group exercise of 6 DFG experts was held to validate the implementation framework.

**STEP ONE: PRACTICAL RELEVANT PROBLEM**

According to Oyegoke (2011), the problem identification phase in the constructive approach relies on the pragmatism approach with the consequences on beliefs/practices and theories. Three major approaches were used in generating the problems: (1) anecdotal evidence, (2) evidence-based practical experience from the practitioners, and (3) evidence from peers' theoretical work. The literature study substantiated practical problems identified from practice and anecdotal evidence. Like in many other developed countries, the UK population is Ageing. According to the ONS (2020), in 2019, there were 13,330 centenarians. This is an increase of 11% compared to 2018. In the same year, more than 600,000 people aged 90 years and over, a rise of 3.6% compared to 2018. Ageing comes with deteriorating health, long-term illness, reduction in mobility, and a degree of disability.

In a study done by Wiles (2005), over 85% of older people have a strong desire for independent living in their own houses to continue to engage with the community. This is underpinned by the ecological theory of Ageing which states that adapting the environment can improve functional performance (Lawton and Nahemow 1973, and Gitlin 2003). Statutorily, local authorities are empowered to provide financial assistance for housing adaptations to enable disabled people to maintain independent living at home (Mandelstam, 2016 Morgan, et al. 2016). Disabled Facility Grants (DFG) aims to facilitate independent living for the disabled/ageing population in the UK. Other funding avenues for adaptations apart from DFG are social service budget and home repair assistance. DFG, according to Zhou et al. (2019a), is the main source of funding for private sector adaptations.

A major problem with DFG is the stressful waiting time for the beneficiaries and costs the NHS a lot of money. Fragility fractures to the UK have been estimated at £4.4bn, and hip fractures alone account for around £2bn of this sum (Public Health England 2017). Zhou et al. (2019b) identified waiting time, delay-related problems, performance management, clients' decision process, and deficiencies in DFG process management as problems confronting DFG application. If the DFG assessment is done swiftly, grants authorisation and installation work on time, the whole process should be done within one month (Heywood, 1994; Keeble, 1979).

Since local authorities have no universal DFG approach, due to different departments and agencies being responsible for different stages, Zhou et al. (2019) categorised local authorities into three based on the DFG process by the local authorities. Category I has five key stages, Category II has three stages, and Category III has the two stages of funding approval and installation. Zhou et al. (2019) timelines studies show that the total length of time for the whole adaptation process on average in Category I, II III were 193 days and 243 and 227 days, respectively. Delays-related problems include insufficient resources, lack of joint work, bureaucratic procedures, the gap between grant and cost, and a shortage of reliable contractors. The time spent by the clients in making decisions about when to start the building work or appointing their contractor is another problem (Zhou et al. 2019b). These problems were identified in

the literature review and was substantiated through a virtual online workshop of 76 highly experienced practitioners. The workshop participants identified the same set of problems across different stages of the adaptation process.

**STEP TWO: COMPREHENSIVE UNDERSTANDING OF THE TOPIC/PROBLEMS**

**DFG Process**

According to Mackintosh et al. (2018), nine out of every ten applications related to physical disabilities and 90% of adaptations provided are either level access showers, stairlifts, or ramps. Showers account for 55%, straight stairlift 15%, curved stairlift 10%, ramp 10%, extension 3% and others 7%. However, the process of housing adaptation is fraught with delay due to its sequential procedure (Audit Scotland, 2004; Jones, 2005; Zhou et al., 2020) instead of a seamless service that should take a month from grant authorisation to installation work (Heywood, 1994; Keeble, 1979). The DFG process begins with referral, as shown in figure 1, where requests are made through a third party. It is followed by the allocation stage, where the initial screening process by the occupational therapists (OTs) or fieldworkers is carried out for assessments.

In the assessment phase, the OT makes the first home visit, assesses the client's need requirements, and uses the eligibility criteria to decide the type of adaptation needed. The OT's assessment is based on the person's needs and on judgment whether the conditions call for the provision of an adaptation (Scottish Government, 2011). This is based on locally determined eligibility criteria. Local authorities often consider a range of risk factors in setting the criteria. This includes health-related conditions, living environment, community participation, and care arrangement (NHS 2021; Scottish Government, 2012). Risk factors are classified into four risk bands for prioritisation: critical, substantial, moderate, and low. According to Zhou (2019), the OT passed the case to the housing department for funding authorisation. At this point, the grant officer will send the client an application form and associated documents for means-testing. DFGs are subject to a means test to determine whether an applicant has to make a financial contribution to an adaptation cost. A range of financial information is required for the means test, such as bank statements, pension books, and proof of benefits. The financial information covers the applicants' and their partner's income and savings against a set threshold (Sheffield City Council, 2016). The current means test is complex and cumbersome to administer. It lacks transparency and consistency (Department for Communities and Local Government. 2011). Mackintosh et al. (2018) criticised it for being complicated, unfair, and in recent years out of date. Some authorities developed their own rules when they were given the discretionary power to do so in 2008 with different ways of assessing bids and relative needs (Department for Communities and Local Government 2011). There is a maximum award limit for DFG, £30,000 in England, £36,000 in Wales, and no upper limit in Scotland. If the clients cannot afford a contribution, local authorities have discretionary powers to provide a top-up to meet the cost (Zhou et al. 2019a).

The funding phase enables the housing officers to process grants and issue approval documents. The client's needs are translated into a specification for the building work; when there are structural modifications, the applicants must adhere to Building Regulations and obtain building control approval. Landlord's consent and planning permission are required when the client is a tenant and when the adaptation involves an extension or a structural alteration (Clayton and Silke 2010). Once plans and specifications are confirmed, contractors are invited to submit quotations. They will select a contractor to carry out the work; the finished work is inspected and approved before payment can be made (Zhou et al. 2019b). The follow-up visit is to check whether the work was carried out as planned.

***Insert: Figure 1 The pathway through the adaptation system***

## Overall Average Waiting Time

Zhou et al. (2019) categorised local authorities in the UK into three categories based on a modification to the DFG process. They reported the length of time to complete the whole process, as shown in Table 1. For category I, referral to OT recommendation usually is three months, OT recommendation to grant approval is 60 days, grant approval to installation is 60 days. Delay is not specific to one stage; all the stages contribute to the waiting time. For instance, Zhou et al. (2019) results show in Table 1 the minimum, average, and maximum waiting time:

- Initial request to case allocation, the quickest local authority is 1 day while the slowest 189 days; the average is 41 days.
- Case allocation and OT visit, quickest is 1 day, and slowest is 103 days; the average was 21 days.
- Assessment period, quickest is 2 days, and slowest is 233 days: the average of 46 days.
- Approval stage, quickest is 3 days, and slowest is 233 days' the average of 85 days.
- Installation work, quickest is 14 days, and slowest is 90 days: the average of 54 days.
- The quickest local authority took up to 60 days to complete the whole process, while the slowest needed 360 days. It is not unusual for the process to take years; for instance, getting funding approved could be up to 630 days in Category II, and it takes the contractors an average of over three months in both Category II and III to complete adaptation work in some cases (Zhou 2019).

**Insert: Table 1. Timelines between stages of the adaptation process**

One participant in the workshop said on delay," we've had feedback from residents that they contacted county council and were told they would have to wait for months for a DFG when we have no waiting lists". A Housing Association Adaptations Officer said, "I often receive adaptation recommendations from NHS Trust OT's, who do not specify precisely what is needed and cannot go through DFG as it has to be an Adult Social Care Occupational Therapist (ASC OT). The customer has to wait to be re-assessed." One of the central issues is the partnership working arrangement that partly delays the process. The lack of a shared database for adaptation provision is a key problem. This will enable strong links between different stages of the provision chain, which are the key to an efficient and seamless service (Ramsay 2010). Inaccessibility of all the necessary data by the partners within and between local authorities presents barriers to improving service performance (Zhou et al., 2017). Adaptation should be delivered within six months [Heywood, 1994; Keeble, 1979]. Unfortunately, this is hardly the case due to sequential application procedural steps, resulting in a lengthy period of delivery (Audit Scotland, 2004; Jones, 2005; Zhou, 2019). Delay is caused by bureaucratic procedures, lack of joint work, the gap between grant and cost, shortage of reliable contractors, time wasted in finalising specifications, means-testing/test of resources, and shortage of staff/insufficient resources. There are also issues with budget management and performance monitoring, which prevent local authorities from getting the best value out of the existing adaptation investments (Zhou 2017 et al.).

The leading causes of delay in the literature include:

i.   Gap between grant and cost: about 25% of the cases granted funding did not access the funding due to the lack of client's contribution (Perry 2015).

ii.  Lack of joint work: three or more organisations work together, but poor communication and ineffective arrangement delay the process (Mackintosh et al. (2018)).

iii. Bureaucratic procedures: excessive paperwork on landlord's consent and planning permission (Zhou 2019).

iv.  Insufficient resources: it takes an average of 6 months to deliver an adaptation due to the combination of unanticipated high demand and limited available resources, including finance and staff, especially Occupational Therapist (Zhou 2019)

v.   Shortage of reliable contractors: lack of materials/equipment, shortage of skilled labourers, or delay of interim payments (Clayton and Silke 2010).

vi.  Clients' decisions:  a major delay when the client took control of the progress, the decision about when to start the building work remained in the hands of the client.

vii. Clients often deal with a network of organisations and numerous professionals when applying for housing adaptations funding (Ramsay 2010)

viii.   Unmet needs: halfway through the financial year, around 25% of local authorities used up their whole year funding allocations on adaptation; another 31% already overspent by a significant margin, and only 43% kept their expenditure within budget limits. (Ramsay 2010)

ix.    Performance management, there is no consistent way to measure service performance across local authorities, and the inconsistency frequently interfered with strategic planning for future adaptation delivery (Bibbings et al., 2015).

x.     Monitoring the outcomes of housing adaptations is indispensable to service quality and improvement (HAC 2013).

xi.    The waiting times for OT assessments can be between 2 and 115 weeks, and the average time was 23.5 weeks (Clayton and Silke, 2010).

xii.   The unmet need for home adaptation, resulting in over 4 million hospital bed days each year in England. £2billion a year healthcare costs associated with fragility fracture (Life Made Better 2020).

Table 2 presents the workshop findings of DFG key areas for process improvement. This is based on the current state-of-the-art DFG process aligned with the Adapt-ABLE solutions.

**Insert: Table 2 Key areas for improvement on the current state-of-the-art**

## STEP THREE: DESIGNING A NEW CONSTRUCT

The new construct is based on an in-depth interpretation and synthesis of the contextual literature review and the practicalities of the problems. The major issues identified are process-related, e.g. delay factors and waiting times; therefore, automated process optimisation is suggested to minimise cost and maximise throughput and efficiency. Swan et al. (2017) postulate that social housing has adopted a wide range of technologies. Ofori-Boadu (2017) develop a Housing Eligibility Assessment Scoring Method (HEASM) for low-income Urgent Repair Programs (URPs).

### Concept of adapt-ABLE platform

Adapt-ABLE relies on dynamic process optimisation for adjusting the DFG process to optimise some specified set of parameters without violating some constraints. It consists of four platforms that cut across the life cycle of the DFG process.

Adapt-ABLE changes the current manual approach to the formal automated system through the proposed framework of multi-objective optimisation process designs. The framework uses a generic process model that is formally defined and specifies actionable processes (home suitability, indicative assessment, means testing,

tendering, and contractor selection and performance management) as objective functions.

It consists of four integrated components that support the whole lifecycle of the housing adaptation process.

1) Home Suitability Assessment/Analytics Platform:
2) Adapt-ABLE Platform for Indicative Assessment
3) Adapt-ABLE Procurement and Tendering Hermeneutics
4) Smart Performance Management Platform


***Insert: Figure 2, A model of the proposed solution***


### a) Home Assessment/Analytics-platform:

This platform was initially designed to assess **home suitability** for the aged, disabled, and others (not only DFG-applicants). This is a disability-friendliness matrix that can be used to determine the suitability of a home. The platform:

- allows users to evaluate their home to determine whether they can age in place based on function impact of health/impairment conditions, the Activities of Daily Living (ADLs), and Instrumental Activities of Daily Living (IADLs)
- enables the users to derive an age and disability-friendliness matrix, with suggestions for improvements that could be made to their home.
- the home analytics platform could be used independently regardless of whether the user is applying for DFG or not.
- have futuristic features which will enable the users to decide on adaptation needs before any potential mobility/impairment problems.
- It will be linked with indicative assessment (platform 2) and a separate platform for predictive and maintenance repair by Local Authorities to allocate and monitor properties.

The design of the algorithm relies on the use of a single metric for the measurement of severity. A robust hierarchical scale with equal-interval measures and Interval-level measures is used to separate persons with different levels of disability as applied by (Buz and Cortés-Rodríguez 2016). The person-invariance is categorised as mild, moderate, and severe, e.g., health conditions. The item-invariance is based on physical features, e.g., house features. It is unbiased by age, gender, and level of disability. Interval-level measures of disability will enable a parametric statistical analysis to examine the relationship between key variables confidently. This will provide the opportunity to gain better insight into the hierarchical structure of functional disability and yield more reliable and accurate estimates of the suitability of homes. Figure 3 shows the home suitability working flow. It starts with demographic data and

includes the nature of the impairment, whether situational, temporary, or permanent. The types are based on three broad categories: anatomical loss, physical/mental, and mental/psychological. Other factors used in its development include the types, severity, and effects of disability and the type of assistive device used. Key home features that impact mobility and health variables are also factors in the development.

*Insert: Figure 3 Home suitability assessment chart*

### b) Adapt-ABLE Platform for Indicative Assessment

This platform combines the current process of referral, allocation, assessment & funding-decision into an integrated platform, reducing the long process (usually 50 - 360 days) to 30minutes. It enables timely assessment, decision-making, and case-escalation by Occupational-therapists. The platform is designed to allow:

- A self-referral or by a third party
- Provide a one-stop-shop where all enquiries or referrals can be channelled to a preferred point of access.
- An indicative assessment will be carried out to meet the needs criteria – eligibility threshold. A test of resources can be made to enable the applicants to assess if they qualify for housing adaptation grants.
- Categorise the application based on low, medium or high need; identify risk bands: critical, substantial, moderate, and low. This will only be seen by the caseworker and displayed instantly on the screen (can be printed and communicated by post). The platform will suggest other relevant agencies that could help non-qualified applicants.

### c) Adapt-ABLE Procurement and Tendering Hermeneutics

The standard DFG procurement methods are time-consuming and cause delays for elderly and disabled people. The suggested platform is designed in accordance with the Public Contracts Regulations (PCR 2015) and is compliant for all contracting authorities to use. This platform includes:

- A database of standardised specifications; the use of Modular Buildings/prefabricated units for specific needs like access to washing etc.
- Standardised contractor selection process through online e-tendering, dynamic procurement process - a list of builders approved by the local authority for carrying out adaptation works; Priced schedule – material/equipment and labour (updated)
- Planning permission - link with planning portal so that planning approval procedures do not add unnecessary delays.

- Direct link/integration with indicative assessment portal
- Pictorial description of adaptation-elements
- Contractors' registration/selection
- e-tendering & payment portal
- Standardised price and scheduling

### d) Smart-Performance-Management Platform:

The performance management system will be designed to achieve the following:

- At the installation phase, the platform will generate a report through the interactive system accessible to stakeholders. It includes embedded monitoring and progress tracking system.
- Performance management through Multi-mode Feedback strategies – to 'feed' metrics to a performance management solution.
- Portal Knowledge-Base Integration – Ensuring that information accessed through all service channels remains synchronised.
- Post assessment platform; dealing with complaints.
- Interactive platform for monitoring & tracking of installation.
- Site supervision & liaison.
- Platform dealing with complaints.
- Knowledge-based integration-portal for monitoring adaptation over time.

The proposed solution is flexible and comprehensive in responding to requests for adaptation, and it is accessible and practicable for self-referral or referral by a third party. The system will ensure equity regardless of when the application is made in the year. It will also promote transparency, public accountability and accessibility to data for monitoring and remedial actions. All requests for financial information, the clarification of any anomalies, and the communication of the assessment outcome will be treated sensitively with the highest level of confidentiality. Other agencies that will be involved in the process will have adequate access to carry out their work. However, the system will protect the confidentiality of the applicants by adhering to the Data Protection Act.

## STEP FOUR: DEMONSTRATE THAT THE NEW CONSTRUCT (SOLUTION) WORKS

To familiarise the workshop participants with the proposed, Adapt-ABLE solution, a summary of the construct with a short questionnaire to aid their understanding was sent to those interested in participating a week before the workshop.

**Key points on the proposed solution**

- **Home suitability assessment**

About 90% think is a good tool not only for DFG but for other users. A few concerns about the flexibility on incremental needs and the link with DFG were raised. The platform's robustness was shown in its design containing different health-related issues, types of impairments, Activities of Daily Living (ADL), etc. The home suitability assessment platform will allow users (not only for DFG) to know if their homes are suitable for them, with the possibility to link it with the DFG indicative assessment. One of the participants said, "it is tough to get the information on how to refer themselves for an OT assessment from the "councils' website. When we try and assist on behalf of customers, we are told we cannot refer due to General Data Protection Regulation (GDPR) and some similar reasons. Many councils will not speak to me as I am not with the customer. However, I cannot always be with the customer as I cover the entire patch from Stoke down" this platform will allow quick and accurate assessment of their home and links to different councils".

- **Indicative assessment**

More than 80% of the participants agree that it will shorten the application time. Some of the OTs raised a few concerns about the accuracy in the representation of needs to prevent fake information by the clients. A participant said, "We shouldn't underestimate the importance of objective OT assessment (as opposed to self-assessment tools)". This is a general problem not peculiar to an automated system; clients giving fake information is also possible in physical assessment. However, additional measures have been developed to safe guide fraud. Where such doubt arises, physical examination can supplement indicative assessment. The possibility to accommodate incremental assessment was raised in the workshop to address clients with deteriorating conditions. Flexibility is built into the system to allow for variations and changes when the client's needs change during the process. A means test is part of the indicative assessment.

- **Procurement and tendering**

The agreement for the need for procurement and a tendering platform was unanimous. This is designed as a dynamic procurement system. A system that will select contractors automatically and ease the method of payment. It will be similar to the Framework Arrangement (FA) with a list of contractors. DFG tender online: with 3-5 contractors in the framework. Other features are:

- Metrics for the availability of the suppliers and the contractors
- Call-offs
- Cost/price competition
- Quality criteria to be in the framework
- Range of suppliers and contractors with their rate
- Offer and acceptance to be within 48 hours
- Specification and schedules standardisation

The Local Authorities (LAs) procurement policy was raised as an impediment because of the limitations of changes that can be made. "My Procurement department is very strict about what they will let me do being part of a LA". Another participant wanted it to be extended to minor adaptation for equipment. One of the participants said, "an electronic contractor portal to communicate with them and receive documents would be useful". Another participant said, "capturing all completion documents/photos would be helpful - including a link to maintenance contracts." Another participant advised that the platform should include "contractors code of conduct" and a means of safe guiding policy, e.g., insurance. Contractor selection can be through the lowest cost, randomly selected, or through a league performance table. Overwhelmingly, most participants think it is overdue and will help shorten the duration. One participant said, "We would really welcome an online platform, we spent ages developing something that legal and procurement were happy with, but it's not online." Costin et al. (2019) suggest that collaborative tools positively improved innovation, cost, time, quality, and work environment.

- **Performance management**

There was a unanimous decision that this would be a useful tool, although performance is presently measured but not standardised. A standardised approach will enable proper measurement within and between local authorities, and improvement can easily be made. The feedback from the workshop indicates some apprehension by some participants. For instance, a fear that"...a lot of people are just not into IT stuff!! They want real people to help them." this concern was raised by one of the participants. The majority agreed that the system might be useful in managing expectations, "Managing expectations is a big issue". However, many overwhelmingly think it will reduce the time and cost associated with local authorities for DFG. One participant thinks" it could be one of the points on the wheel of things available to people and could feed people towards HIAs," Another participant thinks it" might be a valuable tool if it could be used to plant the thought that their home is not suitable. They might want to think about the next line of action". A participant said, "For those self-funders, this would be a good tool as long as it gives information on suppliers, best practice designs, etc." The feedback from the workshops and focus group discussions were used to improve the existing framework and to develop the implementation framework as sown in figure 4.

**Implementation framework**

Implementation of each platform was developed and linked together as an integrated system. The home suitability assessment platform (HSAP) relied on three main areas: (i) the physical and mental impairment that will be used to establish impairment severity index (ii) activities of daily living (ADL) and instrumental activities of daily living (IADL) that will be used to establish features relating to functional assessment domains, that is, a person's functional level in the context of their environment and

their personal needs, and (iii) the home features that will be identified and linked with ADL and IADL through home features analytics. This will be used to establish weight modifiers to understand the relationship between impairment vs home features to develop the index core (-ve and +ve). The aggregated home suitability score can then be determined.

The users will have the option of just viewing the suitability score or progress to an indicative assessment platform (IAP) where the suitability score is low, and at least one of the home features (based on individual conditions) needs adaptation. The result from HSAP will be linked with the indicative assessment platform (IAP). The IAP is based on crucial housing adaptation criteria to develop requirements for housing adaptation. Qualification decision options are built into the system to establish the categories of evidence required and input any further assessment on resources testing before indicatively advising if the applicant is qualified or not.

The IAP is linked with the procurement and tendering portal that focuses on automated selection decision support based on selection criteria, standardised specifications for common adaptation, and tendering requirements. The performance management portal will reply to the adaptation register at different stages in the process. Other councils can compare their performance, providing a feedback loop for various stakeholders.

**Insert: Figure 4 Implementation framework**

**STEP 5: THE THEORETICAL CONNECTIONS WITH THE SOLUTION CONCEPT**

Local authorities need to develop a shared system and a high standard of coordination, which will enable all the partners to process cases quickly and minimise the negative impact of the fragmented service delivery (Zhou et al., 2017). In light of advances in computing systems, optimisation techniques, theory and methods have become increasingly important and popular in different engineering applications to handle various practical problems. Therefore, this study is grounded in optimisation principles to address timeless, delay, and collaboration challenges in housing adaptation in the UK. Csanády et al. (2019) opinioned that optimisation is a powerful tool to design new products with better performance, functional and aesthetic values, and improved operating characteristics for less manufacturing costs.

The study proposes a novel pragmatic approach for the suitability and indicative analysis, procurement and tendering platforms, adaptation register, and a platform for overall performance management. The optimisation processes combine the pattern-based semantic composition of services with their non-functional aspects. This will be achieved in part using Quality-of-Service (QoS)-based Constraint Optimization Problem (COP) solving. The logic is similar to Mazzola et al. (2018); it enables automated understanding of task and services requirements by providing semantic

descriptions in a standardised machine-understandable through formal ontological definitions. In addition, the optimised PSP creation component applies state-of-the-art semantic service selection technologies to implement annotated process tasks (McIlraith, 2001). Non-functional criteria, QoS, is additionally considered to find matching services in terms of functional and non-functional requirements (Zhang et al. 2009, Pilioura and Tsalgatidou, 2009). Therefore, non-functional QoS specifications optimality is achieved at the process model level by solving (non)linear multi-objective COP (muCOP) as an integrated follow-up to the pattern-based composition. The suitability analysis is based on multiple-criteria decision analysis (MCDA), which evaluates multiple conflicting criteria in decision making. The housing features and standards, the IDL and AIDLs criteria, and user level of disability are used to develop the suitability analysis platform. In addition to the level of mobility, home features etc., in suitability assessment, the indicative assessment platform includes DFG regulations to develop an indicative system that can show if the applicant is qualified or not.

The principles of dynamic procurement are applied in developing the procurement and tendering construct. The interaction between risk aversion, profits, cheaper information revelation, output distortions and income effects have important implications for the dynamics of distortions in tendering and procurement systems. The principle was applied by Malin and Martimort (2016) on contract renegotiation and the value of incomplete contracts. Wong (2016) used a three-phase dynamic procurement system to risk management with supplier portfolio selection and order allocation under green market segmentation. Erhun et al. (2009) study show that when the supplier uses a wholesale price contract, even under perfect foresight, the supplier, the buyer, and the end consumers benefit from multiple trading opportunities versus a one-shot procurement agreement. Oyegoke (2001) and Oyegoke et al. (2010) refer to it as a vertically integrated system mirrored framework agreement, partnering, and alliances through integrative social devices.

The concept of predictive maintenance is under the research umbrella of Decision Support Systems (DSS). Noori and Salimi (2005) suggest an SMDSS will aid maintenance decision making. According to Bumblauskas et al. (2017), predictive maintenance can be categorised into two: the traditional predictive method, which focuses on time and condition monitoring data and statistical trending, while the modelled or simulated predictive maintenance is based on statistically predictive techniques (prediction or simulation) based on the expected potential for failure. An adaptation register will be developed based on adaptation rules, home features, medical and disability variables. At the back end, algorithms will be built to predict the time and condition-based maintenance, predictions based on the potential failure, matching algorithms, and mapping properties with those that required adapted homes.

A standardised approach is required to measure performance within and across local authorities. It was established by Ramsay (2010) that strong links between different stages of the provision chain are the key to an efficient and seamless service. Zhou et al. (2019) pointed out that the lack of a shared database for adaptation provision within

one authority or across different authorities is a major flaw in the current system. According to Zhou et al. (2019), most local authorities' records of timelines across key stages varied substantially. Lack of standardisation compared service delivery and efficiency across local councils complex (Zhou et al. 2019). Hall (2001) emphasises the importance of accurate time recording to improve performance. Waiting time was identified by Hall (2011) as a key benchmark for proper assessment of adaptation provision. The performance management platform provides a benchmark to measure performance and a basis for comparison to produce a more efficient system. The platform provides a uniform procedure across all local authorities to record delivery times for all the steps of the adaptation process. The platform allows standardisation of the adaptation process across local authorities to be measured quickly and best practices identified.

In terms of policy implication, the intelligent system development is underpinned by the Local Government and Housing (LCH) Act 1989 and the Housing Grants, Construction and Regeneration (HGCR) Act 1996. Flexibility is built-in the system to accommodate changes in policy at the different tiers of government—for instance, flexibility to accommodate local authority-specific policy on procurement, tendering, and project award.


## CONCLUSIONS

This study proposed a smart system to bridge the long and complicated process for disabled facilities grant from referral to completion. The five stages of constructive research methodology are used to understand the problem of significant delays in assessment, funding approval, and installation. Four different but integrated platforms were suggested to improve the process through process optimisation. Home suitability assessment is recommended to enable quick and accurate assessment of homes with assessment scores in percentage and recommendations on minor and major adaptation needed. The indicative assessment platform enables DFG assessment with recommendations on eligibility or otherwise and the reasons behind the decisions. It also contains a practical means-testing approach. The third platform is dynamic procurement which will prevent the lack of skilled contractors and enable standardisation. The fourth platform enables unique adaptation to be appropriately registered to allow for the users' smart allocation and mapping of properties. A standardised performance management platform will enable the performance to be measured across local authorities based on the same performance metrics.

Adapt-ABLE system will provide a platform for consistency among the local authorities, close coordination between stakeholders, and reduction in the duration. Validation of the suggested approach is done through a workshop and focus group. Theoretical connection linking the solution to basic theory as one of the steps of constructive approach is satisfied. Significant reduction in the application process enables the ageing and disabled population to stay in their own house, thereby enhancing community engagement, self-esteem, privacy, and high-level activity. Adapt-ABLE

provides an integrated and interactive platform for quick assessment and adaptation. Adapt-ABLE system adopts Machine-Learning, advanced-optimisation, Decision-Support-System (DSS) & cloud-computing to streamline the whole process from self/home assessment through installation to performance-management.

## FURTHER STUDIES

Funding was obtained from Innovate UK to develop an Adapt-ABLE solution which commenced in July 2020. Further papers will develop, implement, and test the integrated system.

## ACKNOWLEDGMENT

## References

Audit Scotland (2004) Adapting to the Future—Management of Community Equipment and Adaptations; Audit Scotland: Edinburgh, UK, 2004.

Bamford, C. (2000). Surveying outcomes of equipment and adaptations. York, UK: Social Policy Research Unit, University of York

Bibbings, J.; Boniface, G.; Campbell, J.; Findlay, G.; Reeves-McAll, E.; Zhang, M.; Zhou, P. (2015) A Review of Independent Living Adaptations; Welsh Government: Cardiff, UK, 2015

Bumblauskas, D., Gemmill, D., Igou, A., Anzengruber, J., (2017) Smart Maintenance Decision Support Systems (SMDSS) based on corporate big data analytics, Expert Systems with Applications, Volume 90, 2017, Pages 303-317, ISSN 0957-4174, https://doi.org/10.1016/j.eswa.2017.08.025.

Buz, J. and Cortés-Rodríguez M. (2016) Measurement of the severity of disability in community-dwelling adults and older adults: interval-level measures for accurate comparisons in large survey data sets BMJ Open 2016;6:e011842. doi: 10.1136/bmjopen-2016-011842

Clayton, V.; Silke, D. (2010) Evaluation of the Housing Adaptation Grant Schemes for Older People and People with a Disability; Housing Agency: Dublin, UK, 2010.

Costin, G., Nakai Kidd, A., Simon, T. and Edwards, D.J. (2019), "Collaborative procurement and private-sector housebuilding and refurbishment works: A pilot study investigation of the UK", International Journal of Building Pathology and

Adaptation, Vol. 37 No. 5, pp. 699-717. https://doi.org/10.1108/IJBPA-09-2018-0074

Csanády E., Kovács Z., Magoss E., Ratnasingam J. (2019) Principles of Optimization. In: Optimum Design and Manufacture of Wood Products. Springer, Cham. https://doi.org/10.1007/978-3-030-16688-5_3

Cumming, R. G., Thomas, M., Szonyi, G., Salkeld, G., O'Neill, E., Westbury, C., & Frampton, G. (1999). Home visits by an occupational therapist for assessment and modification of environmental hazards: A randomized trial of falls prevention. Journal of the American Geriatrics Society, 47(12), 1397–1402. doi:10.1111/jgs.1999.47.issue-12

Department for Communities and Local Government (2009). Survey of English Housing, 2007–2008. London: DCLG Publications.

Department for Communities and Local Government. (2011). Disabled facilities grant allocation methodology and means test. London: DCLG Publications

Erhun, F., Keskinocak, P., and Tayur, S. (2009) Dynamic Procurement, Quantity Discounts, and Supply Chain Efficiency, https://doi.org/10.3401/poms.1080.0055

Geschka, H., "Creativity Techniques in Germany", Creativity and Innovation Management, 5, 2, (1996), pp. 87-92.

Gitlin, L.N. (2003) Conducting research on home environments: Lessons learned and new directions. Gerontologist 2003, 43, 628–637. [CrossRef] [PubMed]

Golant, S. M. 2008. "Commentary: Irrational Exuberance for the Aging in Place of Vulnerable Low-income Older Homeowners." Journal of Aging and Social Policy 20(4): 379–97.

Hall, E. (2001) Scottish Work Services Inspectorate. Equipment and Adaptation Services in Scotland: A Survey of Waiting Times for Social Work Provision; Scottish Executive Central Research Unit: Edinburgh, UK, 2001.

Hender, JM, Dean, D L., Rodgers, TL and Nunamker, JF (2001) Improving Group Creativity: Brainstorming Versus Non-Brainstorming Techniques in a GSS Environment, Proceedings of the 34th Hawaii International Conference on System Sciences – 2001

Hennink, M. (2014) Focus group discussions. Understanding qualitative research [Online]. New York: Oxford University Press

Heywood, F. (1994). Adaptions: Finding Ways to Say Yes. Bristol, UK: School of Urban Studies.

Heywood, F. (2004). The health outcomes of housing adaptations. Disability & Society, 19(2), 129–143. doi:10.1080/0968759042000181767

Heywood, F.; Gangoli, G.; Langan, J.; Marsh, A.; Moyers, S.; Smith, R.; Sutton, E.; Hodges, M.; Hamilton, J. (2005) Reviewing the Disabled Facilities Grant Programme; Office of the Deputy Prime Minister: London, UK, 2005.

Housing Grants, Construction and Regeneration Act (1996) s.34 Housing Grants, Construction and Regeneration Act 1996.

Jones, C. (2005) Review of Housing Adaptations Including Disabled Facilities Grants—Wales; Welsh Government: Cardiff, UK, 2005.

Kasanen, E., Lukka, K., & Siitonen, A. (1993). The constructive approach in management accounting research. Journal of Management Accounting Research, 5, 242-264.

Keeble, U. (1979) Aids and Adaptations; Bedford Square Press: London, UK, 1979.

Lawton, M.P.; Nahemow, L. Ecology and the Ageing process (1973) In The Psychology of Adult Development and Ageing; Eisdorfer, C., Lawton, M.P., Eds.; American Psychological Association: Washington, DC, USA, 1973; pp. 619–674.

Life Made Better (2020) The DFG Crisis & The Better Care Fund, [https://www.akw-ltd.co.uk/wp-content/uploads/2016/04/AKW-The-DFG-Crisis-and-The-Better-Care-Fund.pdf](https://www.akw-ltd.co.uk/wp-content/uploads/2016/04/AKW-The-DFG-Crisis-and-The-Better-Care-Fund.pdf), visited 2020

Mackintosh, S., Smith, P., Garrett, H., Davidson, M., Morgan, G., and Russell, R. (2018) Disabled Facilities Grant (DFG) and Other Adaptations – External Review, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/762920/Independent_Review_of_the_Disabled_Facilities_Grant.pdf, visited January 2020

Mackintosh, S. and Leather, P. (2016) The Disabled Facilities Grant Before and after the introduction of the Better Care Fund, Glossop: Foundations. http://www.foundations.uk.com/media/4665/dfg-report-final-interactive-converted-draft-6-small.pdf

Malin, A. and Martimort, D. (2016) "Dynamic Procurement under Uncertainty: Optimal Design and Implications for Incomplete Contracts." American Economic Review, 106 (11): 3238-74.DOI: 10.1257/aer.20150275

Mazzola, I., Waibel, P., Kaphanke, P. and Klusch, M. (2018) Smart Process Optimization and Adaptive Execution with Semantic Services in Cloud Manufacturing, Information 2018, 9, 279; doi:10.3390/info9110279

McIlraith, S. A., Son, T. C. and Zeng, H (2001) "Semantic Web services," in IEEE Intelligent Systems, vol. 16, no. 2, pp. 46-53, March-April 2001, doi: 10.1109/5254.920599.

Miller, N. A., Kirk, A., Kaiser, M. J., & Glos, L. (2014). Disparities in access to health care among middle-aged and older adults with disabilities. Journal of Ageing & Social Policy, 26 (4), 324–346. doi:10.1080/08959420.2014.939851

Ministry of Housing, Communities & Local Government (2021) English Housing Survey Home adaptations report, 2019-20, National Statisctics

NHS (2021) Better care fund - Grants and funding, https://www.england.nhs.uk/ourwork/part-rel/transformation-fund/better-care-fund/grants-and-funding/ , visited May 2021

Noori, B. And Salimi, M (2007) A decision-support system for business-to-business marketing, Journal of Business and Industrial Marketing, 20 (4-5) (2007), pp. 226-236

Ofori-Boadu, A.N., Shofoluwe, M.A. and Pyle, R. (2017), "Development of a Housing Eligibility Assessment Scoring Method for low-income urgent repair programs", International Journal of Building Pathology and Adaptation, Vol. 35 No. 3, pp. 194-217. https://doi.org/10.1108/IJBPA-02-2017-0009

ONS (2020) Estimates of the very old, including centenarians, UK: 2002 to 2019, https://www.ons.gov.uk/peoplepopulationandcommunity/birthsdeathsandmarriages/ageing/bulletins/estimatesoftheveryoldincludingcentenarians/2002to2019, visited 2020

Oyegoke, A. (2011), "The constructive research approach in project management research", International Journal of Managing Projects in Business, Vol. 4 No. 4, pp. 573-595. https://doi.org/10.1108/17538371111164029

Oyegoke, A., and Kiiras, J. (2009). Development and Application of the Specialist Task Organization Procurement Approach. Journal of Management in Engineering, 25(3), 131-142.

Oyegoke, A.S. (2001) Construction management contracting systems in UK and US practices: consulting and contracting perspectives, The Quantity Surveyor; Journal of the Nigerian Institute of Quantity Surveyors Vol.34 edition.

Oyegoke, A.S., McDermott, P. and Dickinson, M. (2010) 'The myth behind integration in the UK construction industry', Int. J. Procurement Management, Vol. 3, No. 3, pp.247–264.

Perry, F.C. (2015) Adaptation Works: How Disabled Facilities Grants Are the Overlooked Solution to the Accessible Housing Shortage and Associated Costs; Disability United: Warwickshire, UK, 2015.

Pilioura, T. and Tsalgatidou, A. (2009) Unified publication and discovery of semantic web services. ACM Trans. Web 2009, 3, 11

Public Health England (2017) Falls and fracture consensus statement Supporting commissioning for prevention https://www.england.nhs.uk/south/wp-content/uploads/sites/6/2017/03/falls-fracture.pdf, visited 2020

Public Health England (2017) Falls and fracture consensus statement Supporting commissioning for prevention https://www.england.nhs.uk/south/wp-content/uploads/sites/6/2017/03/falls-fracture.pdf, visited March 2020

Ramsay, M. (2010) Adapting for a Lifetime: The Key Role of Home Improvement Agencies in Adaptations Delivery; Foundations: Derbyshire, UK, 2010.

Sanford, J. A. (2012). Universal design as a rehabilitation strategy: Design for the ages. New York, NY: Springer Publishing Company

Scottish Government (2011) Age, Home and Community: A Strategy for Housing for Scotland's Older People: 2012–2021; Scottish Government: Edinburgh, UK, 2011.

Sheffield City Council (2020) Disability Sheffield Information Service Equipment and Adaptations Factsheet, https://www.disabilitysheffield.org.uk/admin/resources/equipment-and-adaptations-2.pdf, visited February 2020

Swan, W., Fitton, R., Smith, L., Abbott, C. and Smith, L. (2017), "Adoption of sustainable retrofit in UK social housing 2010-2015", International Journal of Building Pathology and Adaptation, Vol. 35 No. 5, pp. 456-469. https://doi.org/10.1108/IJBPA-04-2017-0019

The DFG Crisis & The Better Care Fund (2020) https://www.akw-ltd.co.uk/wp-content/uploads/2016/04/AKW-The-DFG-Crisis-and-The-Better-Care-Fund.pdf, visited February 2020

Thoring, K., Mueller, RM and Badke-Schaub, P. (2020) Workshops as a Research Method: Guidelines for Designing and Evaluating Artifacts Through Workshops, Proceedings of the 53rd Hawaii International Conference on System Sciences

Tsai, J., Carlsson, J.G., Ge, D., Hu, Y., and Shi, J. (2013) "Optimization Theory, Methods, and Applications in Engineering 2013", Mathematical Problems in Engineering, vol. 2014, Article
ID 319418, 5 pages, 2014. https://doi.org/10.1155/2014/319418

UK Government (2020) Disabled Facilities Grants https://www.gov.uk/disabled-facilities-grants, visited 2020

Vergidis, K., Tiwari, A., Majeed, B., and Roy, R. (2007) Optimisation of business process designs: An algorithmic approach with multiple objectives, International Journal of Production Economics, Volume 109, Issues 1–2, Pages 105-121, ISSN 0925-5273, https://doi.org/10.1016/j.ijpe.2006.12.032

Watson, S., & Crowther, L. (2005). Was it worth it? A study into the effectiveness of major adaptations. Nottingham: Nottingham City Council

Wiles, J. (2005) Conceptualizing place in the care of older people: The contributions of geographical gerontology. J. Clin. Nurs. 2005, 14, 100–108. [CrossRef] [PubMed]

Wong, T. (2020) "Dynamic procurement risk management with supplier selection and order allocation under green market segmentation," J. Clean. Prod., vol. 253, 2020.

Zhang, Y.; Huang, H.; Yang, D.; Zhang, H.; Chao, H.C.; Huang, Y.M. Bring QoS to P2P-based semantic service discovery for the Universal Network. Pers. Ubiquitous Comput. 2009, 13, 471–477

Zhou W, Oyegoke AS, Sun M, Zhu H. (2020) Older Clients' Pathway through the Adaptation System for Independent Living in the UK. International Journal of Environmental Research and Public Health. 2020 May;17(10). DOI: 10.3390/ijerph17103640.

Zhou, W., Oyegoke, A.S. & Sun, M. Service planning and delivery outcomes of home adaptations for ageing in the UK. J Hous and the Built Environ 34, 365–383 (2019). https://doi.org/10.1007/s10901-017-9580-3

Zhou, W.; Oyegoke, A.S.; Sun, M. (2019) Causes of Delays during Housing Adaptation for Healthy Ageing in the UK. *Int. J. Environ. Res. Public Health* 2019, *16*, 192. https://doi.org/10.3390/ijerph16020192

Zhou, W.; Oyegoke, A.S.; Sun, M. (2019a) Adaptations for Ageing at Home in the UK: An Evaluation of Current Practice, Journal of Ageing & Social Policy, DOI: 10.1080/08959420.2019.1685347