architecture

MDPI

Article

One-Stop Shop Solution for Housing Retrofit at Scale in the United Kingdom

Chamara Panakaduwa *, Paul Coates and Mustapha Munir

School of Science, Engineering and Environment, University of Salford, 43 Crescent, Salford M5 4WT, UK; s.p.coates@salford.ac.uk (P.C.); m.y.munir1@salford.ac.uk (M.M.)

* Correspondence: c.s.panakaduwagamage@edu.salford.ac.uk or chamarapanakaduwa@gmail.com

Abstract

Retrofitting the existing housing stock to a high level of energy efficiency will not be limited to achieving the decarbonisation of 80.3 MtCO2e residential emissions and reducing fuel poverty in 4.16 million households, but also improving the health and well-being of UK residents and their overall quality of life. The current progress of housing retrofitting is poor, at less than 1%. The UK expects to achieve net zero by 2050, and the challenge is immense as there are more than 30 million houses. The challenge is similar in other global contexts. Even if the required technology, supply chain, skilled labour, and finance could have been provided, the retrofitting would not move forward without positive engagement from the clients. Proper strategies are required to retrofit at scale. Focusing on the challenges of stakeholder engagement in housing retrofitting, this study focused on developing a hybrid one-stop shop solution through design science research. A theoretical artefact and an empirical system requirement specification document were developed to propose a one-stop shop solution. This was tested through retrofit industry stakeholders. Findings reveal that the one-stop shop model will be a good answer to retrofitting at scale, providing the resident engagement of 30.1 million households. The model can support residents with or without computer literacy due to its hybrid approach. The proposed theoretical and industrial models can be used as base models for developing one-stop shops for housing retrofitting by adapting them for context-specific requirements.

Keywords: housing stock; one-stop shop; retrofit at scale; stakeholder engagement

Academic Editors: Jamal Alabid, Bernard Tuffour Atuahene and Thomas Spiegelhalter

Received: 27 March 2025
Revised: 2 June 2025
Accepted: 17 June 2025
Published: 20 June 2025

Citation: Panakaduwa, C.; Coates, P.; Munir, M. One-Stop Shop Solution for Housing Retrofit at Scale in the United Kingdom. *Architecture* **2025**, *5*, 40. https://doi.org/10.3390/architecture5030040

1. Introduction

1.1. Retrofitting Houses for Sustainability

The United Kingdom has over 30.1 million houses as of 2022 [1]. Currently, 90% of the houses in England are heated by natural gas (86%) and oil (4%) central heating [2]. According to the statistics, the UK housing stock is reported to generate 19.76% of total UK emissions [3]. Apart from the problem of carbon emissions, 13% (3.17 million) of the housing stock is reported to be in fuel poverty in England as of 2023 [4]. Furthermore, UK houses are reported to be smaller, less comfortable, and less healthy than those in other European countries [5]. Based on the above considerations, there is an urgent and important need to upgrade the housing stock in the UK to achieve sustainability goals in environmental, economic, and social aspects.

One of the viable answers to this problem is to retrofit the housing stock. Although there are alternatives such as demolition and rebuilding or shifting to alternative energy sources, they all have opportunity costs. Retrofit can cause high initial investments and

may not always be economically feasible. Repayment through energy bill savings can have extensive payback periods which are not financially rational [6]. Apart from that, retrofit is reported to answer significant problems associated with poor-performing housing stock, such as carbon emissions, fuel poverty, and poor health and well-being or quality of life [7–9]. According to the British Standards Institution, retrofit can be defined as improving energy efficiency, reducing carbon emissions, or improving ventilation [10]. This improves the operational performance of the house [11]. Housing retrofit is reported to have a broader range of benefits apart from energy efficiency. For example, a retrofitted house would be more valuable and durable [12].

Focusing on the delivery of housing retrofit at scale, almost all the houses in the UK are reported to need some level of retrofit [13]. Although the government's residential decarbonisation strategy mainly relies on heat pumps [14], installing heat pumps in the UK has never shown satisfactory progress [15]. Meanwhile, the window to retrofit the 30.1 million houses is closing. The United Kingdom government expects to achieve net zero by 2050 [16]. Existing retrofit strategies are not properly optimised and no clear strategies or policies have been observed to address these challenges [17]. Precise and robust strategies are required to retrofit the UK housing stock at scale. Looking at the number of heat pump installations in the UK (<200,000) [15], the required level of progress of housing retrofit is nowhere near.

1.2. Problem Identification

The retrofit industry is fragmented from the contractors' point of view, and usually one contractor provides only one service [18]. Researchers argue that retrofit clients hesitate to engage in the retrofit process due to its complexity [19,20]. The client has to be a project manager to properly coordinate a housing retrofit project due to the existing fragmented nature of the retrofit industry [18]. This problem has been addressed to a certain level in the UK with the introduction of the retrofit coordinator role under the PAS 2035 project management specification [10]. Retrofit project management and quality assurance are prerequisites for retrofit at scale, while industry collaboration also needs to be improved to a considerable level. Existing top-down approaches to promote retrofit have failed, and researchers suggest a bottom-up approach, focusing on clients [21,22]. Considering these aspects, this study wishes to treat the client as the most critical stakeholder for housing retrofit at scale.

Several key stakeholders can be identified in the housing retrofit industry. Apart from the clients, the contractors play a key role in retrofit delivery. Currently, there is a shortage of skilled labourers and contractors to cater for the demand for retrofit [23]. Further, clients have lost their confidence in contractors due to negative case studies in the past, where the retrofitted houses were observed with unintended consequences [24]. This challenge is severe in the UK, while the global contexts endorse the problem, more or less. Another important stakeholder in the retrofit process is the professionals, such as architects, construction project managers, surveyors, or engineers. There are arguments that the reason for the negative case studies of housing retrofits in the past was partly due to the lack of involvement of professionals in the retrofit [25]. The PAS 2035 specification has introduced retrofit professionals and allocated clear responsibilities to avoid these problems in the future [10]. Another important stakeholder in the process can be suggested as the government and non-government institutions. Government institutions support mass-scale retrofit drives with financial grants for private and social housing projects [26]. In addition, professional, not-for-profit, cooperative, and private institutions are working on retrofit delivery for different purposes.

Although the need for retrofitting the housing stock for sustainability is established, the poor progress of housing retrofit seems to be influenced by several factors. One of the key challenges is poor client engagement. As previously mentioned, the client is a key stakeholder, and without satisfying client requirements, it is unlikely to engage them positively in the process. Due to the lack of strong stakeholder engagement models in the housing retrofit industry, the stakeholders try only to maximise their objectives, overlooking the collaborative synergies and ignoring the client's requirements.

1.3. Outline of the Solution

Researchers have identified the one-stop shop business model as a potential solution to the problem of poor stakeholder engagement in housing retrofits in the global scenario, most prominently in European countries. The basic idea of the one-stop shop model is to provide all the housing retrofit services through a single point of contact to the clients [18,27]. This model eliminates the challenges with the existing fragmented model of housing retrofit and promotes collaboration among the housing retrofit stakeholders. The clients are supported with a seamless journey through the retrofit process from start to end. According to Biere-Arenas & Marmolejo-Duarte (2023), several one-stop shops housing retrofit models exist in Europe and the UK [28]. Although some of them are not explicitly termed as one-stop shops, these entities provide integrated retrofit services to their clients through a single point of contact.

There are several categories of one-stop shops according to their level of responsibility towards their services. Figure 1 shows a general model for a one-stop shop for housing retrofit. Basic models provide information and act as a platform for stakeholder collaboration. They do not take any responsibility. There are other one-stop shops that offer all the services, take responsibility for the energy savings, and ensure the repayment of loans, if any. These one-stop shops bear the highest level of responsibility. Apart from that, there can be entities with different levels of responsibilities in between [18,29]. Other than the level of responsibility, one-stop shops can also be classified as public, private, or hybrid entities [30]. In terms of delivery, there are physical one-stop shops, online one-stop shops, and hybrid models [31].

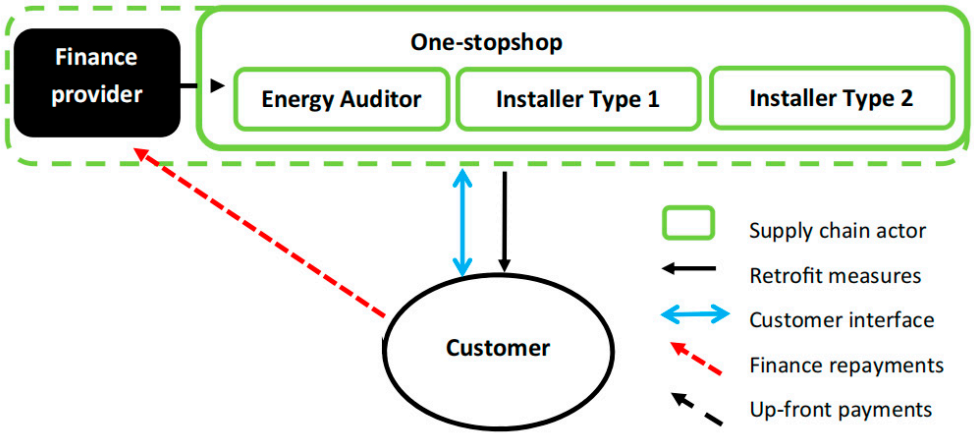

Figure 1. One-stop shop model for retrofitting [18].

Considering the above requirements, this study aims to develop a potential one-stop shop solution for housing retrofit. This model aims to provide integrated services to retrofit clients. Ideally, the retrofit project shall be delivered as a one-off whole-house retrofit. However, the model needs to accommodate step-by-step retrofit plans since not all clients will go for one-off whole-house projects due to financial or time constraints. The existing fragmented nature of retrofit delivery has not fully considered these client requirements. Al-

though this model was developed considering UK retrofit industry requirements, the model will be able to adapt to different contexts according to different contextual requirements.

1.4. Scope of the One-Stop Shop Model

This study has designed a default one-stop shop for a medium level of responsibility over its services. This can be recognised as the ideal "one-stop shop model" according to Brown (2018) [18]. At this level, the entity should provide project management services more than just information and collaboration, but will not provide energy savings or loan repayment guarantees. Due to the presence of PAS 2035 specifications for retrofit project management [10] and the maturity of the housing retrofit industry in the UK, this medium responsibility level will be a good starting point. If the solution is applied to a different context, it is recommended to look at these contextual differences.

Further, the model will be proposed as a hybrid model with physical and online interfaces. Concerning Sequeira & Gouveia (2022), physical and online one-stop shops have advantages and disadvantages. Hybrid one-stop shops will complement the advantages of both models [32]. These hybrid models will be more accessible and cost-efficient than physical and online models themselves [30]. This study does not wish to specify the ownership of the one-stop shop and whether it will be public, private, or hybrid. Required adjustments should be incorporated according to the requirements of the promoters.

The initial scope of the one-stop-shop solution will be limited to providing retrofit awareness and initial retrofit appraisal. Research conducted by Seddiki et al. (2022) has found the potential of retrofit decision-support tools to improve awareness and provide decision support for housing retrofit [33]. Figure 2 provides a schematic representation of the proposed scope.

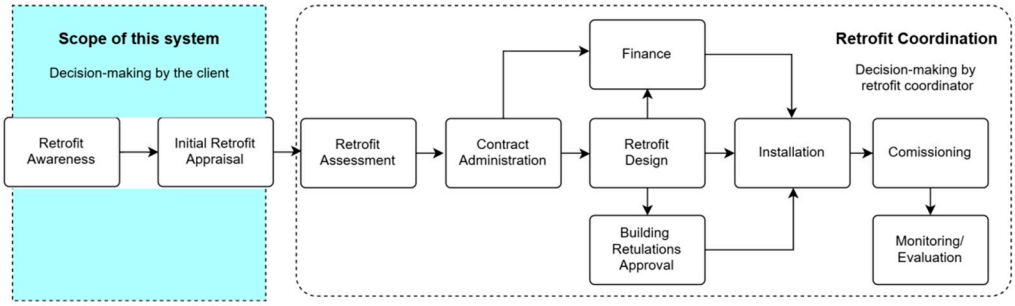

Figure 2. Scope of the solution.

The process of a housing retrofit under the PAS 2035 specification has clear phases of project delivery. They include the retrofit assessment, retrofit design, installation, commissioning, monitoring, and evaluation under the responsibility of relevant retrofit professionals. The whole process is coordinated by a retrofit coordinator [10]. The accreditation agencies have developed software for retrofit assessment and coordination [34]. Application of the concept outside the UK context needs to decide how to complement the retrofit professional roles and processes.

Designers typically use CAD (Computer-Aided Design) software for retrofit design. In brief, systems are available for project management, from retrofit assessment to monitoring and evaluation in the UK. All of these systems are intended for the use of retrofit professionals. No interface is given to the clients, despite the fact that the PAS 2035 specification has recommended early engagement of the client for identifying retrofit measures. The primary focus of the one-stop shop solution is to provide the client with a single online interface for the retrofit process. Accordingly, the model will be proposed as a hybrid one-stop shop, integrating the functionalities of both online and physical one-stop shops. Existing retrofit

coordination systems can be bridged to the online one-stop shop solution to keep the client updated throughout the retrofit process.

1.5. Objectives of the Solution

The selected problem is poor stakeholder engagement in housing retrofit. The client is selected as the key stakeholder for this study. The outlined solution is the one-stop shop model for housing retrofit. This study aims to engage the client in the retrofit process to promote housing retrofit at scale. Finally, a poor-performing house must be retrofitted to become high-performing. Considering the study scope, three key objectives of the solution can be proposed.

1. Engaging the clients with the housing retrofit process by encouraging them to undergo a professional retrofit assessment;
2. Collecting information about the clients and their houses for the government to make better policy decisions;
3. Keeping the clients updated throughout the retrofit process and addressing their concerns through a single point of contact.

Figure 3 shows the objectives of the one-stop shop solution and its intended scenario. The first objective of the solution is to engage the clients with the retrofit process. The proposed one-stop shop solution should enlighten the clients about the benefits, process, and challenges. Getting their commitment to go for a physical retrofit assessment by an accredited retrofit assessor will enable the first step of onboarding clients to the retrofit process. Even if the clients refuse to proceed, they may change their minds later. The retrofit assessment will record all the data required to design a comprehensive retrofit project. If this retrofit assessment could be offered free, that would be ideal.

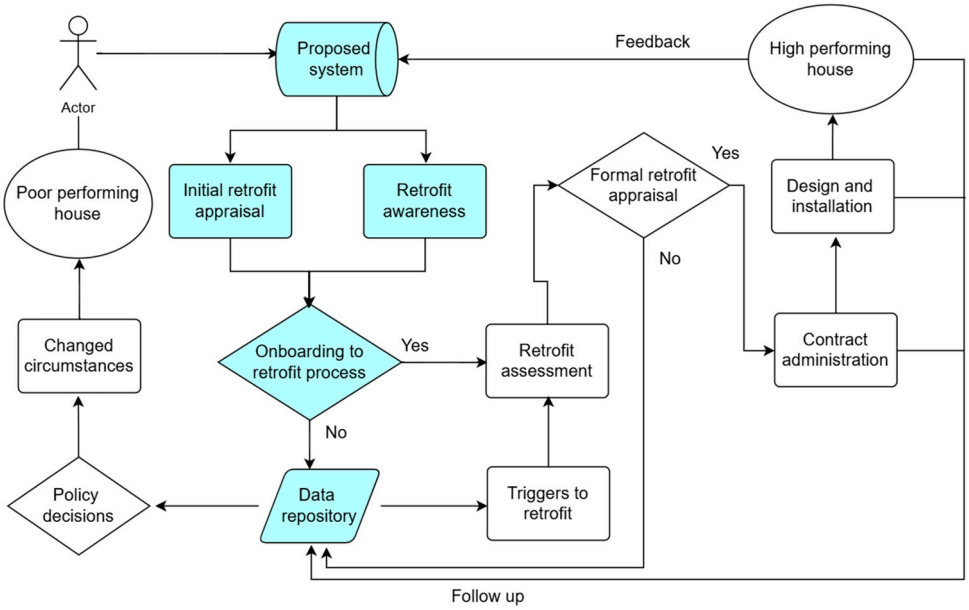

Figure 3. Objectives and the scenario of the solution.

The second objective is to collect data about the clients and their houses. The one-stop shop solution shall collect some data for an initial retrofit appraisal. This will not be perfect, but it will be better than nothing. If they decide to undergo a professional retrofit assessment, it will help collect comprehensive data for retrofit purposes. This data about the retrofit clients and their houses will be helpful for the government in making better policy decisions. For example, the solution shall collect data on why people decide not to

proceed further. This may be due to financial issues, so the government could consider increasing the grants or relaxing their eligibility criteria.

The best scenario will be when clients decide to retrofit their houses. The proposed one-stop shop can be bridged with the existing retrofit project management solutions and the information systems of other retrofit stakeholders. Accordingly, not only the clients but also all other stakeholders can be updated and communicated throughout the retrofit process via a single interface, creating a better retrofit experience for them.

2. Materials and Methods

2.1. Research Design

The design science research method was considered for this study, considering the development of an artefact as a one-stop shop solution for housing retrofit. In addition to the artefact, this study shall contribute to the existing body of knowledge. Design science research is recommended when an artefact is systematically developed to solve a problem in context, with a contribution to the body of knowledge [35–37]. Regarding the research philosophy, the artefact development is viewed from a pragmatist ontology, where practical rigour is valued. The contribution to the knowledge is viewed from critical realism ontology, where the justification is valued. The methodology was referred from the design science research phases suggested by De Sordi (2021) [38].

Table 1 shows the design science research steps applicable to this research with reference to De Sordi (2021) [38]. The problem identification and the objectives of the solutions were made based on the existing literature. Framework design and development were approached as the creative element of the study. There are two outputs related to the design and development phase. One is the theoretical framework for the one-stop shop solution, which is referred to as the "artefact".

Table 1. Design science research steps.

Phases	Description	Source
Problem identification	Poor client engagement with the housing retrofit process.	Literature review
Objectives of the solution	Stakeholder engagement and data collection of housing stock and clients.	Literature review
Design and development	Development of a framework and software requirement specification.	Creative element
Demonstration	Demonstration of a hypothetical case study for housing retrofit stakeholders.	Presentation
Evaluation	Artefact evaluation for intended purposes.	Semi-structured interviews
Communication	Communication of the findings and contribution to the body of knowledge.	Journal article publication

This framework was primarily developed by brainstorming ideas according to the recommendations in the literature. Due to the nature of design science research projects, the authors' contribution to the design activity was identified as a significant characteristic. Applicable theories and literature were prominently referred to for this purpose. Once the framework was developed, it was demonstrated to a sample of 16 retrofit industry stakeholders through a hypothetical case study presentation. The comments received were incorporated into the outputs. Finally, the work was set for communication as a journal article.

There is also a technical output as a software requirement specification (SRS). This SRS document is deposited in a repository and referred to in the text. The document was developed under the international standard of IEEE/ISO/IEC 29148-2018 Requirements Engineering [39] as the practical contribution of this study.

2.2. Data Collection and Analysis

The concept was designed as a hypothetical case study for demonstration purposes and was demonstrated to 16 retrofit industry stakeholders. During the evaluation phase, the framework was evaluated for its intended purposes with the help of semi-structured interviews. Table 2 shows the interview sample for evaluation purposes. The evaluation of the artefact is presented in Section 4.2 in detail. The background details of all the interview participants are given in the Appendix A.

Table 2. The sample of artefact evaluation interviews and their stakeholder group.

	Stakeholder Group	Count	Participants Included in the Sample
1	One-stop shop	1	A representative of an existing online one-stop shop service.
2	Academia/Research	6	Academics who are engaged in retrofit-related research and education.
3	Software engineering	2	Professionals engaged in software development and/or education.
4	Construction	1	Professionals involved in residential construction and retrofit.
5	Clients	1	A homeowner in the United Kingdom.
6	Project management	1	A retrofit project manager of a local authority.
7	Regulations	1	A planning officer who is attached to a local authority.
8	Finance	1	A financial advisor of an entrepreneur support institution for net-zero transmission (government funded).
9	Contractors	2	Representatives of two companies involved in heat pump installation and residential insulation measures.
	Total	16	

Table 2 shows the summary of the evaluation interview sample. Sixteen participants were recruited to represent nine types of stakeholders through a convenient sampling process. The sample mainly consisted of academics (6) as this study was more inclined to research rather than an industry-related project. Twelve interviews were conducted online during April and May 2024. Four further online interviews were conducted during May 2025. All the interviews were conducted by the first author as part of their doctoral study data collection, under the supervision of the other two authors. The data collection received ethical clearance from the University of Salford, UK under the reference number 10,162, dated 9 May 2023.

The interviews were transcribed through MS Teams and further optimised for clarity of content. According to the semi-structured interview questionnaire, they were thematically analysed under five codes: Novelty, Awareness, Option Evaluation, Lead Generation, and

Demand. The findings were incorporated into the SRS document as recommendations to improve the concept.

3. Results

3.1. Key Characteristics and Functionalities

This study aims to develop a hybrid one-stop shop solution with both a physical and online presence. This section focuses only on the development of the online one-stop shop for housing retrofitting. The discussion section presents the use of the online system for delivering the physical one-stop shop. According to Table 3, key functionalities of this proposed one-stop shop solution can be presented under five themes focusing on this study's purposes.

Table 3. Summary of functionalities.

ID	Function Name	Function Description
A	User persona	A persona of the user is to be created to model the client's behaviour.
B	Building information model	To have an information model of the house. Ideally, a Building information model (BIM).
C	Retrofit measures	Information about retrofit measures, products, costs, finance, quality, installers, and interdependence among the measures.
D	Option evaluation	The users shall explore the potential retrofit options for their house and how they can be scheduled, including cost, finance, and quality.
E	Data management	Data about users, house models, and retrofit option appraisals will be stored in cloud space, including the system itself. The data needs to be shared in different formats and media when and where necessary.

Apart from the above five functionalities, there will be several non-functional requirements such as usability, portability, security, and maintainability. This study does not wish to explore these non-functional requirements. Further, making people aware of retrofit benefits and process will be a key requirement in promoting retrofit at scale. This can be approached from two perspectives. One is general awareness-making, without referring to a specific property. There is an exhaustive number of online and physical sources available for this. When a client has a basic awareness of the retrofit process and benefits, they may seek to know the specific benefits of retrofitting their house and understand the nature of the retrofit process. This study mainly focuses on the second perspective to give particular information about retrofitting a house for a client. According to the desk study, providing essential information and awareness has matured in the industry. Promoters can always include such a generic retrofit awareness functionality if they wish.

3.2. User Persona

Purpose: The system can personalise information according to the demographics and requirements of the user using a user persona.

Personalisation of the information to the user is expected to be approached by identifying the user demographics and their requirements. The demographics and requirements can be asked from the user. Based on the user demographics and requirements, the system shall decide what to show the user. For example, the user can only be shown the available

contractors where the house is located. Another example can be given to show eligibility for government grants based on client demographics, since this information can contain sensitive personal data, with particular attention given to the data security and privacy of the clients.

Generations theory can be given as a key theory regarding personalisation of the contents according to user demographics. According to this theory, a person has four lifestyle stages from birth to death. They are youth (0–21), rising (22–43), midlife (44–65), and elder (66–87). The experiences faced during their childhood are believed to shape the characteristics, traits, and personalities of their generations [40]. Further, there are identified generations and perceived characteristics of these generations, such as Generation X, Generation Y, or Generation Z. A study conducted by Liu et al. (2022) [41] noted that retrofit decision-making behaviour is influenced by demographic factors such as age. For example, younger homeowners are more likely to adopt retrofit measures. Huang et al. (2021) [42] have found that older homeowners are more reluctant to pay for energy efficiency improvements.

There are different behaviours of the brains of males and females. Men usually concentrate on one thing at a time, while women can engage in a lot of things at the same time. Men can make sense of spatial things more efficiently, while women are not. Men prefer short wordings, while women prefer a lot of vocabulary [43]. These differences are important to consider when personalising information. As a suggestion, males can be shown one item at a time, while women can be shown an overall idea of the retrofit solution.

The diffusion of innovation theory was proposed by Everett M. Rogers in 1962 in his book "Diffusion of Innovations" after many publications about the topic. This theory proposes how people will respond to innovations. Some people warmly welcome innovations, while some hesitate [44]. By applying this to the user persona model, the one-stop shop solution may prioritise information according to the behaviour of different groups of people. For example, 2.5% of innovators will instantly grab a housing retrofit. Considering the UK housing stock, there will be around 750,000 households in this segment. They have the interest, financial capacity, and appetite to take risks. They will not require more detail but an attractive final proposal. Although this theory can be useful, there will be a problem with identifying the user segment under this theory.

Ned Herrmann developed the whole brain model in the late 1970s. This model describes four functions of the human brain. According to this theory, some people mainly focus on the process, some focus on achievement, some focus on social aspects, and others focus on value [45]. The information can be personalised according to the user's perceived priorities if the relevant user category can be identified. For example, the category that focuses on the process will be motivated by showing how the retrofit process can happen through the one-stop shop model. The category that focuses on social aspects will be motivated by how others have retrofitted the houses with the help of the proposed one-stop shop. Again, there will be a problem identifying the user's category.

John Sweller proposed cognitive load theory in the 1980s. The theory argues that a learner's working memory has a limited capacity and can handle only a limited volume of learning at a time. The theory suggests simplifying the important load of information and reducing the unnecessary load of information [46]. Not all the users of the one-stop shop solution will have the same cognitive capacity. For this reason, it will be important to identify the user's cognitive capacity level and present the information in manageable chunks. Ideally, progressive disclosure techniques can be used to present a complex idea step by step [47].

3.3. Building Information Model

Purpose: A building information model is required to evaluate different retrofit scenarios for a selected house according to client requirements.

A user will engage with the proposed one-stop shop solution to explore retrofit opportunities for their house. A digital model of the house is required to evaluate different retrofit scenarios. The first data point is expected from the Energy Performance Certificate (EPC) database if available. In total, 69% of the houses in England and 66% in Wales have at least one EPC record [48]. Although the EPC report provides a small amount of data about the building, more data is available within the database. Further, the EPC assessor is required to keep further data about the house for audit purposes. Earlier, this data was under the personal custody of the domestic energy assessor. The data was not required to be in a digital format. The accreditation bodies have now enabled the assessors to record this additional data for audit purposes using the software itself. This removes the additional responsibility of the assessors to keep audit data. If the system can access this additional and audit data, it will give more comprehensive information about the house. The existing retrofit decision support systems are also designed based on this database.

The location data is expected from maps and other GIS (Geographical Information System) resources. One source of visual data is Google Street View. Further, as earlier described, EPC audit data can also provide photographs. Finally, the user can also provide images of the house. Energy consumption data is highly informative for making retrofit decisions more accurately. This can be sourced from energy supply companies and smart meters. The system can ask the users for this as a last resort. However, it will increase user stress, and the data may not be accurate enough. One existing decision support system can synthesise smart meter data to improve the accuracy of the estimates. Equipment, appliances and occupancy data are to be sourced from the user. Alternatively, an AI tool may be able to identify them via user photographs or video.

The information sourced at this stage does not have to be 100% accurate. The information shall help the system identify the key retrofit measures and their scope, which will help the client decide whether to retrofit the house or not. For example, around 20% tolerance may be acceptable for the client's decision-making purposes. Once the client chooses to proceed with the retrofit process, there will be a professional retrofit assessment by an accredited retrofit assessor with accurate information to start the formal retrofit process. Accordingly, the initial retrofit assessment will indicate the client's decision-making, while the professional retrofit assessment will be used for retrofit project design and delivery. The first objective of the one-stop shop solution is to drive the clients to a professional retrofit assessment using the indicative retrofit appraisal generated by the system.

3.4. Retrofit Measures

Purpose: Identifying the existing and proposed retrofit measures applicable to the property.

According to the British Standards Institution, there are 41 housing retrofit measures. These measures can be presented under several categories: building fabric measures, building services measures and renewables [10]. Apart from these 41 measures, many other retrofit measures can be applied to properties. For example, green roofs and green walls can be installed for energy efficiency [49]. Repair and maintenance are also necessary, as the retrofit is not feasible without taking the house to a good state of repair. Housing retrofitting is an ideal point to address repairs, too.

The system shall list all the available retrofit measures. One key characteristic of these measures should be the ability to model the retrofit measure according to parameters. This will help the system model energy efficiency, energy consumption, cost of measures, and

life cycle analysis according to the given parameters. For example, the system should be able to model the retrofit cost, u-values, and durability of internal wall insulation if the wall area is given for a particular house. For this purpose, parametric characteristics should be able to be customised.

A key enabler to the success of the proposed one-stop shop will be the active engagement of the contractors. The attractiveness of the one-stop shop can be hindered without the client's commitment and readiness to contribute to out-of- the-box solutions. This is unlikely, considering the existing lack of retrofit contractors in the UK industry [50] and their overcapacity demand. There should be an adequate supply of contractors and a supply chain to deliver retrofits at scale, considering the 30.1 million houses and the shorter period to retrofit the whole housing stock.

Considering the procurement requirements, contractors should be able to update their prices as unit costs; for example, the cost of internal wall insulation for one square meter. Understandably, providing functionality will not be simple. This will help the system compare different contractors and their retrofit solutions, if possible. The users can select contractors and materials by evaluating their options. The inputs from the contractors will mainly support this functionality. The retrofit option evaluation function is considered next, and listing these parametric retrofit measures will be a prerequisite.

3.5. Option Evaluation

Purpose: To design a potential combination of retrofit measures and their scope according to the property and client requirements.

The first functionality is to identify the client. The second is to identify the property. The third is to list the retrofit measures with the support of contractors and other measure-specific characteristics. When these details are available, the one-stop shop shall identify potential combinations of retrofit measures applicable to the property, referring to the characteristics of the house and the client. There are several other aspects to consider under the functionality of option evaluation.

Initially, the one-stop shop shall show a recommended combination of retrofit measures, cost, energy efficiency, estimated project duration and quality. It is suggested that at least three default retrofit packages be shown. One can be the highest energy efficiency level. In terms of EPC, this can be EPC "A" level [51] or Passivhaus EnerPhit level [52]. Ideally, there should be a retrofit package for a minimum recommended level of energy efficiency. Considering the UK government's target to bring all houses to the EPC "C" level by 2035, this can be EPC "C" level [2] or a building energy efficiency of 90 kWh/m2/y [53]. Apart from these two extreme levels, it is recommended that an optimised retrofit package be developed based on investment cost and energy efficiency level. This will give the client an initial idea of the retrofit solution.

Another essential factor to consider is retrofit measures' interactivity and building regulations. According to BSI (2023), the PAS 2035 specification has provided a measure interaction matrix since some retrofit measures cannot be combined [10]. Although fully complying with building regulations can be unrealistic at this stage, the system can consider the basic limitations and recommendations when appraising the packages of retrofit measures.

The availability of the contractors and their retrofit measures will also be a key limiting factor. The one-stop shop should identify the available contractors, their services, and materials to calculate target energy efficiency and cost levels. The previous functionality of retrofit measures shall facilitate this. One way of doing this is to allow the contractors to update their availability by integrating their project resource planning systems into the proposed one-stop shop solution. Providing the right system infrastructure would

enable the system to estimate realistic quotations for the retrofit package rather than just estimates. Although a desk study showed no contractors providing realistic quotations online for housing retrofit, there can be innovations. For example, comparison websites like MoneySupermarket.co.uk (accessed on 26 March 2025) or Confused.com (accessed on 26 March 2025) provide insurance quotations. If retrofit at scale scenarios were assumed for 30 million houses, there would be ways of achieving that.

3.6. Data Management

Purpose: To manage data related to the clients, properties, option evaluations, and retrofit measures collaboratively among the stakeholders.

The system needs to store, retrieve, and share data during its operation. When a user profile is created, the details about the user are gathered first. This can be direct data input from the user or the collection of peripheral data from third parties. One example can be collecting the client's credit rating from a credit agency to help with the mortgage evaluation for retrofit. Apart from that, HM Revenue and Customs (United Kingdom) have data about the financial circumstances of the residents. This will help understand the eligibility of the clients for retrofit grants from the UK government.

The details about the house are to be linked to the profile. According to the requirements, this can be a single or multiple houses. Some details can be obtained directly from the client and third-party sources. Since the data about the house is more technical and may not be familiar to a non-technical user, it is recommended to reduce data collection from the customer and seek ways of collecting data from third parties. As suggested in the second functionality, one of the prominent ways is to get data from the EPC database. Further, there can be an exhaustive list of data sources, e.g., local authority planning portals, real estate websites, or Google Maps.

Figure 4 gives the context diagram of the solution. Integrating the system with energy companies will also be beneficial, as historical energy consumption data can be retrieved to estimate occupancy details more accurately. Smart meters are reported to provide more reliable and timely energy consumption data. During the desk study, it was observed that the one-stop shop model had already considered this aspect. Another key data point is smart home systems. They will help collect detailed energy consumption behaviours of residential houses.

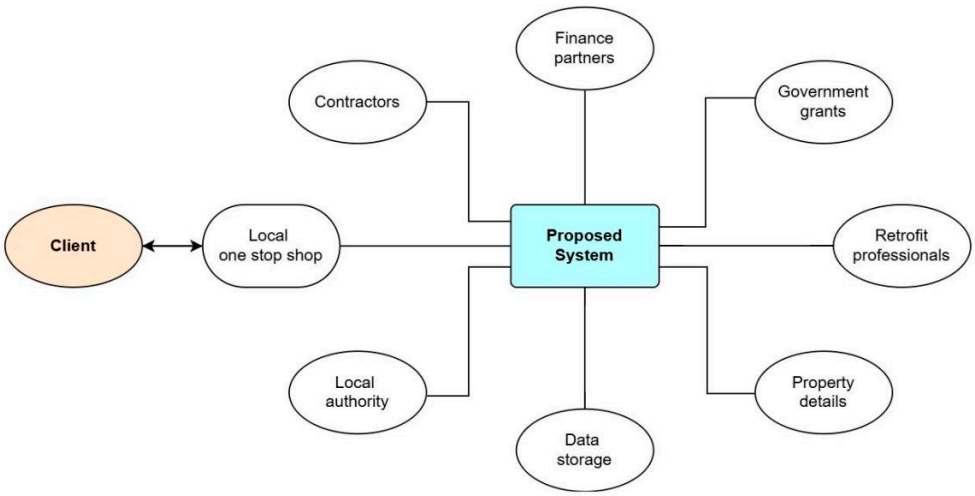

Figure 4. Context diagram of the solution.

Funding is a key aspect of the retrofit delivery. Unless heavily subsidised through government grants, there will be requirements for loans either directly from banks or

through special contractual agreements such as ESCOs (Energy Service Companies) or MESAs (Managed Energy Service Agreements) [18]. In any scenario, the financial provider will assess the client's credit facilities by considering the client's property, financial circumstances, and proposed retrofit solution. They will need to be given one interface of the one-stop shop solution. However, the one-stop solution itself will not address the financial challenges. It will collaborate with clients, financial services, and government grant agencies through a single interface.

Another important stakeholder is the local planning portal. Although some retrofit measures could be considered under permitted development rights, many improvements require planning permissions and building control approvals. The situation can be stricter if the property is protected by heritage significance [54]. If the one-stop shop could be integrated with the approving body, it would be easier for the retrofit designers to manage building control approvals, and the client would be in touch about the progress.

Existing retrofit project management systems (i.e., PAS Hub [34]) are also an important aspect of data sharing. Although the proposed one-stop shop focuses on the whole process of retrofit project management, there are existing retrofit project management systems for retrofit professionals. They do not have an interface for the clients. Having two systems for clients and professionals is inefficient since both systems should use the same retrofit measures and option evaluation methodology. In this scenario, these two systems need to be integrated. The requirement is to have two-way communication by keeping the stakeholders updated throughout the retrofit process.

Sometimes, this may not be developed in a single go. In this case, the system needs to store the incremental progress of the retrofit evaluation until the user completes the evaluation and decides to submit the request to the retrofit assessor. Further, the system may need to email different parties about the updates and send notifications. If the user uses a mobile device, app notifications can also be a good method of communication. The system may also need to send data files to different parties and prepare data for different formats and requirements.

3.7. Local One-Stop Shop and Retrofit Champions

Practice theories [55], social identity theory [56,57], and place-based approaches [58] paved the path to the concept of a local one-stop shop. The idea is to promote retrofit by focusing on a manageable geographic area. This can be a housing scheme, road, town, or village as it needs to be. The people will know each other in such a small geographic location. If the technical aspects of the retrofit are strong, project delivery is efficient, and the risk of unintended consequences is low, there will be a greater chance of spreading the message quickly [59,60]. In this locality, residents may already know each other. The clients may also already know the professionals, installers, and other stakeholders. This will encourage the clients to engage more in the housing retrofit process.

Another side of this approach is promoting the social relations within and outside the system. It is possible to promote online social relations within the system by allowing the users to interact with each other and communicate with the stakeholders. Apart from that, the system shall promote social interactions outside the system wherever possible. For example, the system can list the people in the user's locality who have already retrofitted their houses (subject to their consent). They can meet each other in person to witness and discuss the pros and cons of retrofitting houses. Research recommends the importance of social relations to encourage housing retrofit [21,60].

Another consideration of the local one-stop shop approach is using normal people in the client's neighbourhood to spread the message of housing retrofit. Clients will trust their social network, which comprises their friends and family, more than anyone else. There is

no need for retrofit experts. People hesitate to believe tradespeople and marketing people. However, they do trust people in their neighbourhood. In this situation, if the facts are accurate and reliable, the best way to disseminate them is with the help of the most trusted people. The concept has already been observed in some contexts; for example, energy ambassadors in the Netherlands [61].

The proposed one-stop shop solution is limited as it can only be used by people with some computer literacy. If this type of system is available, any person with computer literacy can easily take others on a retrofit awareness journey with the help of the system. This can be especially helpful for older adults. The researcher has witnessed the potential of such an information system in coffee mornings for older adults as a retrofit advisor. Moreover, a physical one-stop shop will be expensive to maintain with a professional retrofit advisor with vast knowledge of the retrofit process. If a solution like the proposed one-stop shop is available, anybody with computer literacy can do the job. They do not have to have in-depth knowledge about housing retrofit or building physics.

4. Discussion

4.1. Proposed Framework

A one-stop shop solution for housing retrofit was developed by evaluating the above-mentioned factors. The industrial output is given as an SRS Document. A system requirements specification (SRS) is a document that describes what the information system should do and how it is expected to perform. The SRS document for the given schematic design is presented as Supplementary Material [62]. This document shows in detail the system requirements under the international standard of IEEE/ISO/IEC 29148-2018 Requirements Engineering [39]. Figure 5 gives this study's theoretical output as a schematic framework. It briefly presents the idea of the one-stop shop solution.

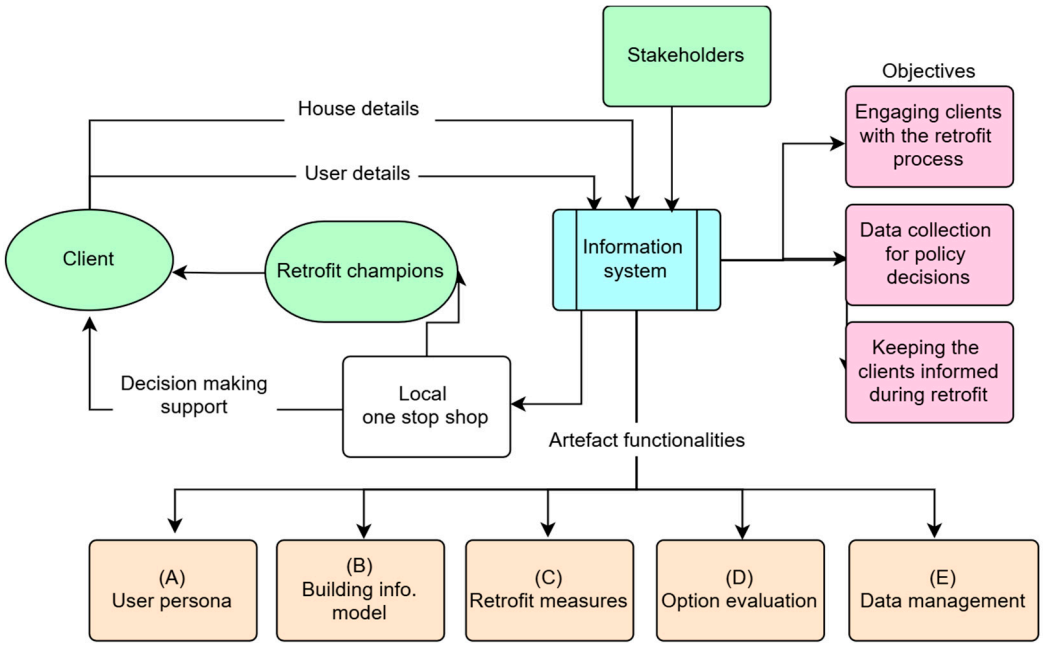

Figure 5. Proposed one-stop shop solution.

The one-stop shop retrofit solution has identified five key functionalities: the user persona, building information model, retrofit measures, option evaluation, and data management. The justifications for these functionalities have already been briefed. The client is depicted first in the diagram since the client is a key stakeholder in the retrofit process. The

proposed one-stop shop solution aims to provide integrated retrofit solutions to the client, keeping them in a central position.

This one-stop shop solution is expected to make three key contributions. The first one is to encourage clients to engage in the retrofit process, which can be suggested as the predominant purpose of this solution. Research suggests that housing retrofit shows poor progress in Europe due to poor client engagement [63]. If the client commits to doing a professional retrofit assessment by interacting with the system, it is considered the engaging point of the formal retrofit process.

The one-stop shop solution cannot solve all the problems in retrofit at scale [64]. Due to this reason, there will still be a considerable share of people who did not decide to join the retrofit process after engaging with the one-stop shop. Accordingly, the second objective is to collect data about the clients and their properties. By having a good idea about the client's behaviour in retrofit decision-making and up-to-date information about the housing stock, the government can make better policy decisions to make housing retrofits more attractive to clients. Not all government actions are aligned for retrofit at scale [53]. Retrofit drives such as the "Green Deal" failed due to poor design and a lack of focus on homeowner behaviour [24].

The third objective is to keep the client informed about the progress of the retrofit project if the retrofit project has started. The one-stop shop shall act as a communication platform [30]. As far as the process of the solution is concerned, there should be an information system platform to provide the functionalities as recommended. This will be the backbone of the solution. This information system should be linked to the stakeholders of the retrofit process and should also facilitate efficient data sharing and management. The installers can provide details on retrofit measures and availability. Banks can give eligibility checks for finance. Government agencies can provide eligibility checks for grants. This way, different process stakeholders can contribute to the retrofit delivery by using the information system as a collaboration platform.

Currently, there are no proper systems capable of making an impact. Subject to the availability of such a system, the clients could get information and obtain services for housing retrofit through a single point of contact. A one-stop shop has been recognised as an effective solution to retrofit at scale [18]. The idea of the local one-stop shop and retrofit champion concept are to facilitate the hybrid delivery of the model. The potential of a retrofit champion/energy ambassador for promoting housing retrofit among homeowners is recommended in the literature [61].

The one-stop shop is designed as an online solution with all the facilities to deliver its services online. It is understood that not all clients are happy with online delivery [31]. Further, there can be accessibility and inclusivity issues. The social and behavioural theories strongly suggest the need for physical presence and the importance of social interactions. These recommendations were endorsed by recent research to recommend relational approaches to retrofit at scale [65,66]. The concept does not expect to recommend a physical location for a one-stop shop, such as a totally physical one-stop shop service. Instead, it expects to use the service of retrofit champions to deliver an in-person service facilitated by the information system (the online one-stop shop).

Retrofit champions will be technical or non-technical people who encourage others to retrofit their houses. Their service can be either paid or voluntary. A retrofit champion can be anybody with computer literacy. They will use their computer literacy and social interaction skills to approach the people in their neighbourhood and engage them in the retrofit process. It is also important to highlight the neighbourhood approach to promote retrofit. Approaching the homeowners through their neighbourhood shall improve the uptake of retrofits due to better trust and social interactions [67,68]. Since there is no

physical place, this will remove the cost barriers to physical one-stop shops and provide the same level of service with the help of the proposed information system.

4.2. Evaluation of the Artefact

The semi-structured interviews evaluated whether the solution would serve the expected objectives if implemented in the real world. Checkland and Scholes (1990), as cited in Venable et al. (2012) [69], have proposed a simplified method of evaluating artefacts as a 5E framework. The five "E"s are efficacy, efficiency, effectiveness, elegance, and ethicality. The solution is not practically developed as an information system but as a framework. Considering the nature of the solution and the background of the interview participants, the evaluation criteria were customised as follows: novelty, awareness, option evaluation, lead generation, and demand.

Table 4 depicts how the customised evaluation criteria are synthesised with the literature-recommended criteria. Some of the literature-recommended evaluation criteria were not adopted. Efficiency cannot be evaluated at this level due to the conceptual nature of the solution. The ethicality of the solution needs to be tested and ensured before starting commercial development. A comparison and contrast of the solution with similar existing systems was made according to the guidelines by Venable et al. (2012) [69]. The interviewees were asked to comment on the five topics mentioned below.

Table 4. Synthesising the evaluation criteria with the literature.

	Customised Evaluation Criteria	**Checkland and Scholes (1990), as Cited in Venable et al. (2012) [69]**	**Venable et al. (2012) [69]**
1	Novelty	-	Knowledge creation
2	Awareness	Efficacy	Satisfying requirements
3	Option evaluation	Efficacy	Satisfying requirements
4	Lead generation	Effectiveness	Effectiveness
5	Demand	Elegance	-

4.2.1. Novelty

Except for three participants, all others stated that the idea was satisfactorily innovative. Although the individual blocks of the concept show no novelty when considered separately, combining them all indicates a greater level of innovation. Besides one participant (C10), nobody knew of a similar concept currently in practice. C10 is working on the same idea, as they have already developed a similar system. C10 agreed that the proposed system has key differences on the positive side. Another participant signposted a mass-scale retrofit decision-making support tool, "Pathways", developed by Parity Projects. It was intended for large-scale renovation schemes [70]. Although they have a model for homeowners, the capability is limited. It is better suited for raising awareness [71].

C1 said that the need for the retrofit should be highlighted first. Users should feel more confident about why they need to retrofit their houses. In agreement with C1, C2 recommended starting with the user's problem and showing them how their problem is solved. C3 said that although the concept seemed innovative, it is still unclear why users should retrofit their house. C4 suggested using artificial intelligence to understand user behaviour better and make the estimates more realistic. C13 and C15 also recommended

to explore the potential of artificial intelligence to optimise the process. For example, C13 recommended a chatbot to help users navigate the system and obtain information.

C8 recommended improving innovativeness by integrating more parties into the system. For example, she recommended integrating the customer profile with DWP (Department for Work and Pensions) and HMRC (HM Revenue and Customs) to see the eligibility for the grants. This needs to be involved with user privacy and confidentiality. Further, it is essential to ensure the users are genuine, not somebody playing around with bogus information. C14 also shared a similar idea about a financial health check tool to understand the availability of overall financial possibilities to the client.

C9 and C10 were both happy about the innovativeness of the concept. Their concern is how to reach the level of capability in practice. C11 sees this as a homeowner-centric approach rather than a property-centric approach. Retrofit is partly a technical problem and also a social problem. C12 was happy to see how the neighbourhood approach (localising the one-stop shop to a small geographical area) has been creatively used to improve the homeowner's trust. C14 gave the idea of giving a "sustainable house" digital badge to share on social media after completing a successful online retrofit assessment. This will encourage them to engage further and spread the message to their social network.

4.2.2. Awareness

The participants generally agreed that the solution would help improve homeowners' awareness of housing retrofitting. Two of them were unhappy about the capability as they could not understand the performance with just a specification for an information system without an actual system. Some participants argued that the best tool to improve awareness is not an information system. They believed it was the best way to do this in person. For example, C9 believed the best way to raise awareness is through people. This is a part of the awareness-making process, but not the whole. The participants who were happy about the system acknowledged that the presented capability would help to improve retrofit awareness, considering the limitations of an information system.

C1 recommended presenting the resources of the awareness section as blogs, which will allow users to comment and share. This will improve the interaction between the system and the users. C4 also stated a similar idea while C13 recommended adding videos, animations, and infographics to convey information in a more user-friendly way. If the resources related to retrofit awareness can be shared on social media, it will help to spread the message. Further, if these posts can be commented on and rated, that will improve user interaction and system interaction. C6 recommended starting awareness from a problem of the user, which triggers the need for upgrades and continues to other areas. In line with this, C13 recommended taking first-time users through a guided walkthrough of the houses related to retrofit measures. C8 highlighted the need for a proper strategy to attract traffic to the information system. Collaborating with similar groups, projects, and organisations might create win-win situations.

C10 said that the system should make people aware if they use it. However, she is worried about how to drive people into the system. C12 highlighted the need for information to be simple and digestible to the homeowners. C13 and C15 recommended having an interactive tool to visualise the application of retrofit measures to the house. For example, the difference it makes when selecting between a gas boiler and a heat pump. C12 is happy with the existing level of information available in the system. C12 further said that it is essential to show the users what they will achieve with this system. In this case, more KPIs (Key Performance Indicators) are better to include to show the potential improvement clearly.

C15 commented that the solution needs to highlight the benefits of heat pumps, as this will be a key driver of retrofit. Further, a "myth buster" is required to remove the myths related to heat pumps and retrofit in general. C16 also proposes a similar idea, as people may not properly understand the benefits and functionality of insulation, which is also a key part of retrofit.

4.2.3. Option Evaluation

The participants recognised the function of option evaluation as a key aspect of the proposed system. It generally received higher ratings from the participants. C1 said presenting retrofit measures all at once is unattractive and can be too much for the user to digest. In this case, it is better to categorise them for easy digestion, e.g., in an insulation category or renewable category. Further, she recommended that benefits be presented as life cycle benefits to make them more meaningful. C6 recommended ensuring that the user can improve the accuracy by inputting more accurate house details. Real estate websites can be a good data source, especially for floor plans.

Without handling the contractor and material prices by this system, outsourcing that part to a comparison site such as MoneySupermarket.co.uk (accessed on 26 March 2025) or Confused.com (accessed on 26 March 2025) was recommended by C6. These comparison sites already have a large user base and are already in a particular business model. As such, the proposed system can use their expertise and resources to make the process more efficient and attractive. Further, the system will reach a broader audience. C8 pointed out that most people in this system may not be eligible for government grants. In this case, it is essential to let them work out their financing strategy with accurate and reliable information. According to C10, getting real-time quotations from the installers using unit rates will not be practical. The first problem is the difficulty of understanding the house without an inspection. The second problem is that installers will not bother updating their prices and availability just to generate quotations.

C9 recommended improving the relational aspect more, if possible, while C11 recommended improving the technical side of retrofit, although they did not provide specific examples. C15 also highlighted the inadequacy of technical information related to the retrofit options. For example, the influence of building fabric measures on the heat pump efficiency. He further recommended including a suitability assessment for heat pump compatibility. C14 noted the importance of showing available retrofit grants for different measures, as some grants only apply to specific measures, e.g., a boiler upgrade scheme. It is also important to show the applicability of Value-Added Tax (VAT), as some products are VAT-free for retrofits, but some are not.

4.2.4. Lead Generation

One of the main objectives of the system is to generate leads. That means a user escalates their interest in a professional retrofit assessment by appointment with a retrofit assessor. This can be called a lead. When the retrofit assessor makes a professional retrofit assessment, data on the house, occupant, and risk information becomes available. This data can be stored in a repository such as the TrustMark data warehouse, similar to the concept of a building renovation passport. This was one of the recommendations made by the Each Home Counts report in 2016 [72]. The most important aspect is that the data will be machine-readable and sufficient to make mass-scale and individual retrofit strategies. For this reason, even if the user decides not to proceed with the retrofit option initially, the data will be essential for future retrofit drives. As there are already systems available to handle the project management part once the professional retrofit assessment is done, the scope of this system stops when the user passes the lead to the retrofit assessor. The

evaluation question asked participants how they see the potential of lead generation by this proposed system.

Generally, the participants agreed that the lead turnover would be increased if the assessment were given for free. This is decided by the literature as well. Further, the user should not be obligated to retrofit their house by calling a professional for a retrofit assessment. Technically, if there is no obligation to retrofit and the evaluation is free, there is a better chance for a client to proceed with a professional retrofit assessment. C4 and C13 said it is better to give points to user interactions. For example, the user can be given points to complete retrofit awareness activities, generate retrofit option evaluations, and input more precise data to improve the system's accuracy. Users will be eligible for a free professional retrofit assessment after accumulating several points. Otherwise, they will have to pay. This might motivate people to engage with the system and contact a retrofit assessor. According to C8, there will be an apparent demand from a particular breed of people who always look out for energy efficiency, health, comfort, sustainability, and similar topics. Some other segments will not find much interest in the concept.

Irrespective of the system's performance, a segment will not go for a professional retrofit assessment. C9 and C11 agreed with this. Contrastingly, C10 was highly prospective about the lead generation. A similar system owned by C10′s company gets one lead generation out of five registrations. In this case, it will work depending on the assessment fees. C12 highlighted an important aspect. She said the hassle involved with the retrofit options needs to be communicated to the user, apart from the disruption. This was not thought of earlier in the solution design. C14 and C16 emphasised the importance of giving an initial free retrofit assessment to attract clients. C13 and C15 proposed to show the credentials of the retrofit professionals to build the trust of the users. This can be combined with a link to their portfolio of retrofitted projects.

4.2.5. Demand

Although the solution is innovative, resourceful and helpful in retrofit decision-making, the intended audience may still not demand it. Considering this, the participants were asked how they saw the potential demand for this concept. The general feedback was positive. Interviewees agreed that there will be a future demand for these technological solutions due to the importance of climate change priorities. The information system has not been built in the real world, so the participants struggled to brainstorm the model context and how attractive it could be. It was clear that there is a demand for a potential solution to the problem of retrofit decision-making that helps homeowners. The question was how close this information system is to the ideal solution.

C1 highlighted the importance of emphasising the benefits more. A comparison between the existing and post-retrofit performance will show a clear justification for the homeowners to proceed with the housing retrofit. This will help homeowners understand the need for a housing retrofit. Some homeowners think they already live in a good-performing house, although it is a poor-performing house. Further, C2 recommended finding the unique selling proposition of the proposed system. A product's unique selling proposition is its value, which a competitive product does not have. C4 also presented a similar idea. He asked to find a "wow" factor in the solution, to which the users would say "wow" over other products. According to the concept of a unique selling proposition, it can be argued that this system has all the information under a single point of contact. In addition, this system has considered extreme personalisation according to the house and the client.

C3 recommended improving the attractiveness of the information system by adding coloured graphs and tables. C5 said that the idea is clear, friendly, and straightforward.

In this case, it is essential to maintain that level of simplicity without putting too much information. C5 believed a medium level of information is more than enough. This was endorsed by C8, C15, C16, and C12 as well. C7 said it would be better to emphasise the benefits, especially the financial ones. The general idea of the interviewees is that it is difficult to understand the demand as it depends on the attractiveness of the information system. No doubt, the solution has a demand. To improve the demand, the information system needs to be highly attractive.

C9 had no issue with the demand. She thought the information system will be in demand only from a particular segment of people. According to C10, the demand from the stakeholders has not picked up so far for their digital one-stop shop solution, although the users are delighted with it. There will be a demand, but it may take time. The solution needs to come with policy support. C11 warned that the developers would have to do many things regarding the infrastructure outside the system to make the concept a reality. That means the required background is not there yet. This was agreed by C16 as well. Some people may still prefer to do things in the old-school way. For example, they may rely on a professional to decide on insulating a solid wall rather than asking ChatGPT 3.5.

4.3. Comparison with Existing Models

No hybrid one-stop shop solutions were found in the UK that were similar to the proposed solution. In this situation, a desk study was conducted to find online decision support systems in housing retrofit for homeowners. A similar study conducted by Seddiki et al. (2021) also referred to understanding the nature of the existing retrofit decision support systems [73]. Apart from the EPC report, three retrofit decision support systems for non-technical users were found in the UK context [51]. One is "EcoFurb", developed by Parity Projects. This system uses the EPC database, Ordinance Survey maps, and its own cost databases to generate personalised housing retrofit recommendations [71]. Another system developed by Energy Savings Trust is called the "Home Energy Saving (HES) Tool" [74]. The third information system is "Snugg" [75]. All the above systems share the same level of capability. On the positive side, their use is straightforward, nice, and simple, but more powerful than the EPC report. Table 5 compares and contrasts these systems, the proposed solution, and the EPC report.

Table 5. Comparison between existing systems and the proposed artefact.

	Capability	EPC Report	EcoFurb	HES Tool	Snugg	Proposed Solution
1	Ability to personalise retrofit options.	-	Available	Available	Available	Available
2	Recommendations for the retrofit packages.	Available	Available	Available	Available	Available
3	Simplicity and a user-friendly interface.	Available	Available	Available	Available	Available
4	Actual quotations and up-to-date information.	-	Up-to-date info.	Up-to-date info.	Up-to-date info.	Available
5	Finance & grant eligibility.	-	-	-	Partially available	Available
6	Quality of the retrofit measures and products.	-	-	-	-	Available

Table 5. *Cont.*

	Capability	EPC Report	EcoFurb	HES Tool	Snugg	Proposed Solution
7	Facilitating social interaction through the system.	-	-	-	-	Available
8	Retrofit champion concept to deliver hybrid solutions.	-	-	-	Supported	Available
9	Client interface to monitor the progress of the retrofit.	-	-	-	Partially available	Available
10	A diverse range of stakeholders.	-	-	-	Contractors only	Available

Table 5 shows a comparison between existing systems and the proposed artefact. By looking at the above comparison, generally, all the solutions provide personalisation of retrofit options (except the EPC report), recommendations for retrofit measures, and a user-friendly, simple interface. The proposed one-stop shop solution has incorporated several advantages over similar existing systems. Although some systems provide estimates with up-to-date prices, none provide actual quotations over estimated quotations. This would be a key competitive advantage of the proposed solution and a key driver of success. This will also be a considerable challenge.

No solutions mentioned the quality assurance of the retrofit measures, compliance with regulations and certifications, and quality of the products and services. Further, none of the solutions facilitates social interactions through the information system. For example, if a client could see who else has retrofitted their houses in their neighbourhood, that would encourage them to contact these people outside the information system. These two recommendations are essential to make the solution successful. Due to this robust option evaluation, the proposed solution can be used as a supporting online platform for a retrofit champion to help others in need.

There are diverse stakeholders in the retrofit process, and they can have different levels and interactions with a client's retrofit journey. The proposed solution is recommended to consider these stakeholder engagements deeply and facilitate them. In this way, an interface to the client will show the progress of the retrofit journey through the information system, providing the true meaning of a single point of contact. According to the stakeholder power influence matrix [76], the client can be considered a key stakeholder, and keeping them updated and closely managing them are key requirements.

4.4. Way Forward

Selected existing retrofit decision support solutions for this study have not reached a satisfactory level to create an impact. The literature suggests that there are no satisfactory retrofit decision support systems, even globally. The existing systems have a basic level of functionality [73]. The proposed one-stop shop solution will provide an online platform to deliver integrated retrofit solutions to clients while providing a hybrid approach with the help of retrofit champions. The hybrid delivery method will be helpful for clients without computer literacy or accessibility to the internet. Although this solution has outlined the concept theoretically with a framework and empirically with the system requirement specification document [62], there will be a considerable amount of work to develop the solution practically. The interviewees said a higher infrastructure level is needed to

make this solution successful due to certain features; for example, the provision of actual quotations over estimates. Further, this solution will require the contribution of several stakeholders, such as finance partners, government institutions, contractors, professionals, or the supply chain. Getting their active involvement will be challenging.

This solution is intended to be promoted by the government. Accordingly, this one-stop shop can be provided to clients free of charge, without any conflict of interest. First, the solution is expected to engage clients in the formal retrofit process and keep them informed during the project's progress. Secondly, the solution should collect data on the housing stock and client behaviour in housing retrofit. This will help the government to make better policy decisions. A contractor can develop this system and use it to attract business to their company. A potential investor can also establish a system to earn income through referral commissions. The profit-oriented scenarios may pose challenges due to the possible conflict of interest of the promoters. For example, contractors are perceived by clients not to work in their best interest but to maximise their profits.

5. Conclusions

Although the required technology, supply chain, and financing could be facilitated, without the positive engagement of the clients, it would not be easy to promote retrofit at scale. Due to the number of houses to retrofit and the limited time to do that, urgent strategies will be required to deliver retrofit at scale, not only in the UK but also in the global context. Currently, the PAS 2035 specification and relevant online solutions have paved the way for the delivery of project management aspects of retrofit projects in the UK. Still, there is no technological interface to bridge the gap between the client and the retrofit professional, which can facilitate retrofit at scale. Although some online and offline solutions are available, they are far behind in making a considerable impact. By considering the above, a model was developed using design science methodology to propose a one-stop shop solution to deliver housing retrofit at scale. It will work as a bridge between the client and the other retrofit stakeholders by providing a single point of contact throughout the retrofit process.

One of the solution's key highlights is the hybrid approach of a one-stop shop. This will make housing retrofit at scale more cost-efficient. The one-stop shop has no physical location, but it is facilitated via a retrofit champion, who can even be a non-technical person interested in promoting retrofit. The other essential recommendation is to provide actual quotations to the clients. The ideal promoter of the one-stop shop will be the government or an entity funded by the government. Profit-oriented models may lose clients' trust due to the perceived conflict of interest. According to this study, the technology required to deliver retrofit at scale is already available. The required supply chain, skills, and funding can be facilitated. Now, it is time to improve them to a level that can make an impact, engage residents, and, most importantly, put them in the right combination.

Supplementary Materials: The System Requirements Specification document can be downloaded at: https://doi.org/10.5281/zenodo.15088998.

Author Contributions: Conceptualisation, C.P., P.C. and M.M.; methodology, C.P., P.C. and M.M.; software, C.P.; validation, C.P.; formal analysis, C.P.; investigation, C.P.; resources, C.P.; data curation, C.P.; writing—original draft preparation, C.P.; writing—review and editing, P.C. and M.M.; visualisation, C.P.; supervision, P.C. and M.M.; project administration, C.P. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: This study was conducted in accordance with the Declaration of Helsinki and approved by the Ethics Panel of the University of Salford Application ID: 10162, dated 9 May 2023.

Informed Consent Statement: Informed consent was obtained from all subjects involved in this study.

Data Availability Statement: The participants of this study did not give written consent for their data to be shared publicly. Due to the sensitive nature of the research, supporting data are not available.

Acknowledgments: We are grateful to the anonymous interviewees whose insights significantly enriched this study's data and findings.

Conflicts of Interest: The authors declare no conflicts of interest.

Abbreviations

The following abbreviations are used in this manuscript:

BIM	Building Information Modelling
CAD	Computer-Aided Design
DWP	Department for Work and Pensions
EPC	Energy Performance Certificate
ESCO	Energy Service Company
GIS	Geographical Information System
HES	Home Energy Saving
HMRC	HM Revenue and Customs
KPIs	Key Performance Indicators
MESAs	Managed Energy Service Agreements
PAS	Publicly Available Specification
SRS	Software Requirement Specification
VAT	Value-Added Tax

Appendix A Details of the Interviewees

		Category	Position	Organisation	Expertise	Education
1	C1	Academia/ Research	PhD student	University in UK	Sustainable construction and smart building	Masters
2	C2	Software engineering	Software developer/Academic	College in UK	Software development and business management	Masters
3	C3	Software engineering	Data scientist	GIS company	Data science and GIS	Masters
4	C4	Construction industry	Engineering assistant	Government department	Civil and building construction	Masters
5	C5	Clients	Homeowner	A local business	Banking and finance	Diploma
6	C6	Academia/ Research	Researcher	University in UK	Design science research	PhD
7	C7	Academia/ Research	PhD student	University in UK	Sustainable construction and project management	Masters
8	C8	Retrofit project delivery	Project manager	Local authority	Retrofit project delivery	Bachelors

Table A0. *Cont.*

		Category	Position	Organisation	Expertise	Education
9	C9	Academia/ Research	Lecturer	University in UK	Sustainable housing	PhD
10	C10	One stop shop	Business development lead	Innovation startup in Scotland	Sales and marketing	Unknown
11	C11	Academia/ Research	Professor	University in UK	Energy efficiency and retrofit	PhD
12	C12	Academia/ Research	Policy expert	Climate and energy policy research institution in EU	Homeowner engagement with housing retrofit	PhD
13	C13	Regulations	Building surveyor	Local authority in UK	Building surveying, planning, and building control	Bachelors
14	C14	Finance	Financial advisor	A company helping businesses to level up	Business management and sustainability	Masters
15	C15	Contractors	Electrical engineer	A heat pump installation company	Mechanical, electrical, and plumbing engineering	Masters
16	C16	Contractors	Supervisor	A company engaged in residential insulation	All types of insulation and minor residential works	Unknown

References

1. ONS. *Dwelling Stock: By Tenure, United Kingdom, as at 31 March*; Office for National Statistics: London, UK, 2022.
2. DBEIS. *Heat and Buildings Strategy*; Department for Business, Energy & Industrial Strategy: London, UK, 2021.
3. DESNZ. *2022 UK Provisional Greenhouse Gas Emissions*; Department for Energy Security and Net Zero: London, UK, 2021.
4. DESNZ. *Annual Fuel Poverty Statistics in England, 2024 (2023 Data)*; Department for Energy Security and Net Zero: London, UK, 2024.
5. Butt, B.; Jones, R.V.; Fuertes, A. Opportunities and barriers to business engagement in the UK domestic retrofit sector: An industry perspective. *Build. Serv. Eng. Res. Technol.* **2021**, *42*, 293–305. [CrossRef]
6. Liu, Y.; Liu, T.; Ye, S.; Liu, Y. Cost-benefit analysis for Energy Efficiency Retrofit of existing buildings: A case study in China. *J. Clean. Prod.* **2018**, *177*, 493–506. [CrossRef]
7. May, N.; McGilligan, C.; Ucci, M. *Health and Moisture in Buildings*; UK Centre for Moisture in Buildings: London, UK, 2019.
8. Simcock, N.; Walker, G.; Day, R. Fuel poverty in the UK: Beyond heating? *People Place Policy Online* **2016**, *10*, 25–41. [CrossRef]
9. Shwashreh, L.; Taki, A.; Kagioglou, M. Retrofit Strategies for Alleviating Fuel Poverty and Improving Subjective Well-Being in the UK's Social Housing. *Buildings* **2024**, *14*, 316. [CrossRef]
10. BSI. *PAS 2035:2023 Retrofitting Dwellings for Improved Energy Efficiency–Specification and Guidance*; The British Standards Institution: London, UK, 2023.
11. Suhr, M.; Hunt, R. *Old House Eco Handbook: A Practical Guide to Retrofitting for Energy Efficiency and Sustainability*, 3rd ed.; Quarto Publishing PLC: Lincoln, UK, 2019; ISBN 978071123977.
12. Mecca, U.; Moglia, G.; Piantanida, P.; Prizzon, F.; Rebaudengo, M.; Vottari, A. How Energy Retrofit Maintenance Affects Residential Buildings Market Value? *Sustainability* **2020**, *12*, 5213. [CrossRef]
13. Holms, C. *Demand: Net Zero Tackling the Barriers to Increased Homeowner Demand for Retrofit Measures*; Citizens Advice: London, UK, 2023.
14. DESNZ. *Heat Pump Net Zero Investment Roadmap*; Department for Energy Security and Net Zero: London, UK, 2023.
15. MCS. Record Number of Heat Pumps Installed in UK Homes in 2023. Microgeneration Certification Scheme. Available online: https://mcsfoundation.org.uk/news/record-number-of-heat-pumps-installed-in-uk-homes-in-2023/ (accessed on 10 March 2025).

16. UK Government. *Climate Change Act 2008*; UK Government: London, UK, 2019.
17. Alabid, J.; Bennadji, A.; Seddiki, M. A review on the energy retrofit policies and improvements of the UK existing buildings, challenges and benefits. *Renew. Sustain. Energy Rev.* **2022**, *159*, 112161. [CrossRef]
18. Brown, D. Business models for residential retrofit in the UK: A critical assessment of five key archetypes. *Energy Effic.* **2018**, *11*, 1497–1517. [CrossRef]
19. Liu, G.; Tan, Y.; Huang, Z. Knowledge Mapping of Homeowners' Retrofit Behaviors: An Integrative Exploration. *Buildings* **2021**, *11*, 273. [CrossRef]
20. Wilde, M.D. The sustainable housing question: On the role of interpersonal, impersonal and professional trust in low-carbon retrofit decisions by homeowners. *Energy Res. Soc. Sci.* **2019**, *51*, 138–147. [CrossRef]
21. Galvin, R.; Sunikka-Blank, M. The UK homeowner-retrofitter as an innovator in a socio-technical system. *Energy Policy* **2014**, *74*, 655–662. [CrossRef]
22. Soliman-Junior, J.; Awwal, S.; Ayo-Adejuyigbe, M.; Tzortzopoulos, P.; Kagioglou, M. Stakeholders' Perception in Early Stages of a Social Housing Retrofit Living Lab. *Iop Conf. Ser. Earth Environ. Sci.* **2022**, *1101*, 052025. [CrossRef]
23. DBEIS. *International Review of Domestic Retrofit Supply Chains*; Department for Business, Energy & Industrial Strategy: London, UK, 2021.
24. Rosenow, J.; Eyre, N. A post mortem of the Green Deal: Austerity, energy efficiency, and failure in British energy policy. *Energy Res. Soc. Sci.* **2016**, *21*, 141–144. [CrossRef]
25. Rickaby, P. *The Importance of Standards for Safe Energy Retrofit A BSI White Paper*; The British Standards Institution: London, UK, 2023.
26. Skidmore, C.; McWhirter, S. *Mission Retrofit*; United Kingdom Green Building Council: London, UK, 2023.
27. Pardalis, G.; Mahapatra, K.; Bravo, G.; Mainali, B. Swedish House Owners' Intentions Towards Renovations: Is there a Market for One-Stop-Shop? *Buildings* **2019**, *9*, 164. [CrossRef]
28. Biere-Arenas, R.; Marmolejo-Duarte, C. One Stop Shops on Housing Energy Retrofit. In *European Cases, and Its Recent Implementation in Spain. in Sustainability in Energy and Buildings 2022*; Springer Nature: Singapore, 2023. [CrossRef]
29. Copiello, S.; Donati, E.; Bonifaci, P. Energy efficiency practices: A case study analysis of innovative business models in buildings. *Energy Build.* **2024**, *313*, 114223. [CrossRef]
30. Bagaini, A.; Croci, E.; Molteni, T. Boosting energy home renovation through innovative business models: ONE-STOP-SHOP solutions assessment. *J. Clean. Prod.* **2022**, *331*, 129990. [CrossRef]
31. Bertoldi, P.; Boza-Kiss, B.; Della Valle, N.; Economidou, M. The role of one-stop shops in energy renovation-a comparative analysis of OSSs cases in Europe. *Energy Build.* **2021**, *250*, 111273. [CrossRef]
32. Sequeira, M.M.; Gouveia, J.P. A Sequential Multi-Staged Approach for Developing Digital One-Stop Shops to Support Energy Renovations of Residential Buildings. *Energies* **2022**, *15*, 5389. [CrossRef]
33. Seddiki, M.; Bennadji, A.; Alabid, J.; Gray, D.; Deveci, G. Development and Pilot Evaluation of an Online Retrofit Decision-Making Tool for Homeowners. *Buildings* **2022**, *12*, 1513. [CrossRef]
34. CoreLogic. PAS Hub-Web Based Workflow Management System to Enable the Delivery of PAS 2035 and ECO Compliant Measures. Available online: https://www.corelogic.uk/products/pas-hub/ (accessed on 10 March 2025).
35. Johannesson, P.; Perjons, E. *An Introduction To Design Science*, 2nd ed.; Springer: Cham, Switzerland, 2021; ISBN 978-3030781316.
36. Dresch, A.; Lacerda, D.P.; Antunes, J.A.V.A. *Design Science Research*, 1st ed.; Springer: Cham, Switzerland, 2015; ISBN 978-3-319-07374-3.
37. Wieringa, R.J. *Design Science Methodology for Information Systems and Software Engineering*, 1st ed.; Springer: Cham, Switzerland, 2014; ISBN 978-3-662-43839-8.
38. De Sordi, J.O. *Design Science Research Methodology*; Springer: Cham, Switzerland, 2021; ISBN 978-3-030-82156-2.
39. *ISO/IEC/IEEE 29148:2018*; Systems and Software Engineering—Life Cycle Processes—Requirements Engineering. International Standards Organisation (ISO): Geneva, Switzerland, 2018.
40. Strauss, W.; Howe, N. *Generations: The History of America's Future, 1584 to 2069*; William Morrow: New York, NY, USA, 1992; ISBN 978-0688119126.
41. Liu, G.; Ye, K.; Tan, Y.; Huang, Z.; Li, X. Factors influencing homeowners housing renovation decision-making: Towards a holistic understanding. *Energy Build.* **2022**, *254*, 111568. [CrossRef]
42. Huang, C.; Ma, J.; Song, K. Homeowners' Willingness to Make Investment in Energy Efficiency Retrofit of Residential Buildings in China and Its Influencing Factors. *Energies* **2021**, *14*, 1260. [CrossRef]
43. Pease, A.; Pease, B. *Why Men Don't Listen and Women Can't Read Maps*; Orion: London, UK, 2001; ISBN 978-0752846194.
44. Rogers, E.M. *Diffusion of Innovations*, 3rd ed.; Free Press: New York, NY, USA, 1983; ISBN 9780029266502.
45. Herrmann, N.; Herrmann-Nehdi, A. *The Whole Brain Business Book: Unlocking the Power of Whole Brain Thinking in Organizations, Teams and Individuals*, 2nd ed.; Mcgraw-Hill: New York, NY, USA, 2015; ISBN 978-0071843829.

46. Sweller, J.; Paul, A.; Slava, K. Cognitive load theory. In *Explorations in the Learning Sciences, Instructional Systems and Performance Technologies*; Springer: Berlin/Heidelberg, Germany, 2011. [CrossRef]
47. Ding, G.J.; Hwang, T.K.P.; Kuo, P.C. Progressive Disclosure Options for Improving Choice Overload on Home Screen. In *Advances in Usability, User Experience, Wearable and Assistive Technology*; Springer: Cham, Switzerland, 2020. [CrossRef]
48. ONS. *Energy Efficiency of Housing in England and Wales*; Office for National Statistics: London, UK, 2024.
49. Feitosa, R.C.; Wilkinson, S.J. Attenuating heat stress through green roof and green wall retrofit. *Build. Environ.* **2018**, *140*, 11–22. [CrossRef]
50. Panakaduwa, C.; Coates, P.; Munir, M. Analysis of the UK Homeowners' Practices Prompting Housing Retrofits: A Practice Theory Approach. In *Climate Change Adaptation in the Built Environment*; Malalgoda, C., Amaratunga, D., Haigh, R., Nissanka, S., Fernando, N., Ruben Paul Borg, R.P., and Mo Hamza, M., Eds.; Springer: Cham, Switzerland, 2025; ISBN 978-3-031-75826-3.
51. DCLG. *A Guide to Energy Performance Certificates for the Marketing, Sale and Let of Dwellings Improving the Energy Efficiency of Our Buildings*; Department for Communities and Local Government: London, UK, 2017.
52. Traynor, J. *EnerPHit: A Step by Step Guide to Low Energy Retrofit*; RIBA Publishing: London, UK, 2019; ISBN 9781859468197.
53. Panakaduwa, C.; Coates, P.; Munir, M. Evaluation of Government Actions Discouraging Housing Energy Retrofit in the UK: A Critical Review. In *European Energy Markets 2024*; IEEE: Istanbul, Turkey, 2024. [CrossRef]
54. Panakaduwa, C.; Coates, P.; Munir, M. Identifying sustainable retrofit challenges of historical Buildings: A systematic review. *Energy Build.* **2024**, *313*, 114226. [CrossRef]
55. Oerther, S.; Oerther, D.B. Pierre Bourdieu's Theory of Practice offers nurses a framework to uncover embodied knowledge of patients living with disabilities or illnesses: A discussion paper. *J. Adv. Nurs.* **2018**, *74*, 818–826. [CrossRef]
56. Leaper, C. More Similarities than Differences in contemporary Theories of social development? *Adv. Child Dev. Behav.* **2011**, *40*, 337–378. [CrossRef] [PubMed]
57. Hatch, M.J.; Schultz, M. *Organizational Identity: A Reader*; Oxford University Press: London, UK, 2023; ISBN 9781383041279.
58. Ingold, T. *The Perception of Environment: Essays in Livelihood, Dwelling and Skill*; Routledge: London, UK, 2000; ISBN 9781032052274.
59. Fransman, R.; Timmeren, A.V. Psychological and social factors underlying pro-environmental behaviour of residents after building retrofits in the City-zen project. *Energy Procedia* **2017**, *122*, 1051–1056. [CrossRef]
60. Cinderby, S.; Archer, D.; Mehta, V.; Neale, C.; Opiyo, R.; Pateman, R.M.; Muhoza, C.; Adelina, C.; Tuhkanen, H. Assessing Inequalities in Wellbeing at a Neighbourhood Scale in Low-Middle-Income-Country Secondary Cities and Their Implications for Long-Term Livability. *Front. Sociol.* **2021**, *6*, 729453. [CrossRef]
61. Ebrahimigharehbaghi, S.; Qian, Q.K.; De Vries, G.; Visscher, H.J. Municipal governance and energy retrofitting of owner-occupied homes in the Netherlands. *Energy Build.* **2022**, *274*, 112423. [CrossRef]
62. Panakaduwa, C. *System Requirement Specification for One Stop Shop Housing Retrofit*; Zenodo: Geneva, Switzerland, 2025. [CrossRef]
63. Wang, Y.H.; Qu, K.; Chen, X.; Gan, G.; Riffat, S. An innovative retrofit Motivation-Objective-Criteria (MOC) approach integrating homeowners' engagement to unlocking low-energy retrofit in residential buildings. *Energy Build.* **2022**, *259*, 111834. [CrossRef]
64. Pardalis, G.; Talmar, M.; Keskin, D. To be or not to be: The organisational conditions for launching one-stop-shops for energy related renovations. *Energy Policy* **2021**, *159*, 112629. [CrossRef]
65. Bolton, E.; Bookbinder, R.; Middlemiss, L.; Hall, S.; Davis, M.; Own, A. The relational dimensions of renovation: Implications for retrofit policy. *Energy Res. Soc. Sci.* **2023**, *96*, 102916. [CrossRef]
66. Brown, D.; Middlemiss, L.; Davis, M.; Bookbinder, R.; Cairns, I.; Hannon, M.; Mininni, G.; Brisbois, M.C.; Own, A.; Hall, S. Rethinking retrofit: Relational insights for the design of residential energy efficiency policy. *Energy Res. Soc. Sci.* **2025**, *120*, 103863. [CrossRef]
67. Putnam, T.; Brown, D. Grassroots retrofit: Community governance and residential energy transitions in the United Kingdom. *Energy Res. Soc. Sci.* **2021**, *78*, 102102. [CrossRef]
68. Karvonen, A. Community Housing Retrofit in the UK and the Civics of Energy Consumption. In *Retrofitting Cities for Tomorrow's World*; Wiley-Blackwell: Hoboken, NJ, USA, 2017; pp. 17–32. [CrossRef]
69. Venable, J.; Pries-Heje, J.; Baskerville, R. A Comprehensive Framework for Evaluation in Design Science Research. In *Lecture Notes in Computer Science*; Springer: Berlin/Heidelberg, Germany, 2012; pp. 423–438. [CrossRef]
70. Parity Projects. Pathways. Available online: https://parityprojects.com/platform/pathways/ (accessed on 12 March 2024).
71. Parity Projects. Ecofurb-the Low Carbon Home Service. Available online: https://www.ecofurb.com/ (accessed on 18 April 2024).
72. TrustMark. TrustMark Data Warehouse. Available online: https://www.trustmark.org.uk/business/data-warehouse (accessed on 12 March 2024).
73. Seddiki, M.; Bennadji, A.; Laing, R.; Gray, D.; Alabid, J.M. Review of Existing Energy Retrofit Decision Tools for Homeowners. *Sustainability* **2021**, *13*, 10189. [CrossRef]
74. Halifax. Halifax Home Energy Saving Tool Where Do You Live? Available online: https://home-energy-saving-tool.halifax.co.uk/ (accessed on 18 April 2024).

75. Snugg. The Simple and Affordable Way to Make Your Home Energy Efficient. Available online: https://www.snugg.com/ (accessed on 18 April 2024).
76. Johnson, G.; Scholes, K.; Whittington, R. *Exploring Corporate Strategy*, 8th ed.; Financial Times/Prentice Hall: Englewood Cliffs, NJ, USA, 2008; ISBN 978-0273711919.