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Aesthetic appealing wall insulation: A novel approach for uptake of solid wall insulation in the UK

Mahsa Seifhashemi *, Hisham Elkadi

School of Science, Engineering, and Environment, University of Salford, The Crescent, Salford, Great Manchester, M5 4WT, UK

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ABSTRACT

Solid wall dwellings in the UK are in urgent need for energy retrofit to support achieving the UK net-zero strategies in the building sector and reduce fuel poverty. Several barriers are a cause of uncertainty for householders about Solid Wall 1nsulation (SWI) and slow down the progress. This paper aims to examine people's perceptions of possible inclusion of aesthetics elements in Internal Wall Insulation (IWI), providing a suitable solution to promote wall insulation intake and attractiveness. To achieve this aim, first, the current literature is critically reviewed and analysed to highlight the gap between energy studies and design/aesthetic features of SWI retrofit. Then, an online survey is conducted, and the collected data are analysed. The results show that the aesthetic factor is very important for participants with more than 90% agreement. This level of agreement is as high as other well-known critical factors in renovation such as cost and energy saving. Also, aesthetic integration in IWI can surpasses negative concerns such as the retrofit cost or losing internal space. Furthermore, over 2/3rd of participants are in agreement with a suggested business model for delivering both aesthetic and energy improvement in combined retrofit plans by established approved organizations. It is concluded that aesthetic inclusion is the priority and an encouraging factor in the internal renovation to reduce the barriers and increase success. Finally, the findings from this research pointed to how the retrofit industry, policymakers, and designers should evolve to achieve the benefits of aesthetics in SWI.

1. Introduction

Climate change is one of the greatest challenges currently facing the world. To strengthen the global response to this challenger, the last agreement in Glasgow is to halve emissions over the next decade and reach net zero carbon emissions by the middle of the century in order to limit global temperature rises to 1.5°. To achieve this target, emissions from different sectors including housing should be reduced. It is estimated that the housing sector is responsible for more than 15% of the UK's greenhouse gas emissions equivalent to 69.1 $MtCO_2e$ from the total of 451.5 $MtCO_2e$ [1].

Of the total UK existing homes, around 8 million (~30%) are solid wall houses [2]. In the UK, 36% of carbon emission from the domestic sector belongs to solid wall dwellings [3]. Solid Wall Insulation (SWI) technology was therefore brought forward as a key pathway toward meeting the net-zero-emission target of the UK in the residential sector by 2050 [4]. However, the number of SWI installations is not very high despite the vast number of solid wall houses in the UK, various government initiatives, and the great potential for energy saving and CO_2 reduction from wall insulation [4–7]. SWI progress remained significantly slow despite current policies that support the SWI applications with subsidies and grants such as the Government's Energy Company Obligations (ECO) scheme. According to National Statistics 2017, around 92% of solid wall homes remain to be insulated [8,9]. At the end of 2019, only 9% of houses with solid walls were insulated which was around 764,000 houses with 7.7 million houses that remained uninsulated [7]. This figure remained almost the same with 772,000 and 794,000 insulated homes meaning that still, around 91% of solid wall homes remained uninsulated at the end of 2020 and 2021, respectively [10,11]. These figures show that the SWI only increased by around 1% in four years [12].

There are different barriers in the case of SWI which slow down its uptake. These barriers are related to the demand side, supply/investment side, absence of a strong incentive to act, and/or a poor value proposition for investors and consumers [8]. Also, there is uncertainty about achieving the expected energy efficiency following the retrofit [13]. For example, there are some concerns about poor quality installation which affected the SWI's reputation [14,15]. Furthermore,

* Corresponding author.
E-mail address: s.m.seifhashemi@salford.ac.uk (M. Seifhashemi).

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several solid wall dwellings are among the historic buildings and it is not possible to apply external wall insulation [16]. Moisture formation issue and overheating are among the other negative aspects of the solid wall insulation [17,18] which were more highlighted instead of its benefits. The users and their desires play a critical role in promoting energy efficiency measures such as SWI, but they were ignored in existing policies in the UK. Innovation is required to leverage the latent possibilities and unlock the demand for SWI among users [2]. Such innovations should include the households in the processes of housing retrofit, and be motivating and satisfactory enough for householders to encourage wall insulation in solid wall houses [19].

Efficiency gains will come from technical inventions, but it will often require parallel innovations in technology and changes in human behaviour [20]. Knowledge and attitudes in combination with other psycho-social constructs are typically effective to produce changes in behaviour [21]. Behaviour change is often difficult [20], but the literature on the psychology of environmental identified promising possibilities for behaviour change when several constructs including psychological, cognitive, and socio-cultural factors are considered together [20–26]. The user-centred design includes occupant attitude and delivers behaviour change towards energy is a key factor in developing any retrofit and energy program [16,27–29]. It is important to consider users' experiences, values, and practices related to the UK domestic energy demand reduction and incorporate them into engineering-focused energy research [30]. This involves a socio-technical approach to identify the occupant preferences and satisfaction. It can also provide additional insight and understanding of the users' needs in designing any energy reduction strategies by engineers.

Renovations to achieve non-energy benefits are driven mainly by a user's desire as there are no granted payback or savings [31]. Understanding users' motivations for self-oriented non-energy benefits renovations and combining those aspirations in energy renovations would help in increasing the demand for SWI. This has been highlighted in the literature that the number of renovations with the goal of indoor aesthetics and function improvement was higher than renovations with the energy-saving intention [32]. In some renovations, the aesthetics aspect is preeminent for the process to begin and it may lead to an additional benefit of energy-related interventions while it was not included in the main initial goal of renovation [31,32]. Industrial designers, car manufacturers, building designers, and product developers are taking the advantage of paying exceptional attention to aesthetics in their design [33–36]. Brand satisfaction and perceived product quality are influenced by positive aesthetic experiences [37,38]. Aesthetics features in those industries promote their market and improve customer satisfaction. A similar approach could also be followed in the energy building industry. The products that deliver excitement to customers are more successful than the ones that don't [38,39].

As discussed, the renovations to increase the indoor aesthetic and functions were purported to be a highly popular and voluntary approach among homeowners. However, energy improvement alterations are the less renovation priority for them possibly due to the lack of attractiveness and aesthetic aspects. It would be possible to unlock the demand for SWI by increasing its attractiveness while aesthetic features are used as a trigger, particularly for Internal Wall Insulation (IWI) with high potential energy savings. So, in this paper, an analytical literature survey is developed to bring forward the theory of aesthetic inclusion for the uptake of SWI followed by a questionnaire survey to evaluate people's perceptions and behaviour change towards this solution. The result of this paper is expected to provide new insight into the energy retrofit of solid wall buildings by recommending the aesthetic integration in IWI and evaluating the role of aesthetic in improving the interest in IWI retrofit among homeowners in the UK.

2. Method

This study intends to develop a novel solution for the promotion of SWI in the UK. To achieve this aim, the current literature was critically analysed, and an online survey was conducted. In the literature review section, the current energy performance of the solid wall buildings, the potential for improving their energy efficiency through wall insulation, user-centred design approach and the role of aesthetics on users' renovation preferences were analysed and the theory of aesthetic inclusion in SWI to increase its popularity was brought forward.

Then, an online survey was designed to evaluate the importance of aesthetic in internal spaces and in renovation for householders. It also examined the aesthetic effect in reducing the negative concern of IWI as identified in literature such as cost and area loss. Furthermore, the view of participants on the existence of trustful professional organizations, as single actor, to deliver comprehensive packages of interior design and energy renovation was appraised in the survey.

The survey was a quantitative questionnaire, consisting of 20 multiple choice questions developed for the purpose of this study. The first questions were mainly about the house, income, age, gender, origin, ownership status and household size. Households' income and the number of people living in the household were asked aiming to be used for analysing the financial position of people to identify its relation to other factors such as aesthetics preferences. Other questions were designed for the purpose of survey and some with respect to the negative aspects of the reputation of wall insulation, which were captured from the literature. A flowchart showing the methodology concept map of this study is presented in Fig. 1.

2.1. Survey design

Householders' preferences, including those living in solid wall properties, directly affect the retrofit decision for their properties [40]. Therefore, the target participants for the survey analysis were householders living in the UK, the age of 18 and over and who can contribute to take decisions regarding retrofitting of their property. They may or may not live in solid wall homes, but their views about the importance of aesthetics on renovation and wall insulation of their properties are important. There are vast numbers of solid wall dwellings in the UK, and any UK residents may become the householders of such properties in future.

Choosing a sample helps in obtaining a manageable part of population which supposedly have the same qualities as the whole [41]. Convenience sampling, which is one of the non-probability sampling techniques, is used in this study. Using the convenience sampling is often "a norm" used in different studies [42,43]. The main objective of convenience sampling is to collect information from participants who are easily accessible to the researcher. It is a quick, inexpensive, and uncomplicated method of data collection and it is useful especially for large populations when randomisation is almost impossible [44]. To achieve a high response rate and easy access, all employees of the University of Salford in the UK were invited to participate in this online survey. The university of Salford has around 2300 staff members and it could be a good sample for target population (UK households who are the retrofit decision makers) as they reflect a variety of gender, age, ethnics, ownership statues and housing typologies. Also, they work in various diverse roles within the university with different income range, including admin, human resources, lawyers, finance, IT, estate and maintenance, engineers, technicians, academic, managers and etc. To ensure that the results are not biased, the characteristics of the selected sample is expected to be similar to the target population. This is especially true when we are looking at some of sample characteristics (such as proportion of old homes, origin, ownership, etc.) which are similar with whole the UK population. The survey was made in Greater Manchester which has a large stock of solid wall houses.

The sample size required for this study was calculated from the

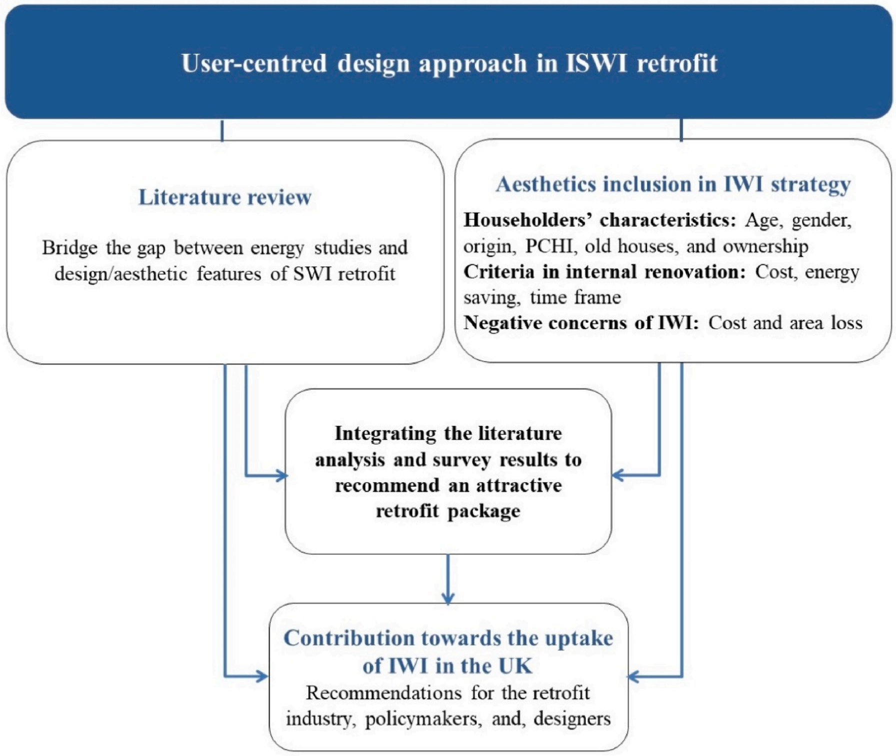

Fig. 1. Methodology concept map of this study.

following formula for large populations [45–47].

$$N = P(1 - P)\, z^2 / e^2 \tag{1}$$

where N = population size; e = margin of error; z = z-score and P = the population proportions. For the purpose of this study, 271 respondents are needed from the above equation, with a 90% confidence interval (z-score = 1.645) and a margin of error of ± 5%, meaning that calculated results are accurate to within 5% points 90% of the times. Out of 2296 sent invitation, 306 responses were received in which 273 participants selected "Yes" for consent question (Q1) to participate in this study (33 participants selected "No" and were not able to answer the rest of survey questions). Therefore, the required sample size of 271 participants for this study was achieved.

After developing the questionnaire and before survey distribution, piloting was performed for the overall success of the survey. The peer review and cognitive interview are two well-known piloting methods which were used in this study [48]. In the peer review piloting method, a number of people expert in survey subject or questionnaires are asked to review the questions [48]. In this study, the questionnaire was reviewed and consulted with research experts and academics to ensure the questions were appropriately designed. The questionnaire was amended and improved based on experts' feedback and consultations. This process was repeated until no more changes were needed [49]. The other piloting method, called the cognitive interview, was used which involved interviewing the experts to understand how they perceive the questions to ensure they were answered correctly [48]. Hence, the questionnaire was completed by four test respondents and the answers were discussed with them. According to the feedback received, the necessary amendments were implemented to the questions to make sure questions were making sense for participants, prior to its distribution. Both piloting stages performed in this study were with the aim to improve the quality and validity of the questionnaire, without collecting any data.

2.2. Survey distribution

There is a variety of tools for conducting the online survey with different capabilities. An online survey tool formerly known as Bristol online survey (BOS) is a powerful and flexible online survey that was designed and used for academic research, education, and public sector organizations [49,50]. The BOS tool was preferred for this study because it is specifically designed for research and education organizations, and it is easy to use. Also, it was widely used for different research projects in the literature in a similar domain and its applicability was confirmed [51–53]. The survey was distributed by email to the target participants for data acquisition using the BOS tool. Those who accepted the invitation completed the survey after giving their consent. The response data were then extracted from BOS and SPSS software (version 25) was used for data analysis.

3. Literature analysis

3.1. Solid wall dwellings in the UK

A large number of solid wall dwellings are located in England, with London and North West having the highest number of solid wall houses distribution respectively in the UK [54]. Most of this typology are low-rise (two-story) buildings including detached, semi-detached, or terraced type homes [55]. Looking at the history of construction methods in the UK, houses built before the 1930s used frameless structures where the external façades act as load-bearing walls. These solid walls consisted of regular and rectangular shape units (bricks, blocks, or slabs of natural stone, fired clay, concrete, or calcium silicate) usually combined with a mortar. The majority of the walls were typically one layer of material (solid walls). However, cavity walls were also in existence before the 1930s. Nearly 70% of the dwellings built before 1918 have solid walls and the older properties are more likely to have solid masonry walls. Around the late1800s and early 1900s, a range of masonry materials with different thicknesses were used in solid masonry walls. The most commonly used materials were clay brickwork with thickness of nominally 230 mm. The material used in solid walls present specific technical and buildability issues which should be considered at the time of thermal upgrading. Fig. 2 shows a typical solid brick wall and a sample of IWI.

Solid wall homes have the largest potential to reduce energy demand and CO_2 emission among various housing types [54]. According to the Energy Saving Trust, a third of the heat loss is happening through the wall of a house [57]. Many solid wall properties have no wall insulation in the UK which put them in a position for high waste of energy. Wall insulation could be a very effective method for energy saving and it is commonly deployed in different countries [58]. In SWI, the internal or external face of an exterior solid or "hard to treat" cavity wall would be insulated [59]. Several government policies were designed to support SWI across the UK [59]. However, the SWI with only around 9% progress is far behind the uptake of cavity wall and loft insulation with 72% and 66% progress, respectively [7]. There is a substantial potential for energy improvement of SWI which can contribute to emission reduction pledged by the UK Government. SWI remains one of the greatest challenges for the progress of energy efficiency policies [55].

3.2. The user-centred design approach for energy demand reduction

The reduction of energy consumption in buildings is not only a technical and economical challenge but is also a social problem [60,61]. Occupant attitudes and behaviour towards energy consumption play a key factor in developing any retrofit program [16,27]. Nevertheless, in current policies, this central parameter has not been reflected well [30, 31]. Improving the new policies with a focus on the social dimension of renovation and the role of householders in the renovation process is therefore essential [31,62]. To achieve this, the effect of some qualitative parameters about users' experiences, values, and practices related to UK domestic energy demand reduction should be understood and incorporated into engineering-focused energy research [30].

To meet the requirements of the users, a proper plan focusing on the user preferences during the design process is required and needs to be revised iteratively [63]. In this regard, user-centred design considers user requirements before, during, and after the design process [64,65]. In a user-centred design concept, the creative design within the technical and economic constraints is not everything. The focus of the design is on the people for whom the design is intended, and understanding the motivations, values, and attitudes of the user is essential [66].

The importance of a user-centred designed concept for SWI was highlighted in the CALIBER project [67]. The project aimed to establish a validated comprehensive mechanism for reducing UK domestic carbon emissions within the solid wall housing. As part of the CALIBER project, interview-based research was developed to understand the motivation factors for home improvement [68]. Most of the reasons for home alternation pointed out by the participants were related to the cost reduction and pleasant living conditions while they rarely highlighted energy as a motivator for their home improvements. In another study conducted by energy-saving trust [69], the Scottish Government's behaviour change tool (individual, social, and material (ISM)) found that the positive messages and information about SWI would spark more interest in SWI implementation.

As discussed, the householders' preferences for taking part in energy retrofit are not limited to technical factors. Any ambitious retrofit plans could be successful if the householders are considered and an appropriate level of information is available to them [70]. It is essential therefore to understand and include measures to enhance the users' experiences and preferences for possible functional, instrumental, and sociotechnical improvements to their homes.

3.3. Aesthetic features and their potential contribution toward energy efficiency

Recently, user-centred design approaches with the goal of energy and CO_2 reduction started to penetrate the energy efficiency technologies. In this concept, aesthetic inclusion can play an important role. Aesthetics can be defined as the philosophical concept of beauty linked to emotion [71]. It affects the level of satisfaction and happiness of individuals [72,73] while having the ability to improve the market [73, 74]. Aesthetics is a known and common factor in the design elements of the buildings. It is considered a signature of the building for example when it comes to building facades [75]. However, aesthetic inclusion in building energy applications is observed in only very limited studies in the literature [76,77], but this has not been evaluated for the energy retrofit applications such as SWI up to now. In this study, aesthetics is considered in term of its influence on occupants' preference and persuasion to apply and invest IWI in their houses. Aesthetics is therefore a term used in reference to provision of interior materials and finishes that would possibly be included in an overall products or strategies for IWI and it is not the aim of this study to include personal taste or cultural related preferences or choices.

It was reported in the literature that most technological energy-efficient measures are not aesthetically pleasing [78–80]. In a study by Buckley and Logan [80], 86% of the 1000 participants from 13 different countries believed that energy-efficient buildings are not aesthetically appealing. In another study, Norwegian architects indicated that energy efficiency measures technologies are "ugly" [78]. Also, the term "unappealing aesthetic" was used by buyers of energy-efficient buildings in the US [79].

The existing literature on renovation projects shows that aesthetics is powerful leverage for householders to start the renovation [32,74,81, 82]. Furthermore, house owners' aesthetic convictions can significantly affect the outcome of the retrofits [83]. Availability of a trusted company or brand, social influences, increases comfort, subsidies, discounts and potential financial savings are among the other retrofit drivers

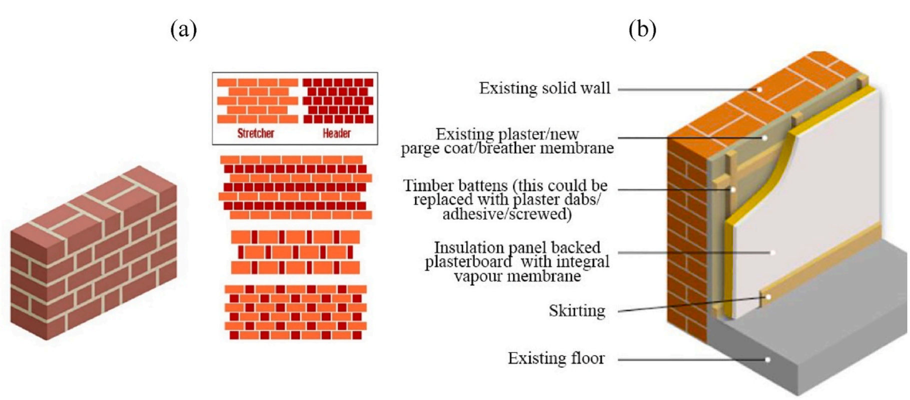

Fig. 2. a) Solid wall, b) Internal solid wall insulation [56].

mentioned in the literature [81,82,84] while the non-energy benefits such as aesthetics and lifestyle are the main reasons for building renovation work during the occupancy lifetime [31,68,84]. Householders are motivated to non-energy retrofit by aspiration related to aesthetics and a new lifestyle status or prestige in their living conditions more than for energy efficiency benefits.

The aesthetic pleasing outcome was confirmed to be the ambition of people in renovation even without any expectations for financial support or savings [31]. As discussed, aesthetics can contribute to homeowners' decisions towards implementing energy-efficient technologies, however, lack of research in this area was highlighted in previous publications [74,85] and some research studies have advised the necessity of demonstrating both non-energy benefits and energy benefits together in future related research [31,32].

3.4. Aesthetic implementation in the energy efficiency market

The question that is arising from the literature is about how to increase the SWI applications in people's homes when energy efficiency is not their priority? However, internal home improvement was purported to have the priority in the householder's renovation list, and in most cases, they are happy to invest for aesthetic reasons. Home improvements are a voluntary approach taken place by householders where they redecorate the walls, and floors or change the furniture to raise the internal aesthetic features and cleanliness to achieve more pleasant living conditions [68].

The building does not use energy but people do [86], and socio-demographic characteristics such as family typologies, demographics, and occupancy patterns can contribute on the energy consumptions [87]. So, designers should work closely with people to deliver attractive energy reduction solutions for the building users. As stated by Zaunbrecher et al. [88], intermediates such as craftspeople, architects, and energy advisors can play a positive role in the promotion of the retrofit process. One of the greatest challenges in product development is creating a form that is aesthetically attractive to the intended market audience [89]. The consumers' aesthetic preferences should be well communicated with the product designer to make sure the final product is satisfying for the consumer. This can be more successful when the communication between the designer and consumers takes place effectively [90] to understand the gaps in the existing products and consumers' willingness leading to satisficing improvement. The engineering culture should support these changes to embed such strategies in practice [91]. If such products can be used and publicized in the market, the householders are more likely encouraged to use them in their mainstream home improvement to not only achieve the main renovation goal of the new aesthetical look in their living spaces but also enhance the energy efficiency of their houses.

So far, the energy retrofit is seen as a separate matter from home improvement [92] resulting in a lack of SWI retrofit uptake [93]. The aesthetic feature can be included in SWI products specifically in IWI as an effective solution to help its promotion. The aesthetic aspect of the IWI can be fulfilled by a selection of the customer's favourite pattern from a variety of the decorative materials available such as wallpaper, and paint, or by even customizing the wall design for a specific desire or function in their homes. The aesthetic features can also be embedded onto the insulation material as an integrated product in large or small panels for the use in modular design or it can be applied after installation by the same installers when they have all the aesthetic patterns and finishes ready for quick fixing. Creating an aesthetically appealing insulation product would be a promising approach to flourish the energy efficiency technology market and increase the energy efficiency of poorly insulated houses. However, there is a lack of research on the aesthetic aspects of energy-efficient technologies in the literature [31,74].

There is also a need for renovation practices to deal with customers from the start point, during the decision process, up till the end of the renovation. The poor installation of SWI by unprofessional craftsmen was one of the barriers which decreases the effectiveness of SWI and depresses the market [31]. A solution in energy efficiency technology should include a comprehensive package delivered by professional to minimize the challenges currently associated with the energy retrofit for the customers. While in a recent study by Putnam and Brown [94], the community-led business model is found to be more effective than the government retrofit approach, it is also suggested that the scale retrofit would not be possible without government involvement and financial support. So, Government related bodies should also review their policies and performance of retrofit routinely for improvements. Providing financial support for professional organizations by providing a comprehensive retrofit package by the Government would be significantly beneficial for the uptake of SWI. Performing the wall insulation mainly through such organizations can help to reduce the installation costs considerably as the installation at scale could cut the costs even by half [4,95]. Due to the importance of cost in any decision-making, the financial element is discussed further in the next section.

3.5. Economic justifications of aesthetics in the energy efficiency market

In the building sector market, aesthetic preferences are the base of decision-making. Aesthetic features as a hedonic motivation [96] play a crucial role in the marketability of products and they can also help the energy efficiency technology market [85,97]. Added value to the property and neighbourhood is the economic benefit of aesthetic features in the buildings. It was confirmed in the literature that the potential added value to the property through the aesthetics feature is very high compared to other alterations [85]. For example, the rental value of an energy-efficient workplace is associated more with aesthetic features rather than energy efficiency features [73]. The US office buildings were reported to be rented and sold by 7% and 17% higher respectively as a result of having better aesthetical features [98]. Aesthetics can also increase the value of neighbouring buildings as was confirmed in an empirical analysis of the 5000 homes' sold prices in New Zealand, showing that more than one-third of additional value from attractive neighbouring buildings [99].

Therefore, including the aesthetic features in energy retrofit is an economical and technical approach to not only maximize the economical added value to the building following a renovation but also motivate more householders to get the energy measures implemented in their dwellings. These motivations can help to lift some of the negative barriers of energy retrofit in dwellings such as the high initial cost compared to the low market added value. In other words, this approach raises the worth of the energy-efficient building in eyes of owners to bring forward the energy efficiency measures in their renovation priority list.

4. Survey results and discussion

The key focus behind the data analysis in this study is to explore people's views on the aesthetic factor in renovation and internal living spaces and to see whether this factor can be used as a trigger to uptake the application of IWI. Statistical Package for the Social Science (SPSS) software (version: 25) is selected for statistical analysis of the questionnaire outcome. This software can perform highly complex data operations and analyses with simple instructions. Its suitability and validity were proved previously in numerous studies, and it was widely used in research survey analysis in the literature [100–102].

From a total of 273 responses received, the participant's gender is almost equal with 50.2% female and 49.8% male respondents. Therefore, the gender characteristics of the sample is similar to the population of the UK by gender (~50.6% female and 49.4% male in 2020) [103]. About 82.4% of the participants are of UK origin and 15.8% are from non-UK countries, with almost 1.8% who preferred not to reveal their origin. This is also a good representative of the UK population, with 9.5 million(~14%) non-UK-born [104]. As presented in Fig. 3, there is a

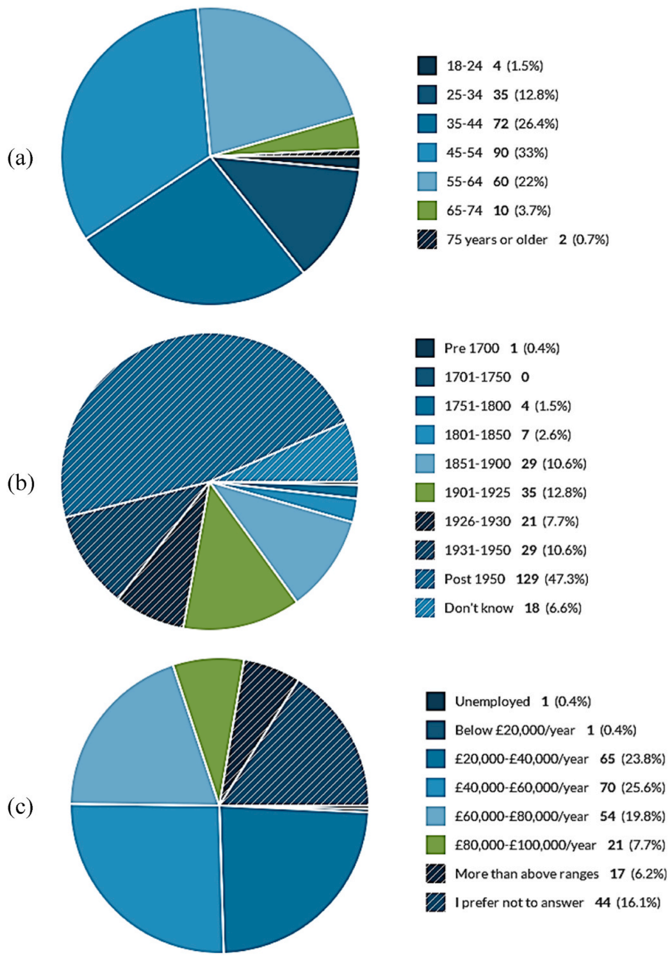

Fig. 3. a) Age, b) built date and c) household income distribution among participants.

good representation of all age groups among the participants as well. The household incomes for most participants are between £20,000 and £80,000 and participants were living in houses of variety of ages with most of the respondents were living in homes post 1950, while 97 participants (around 35% of participants) were living in homes built before 1930 and possibly have solid walls. This proportion of old houses of participants is similar to the number of old houses suitable for SWI with no/poor wall insulation (7.7 million solid wall and 1.75 million cavity wall) in the UK which count for around 33% of the total UK housing stock [2,55,105].

The next analysis is directly related to the purpose of the research. Relevant questions were designed mostly as a 5-point Likert scale from 'strongly disagree' to 'strongly agree' or 'very important to 'not important. The option of 'Don't know was also provided to achieve more precise data. The participant's views on energy efficiency improvement, cost, the timeframe of renovation, and more importantly, the aesthetic features were evaluated. From the valid responses, it is found that 99.2% of participants are keen to improve the energy efficiency of their homes, however, it is only the priority of 42.6% of participants in retrofitting their house. These drop-in percentages reveal that uncertainties exist among households slowing down the energy retrofit implementation as was also confirmed in the literature. Moreover, there is a high agreement with an internal wall decoration with over 96% in favour of the aesthetic appearance of living space. There is a slight drop in participant opinion about aesthetic consideration in retrofit, but it was still high with over 90% of participants in the agreement. According to the other survey questions, this drop is due to cost concerns; because the aesthetically appealing product is selected by 99.3% of participants among the products with the same functionality, quality, and cost. However, when there is a cost increment for the aesthetically appealing product, 88.6% of participants are willing to pay extra within their budget to bring aesthetic features into their living space. On the other hand, the analysis also confirms that a high percentage of participants are ready to pay extra to achieve aesthetic improvement, which again itself highlights the importance of the aesthetic in convincing people toward a retrofit plan.

The importance of other factors, such as energy-saving, cost, and time frame along with the aesthetics in the internal renovation was also evaluated in this research and the relevant results are presented in Table 1. Categorizing the Likert scale responses into two categories of the important and not important show that aesthetics, energy saving, cost, and time frame are highly important in internal renovation for participants with 98.9%, 99.6%, 100%, and 98.9% in agreement respectively. However, in reviewing the responses, most of them are in the first two scales of very important and important, so the important priority of the four-understudy factors (aesthetics, energy saving, cost, and time frame) is analysed more closely in Table 2 and Fig. 4. From the results, it is identified that aesthetics, energy-saving, and cost are almost equally important for participants with more than 90% whereas time-frame is of less priority for participants with 65% in the internal renovation.

Fig. 5 is a bar graph that represents the summary of the results for a better comparison of aesthetic, energy saving, cost, and time frame factors in relation to Per Capita Household Income (PCHI). Table 3 shows a cross-tabulation analysis of the importance of four understudy factors versus PCHI for all participants. PCHI was calculated by dividing the household income range by the number of people living in the household and then it was categorized into three categories: low (below 1.99), average (2–3), and high (above 3.1). As can be seen, aesthetics, energy saving, and cost have similar high importance levels in internal renovation for participants.

Similarly, a cross-tabulation analysis is performed for the four understudy factors versus various categories such as age, gender, income and country of origin. No matter how the data are categorized for analysis, the response rate for all is almost always well matched. This confirms that the aesthetic factor importance, while it is not included in current retrofit strategies, is almost at the same level of importance to cost and energy saving in the internal renovation. These analyses are performed for participants living in old homes and homeowners, to compare different cases with view of all participants. A slight drop or increase in figures was observed in some cases, but in general, the view of participants living in old homes and homeowners was almost the same with all participants. Table 4 is an example of a similar analysis to the table above but for participants living in old homes. The slight change in percentages does not provide a meaningful comparison as the number of responses are different in each category.

The view of male and female participants, which their distributions are almost equal, were compared about four factors under study variables (see Table 5). It seems time frame and aesthetics are more important for female respondents compared to male participants while energy-saving and cost factors are almost equally important for participants in both gender categories. Similar to the previous analysis, the aesthetic, energy-saving, and cost factors are of higher priority for the participants compared to the time frame factor.

Moreover, the effect of cost on aesthetic preferences is assessed among participants. According to the responses, we can conclude that aesthetically appealing products receive a high percentage of acceptance (99.3%). However, only 10.7% of the participants ignore the aesthetic aspect of the product due to the higher cost. Furthermore, it is observed that adding aesthetic features to internal solid wall insulation will alter the negative concerns about losing internal space for most participants with only around 11% disagreement from valid responses as shown in Fig. 6.

As presented in Fig. 7 a, more than half of the valid responses are in support of insulating the walls with internally appealing wall insulation

Table 1
Overall significance frequency table of four understudy internal house retrofit factors.

			Aesthetic	Energy saving	Cost	Time frame
Significance	Important	Frequency	269	272	273	269
		%	98.9%	99.6%	100.0%	98.9%
	Not important	Frequency	3	1	0	3
		%	1.1%	0.4%	0%	1.1%
Total		Frequency	273	273	273	273
		%	100.0%	100%	100.0%	100%

Table 2
Aesthetic, energy saving, cost, and time frame factors priorities in internal house retrofit for participants.

	Aesthetic		Energy saving		Cost		Time frame	
	Frequency	Valid%	Frequency	Valid%	Frequency	Valid%	Frequency	Valid%
Very Important	130	47.8	129	47.3	142	52.0	64	23.5
Important	115	42.3	117	42.9	108	39.6	113	41.5
Moderately Important	20	7.4	20	7.3	19	7.0	74	27.2
Slightly Important	4	1.5	6	2.2	4	1.5	18	6.6
Not Important	3	1.1	1	.4	0	0.0	3	1.1
Total	272	100.0	273	100.0	273	100.0	272	100.0

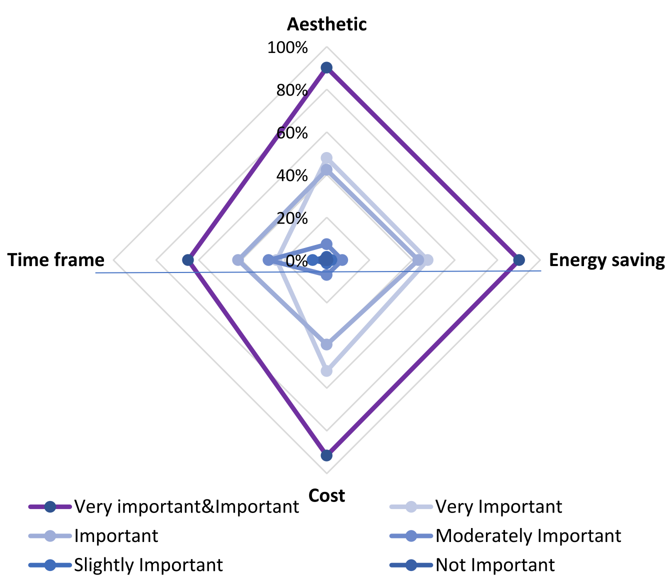

Fig. 4. The spider graph for aesthetic, energy saving, cost, and time frame factors priority level in internal house retrofit for participants.

to benefit from the aesthetic and energy improvement in a single package, while about 20% of participants disagreed. Also, about 75% of participants agree with the establishment of the organizations to deliver both aesthetic and energy improvements in one package to design the retrofit plan based on user's preferences to implement and supervise the process to achieve the target energy saving (see Fig. 7 b). More than 20% of participants impartially responded to both questions, which could be due to the newness of the subject for participants that may not have experience with aesthetic panels or such organizations. The agreement figures may have the potential to increase even more if the benefits of this approach are perceived by the public. The severity of aesthetic importance for IWI may vary for people with different gender, income, age, and country of origin, however, the "very significant" impact of aesthetic factors in internal renovation is proved to be conclusive from the analysis. The results have also confirmed the importance of aesthetics in encouraging residents to engage with SWI projects and the necessity of aesthetic integration in current retrofit strategies.

5. Conclusion and recommendations

This research was built upon the immediate need for making old dwelling stock more energy efficient in the UK to meet the CO_2 emission reduction targets and tackle the effects of climate change. Despite all the policies, subsidies, and grants available to support SWI, the progress has been very slow compared to other energy retrofit measures in old uninsulated dwellings. Innovative and encouraging retrofit plans are urgently required to lead to householders' behaviour change towards acceptance of SWI and unlock the demand for SWI implementation in UK old houses to improve their energy performance. Therefore, the idea of integrating the aesthetic factor in IWI to promote SWI was explored in this study.

The results show that the aesthetics factor is as important as cost and energy saving for participants with more than 90% agreement. The result also confirms that including the aesthetics in wall insulation can challenge the negative view of participants on losing internal space. Additionally, the preferences of participants towards aesthetics can surpass the concerns of cost since 88.6% of participants are ready to pay more to achieve an aesthetically appealing insulation product. Furthermore, more than 50% of the participants agree with the internal aesthetic insulation panels which offer aesthetic and energy savings in a single package. More than 2/3rd of participants also agree with delivering both aesthetic and energy improvement in combined retrofit plans by established approved organizations as a suggested business model. Adding the aesthetic factor in SWI is therefore a motivation for householders and can lead to increase attractiveness and behaviour change. Aesthetic inclusion is proven to be the priority and an encouraging factor in internal renovation. Therefore, the proposed solution of integrating the aesthetic factor in energy retrofit strategies, especially in the case of IWI is highly recommended to achieve a behaviour change in favour of uptake of wall insulation.

The results of this research have led to several recommendations for the retrofit industry, policymakers, and designers which are discussed in the following:

Recommendations for the retrofit industry: It is highly recommended that retrofit industries perform SWI only with their approved fully trained installers. This will greatly contribute to improving the current negative reputation of SWI because of poor installations [14]. Centralising the retrofit measures for old housing stock is recommended from the findings of this research. Such one-stop-shop business models were also suggested in the literature to accelerate energy efficiency renovations [106,107]. This could be achieved by integration or close

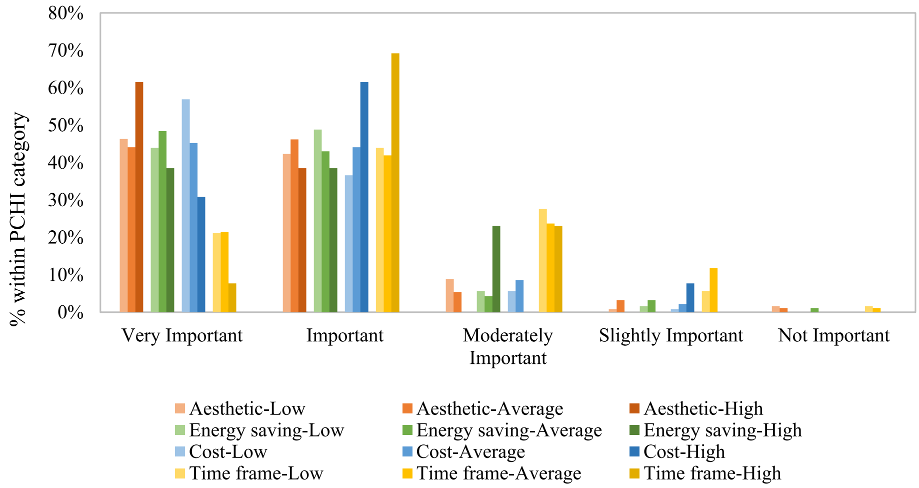

Fig. 5. Bar graph for aesthetic, energy-saving cost, and time frame factors according to participants' PCHI.

Table 3
Importance of aesthetic, energy saving, cost, and time frame factors in internal house retrofit for participants.

			Aesthetic	Energy saving	Cost	Time frame
Per Capita Household Income (PCHI)	Low	Count	109/123	114/123	115/123	80/123
		Expected Count	109.0	114	115.0	80.0
		% Within PCHI category	88.6%	92.7%	93.5%	65%
	Average	Count	84/93	85/93	83/93	59/93
		Expected Count	84.0	85.0	83.0	59.0
		% Within PCHI category	90.3%	91.4%	89.3%	63.4%
	High	Count	13/13	10/13	12/13	10/13
		Expected Count	13.0	10.0	12.0	10.0
		% Within PCHI category	100%	77%	92.3%	76.9%
Total		Count	206/229	209/229	210/229	210/229
		Expected Count	206.0	209.0	210.0	210.0
		% Within PCHI category	90%	91.3%	91.7%	91.7%

Table 4
Importance of aesthetic, energy saving, cost, and time frame factors in internal house retrofit for participants who are living in old homes (solid wall or pre-1930s dwellings).

			Aesthetic	Energy saving	Cost	Time frame
Per Capita Household Income (PCHI)	Low	Count	86/93	87/93	88/93	64/93
		Expected Count	86.0	87.0	88.0	64.0
		% Within PCHI category	92.5%	93.6%	94.7%	68.8%
	Average	Count	60/68	62/68	60/68	41/68
		Expected Count	60.0	62.0	60.0	41.0
		% Within PCHI category	88.2%	91.1%	88.2%	60.3%
	High	Count	9/9	7/9	8/9	7/9
		Expected Count	9.0	7.0	8.0	7.0
		% Within PCHI category	100%	77.8%	88.9%	77.8%
Total		Count	155/170	156/170	156/170	112/170
		Expected Count	155.0	156.0	156.0	112.0
		% Within PCHI category	91.2%	91.7%	91.8%	65.9%

collaboration of home improvement and energy retrofit companies, as a single actor, to offer both energy saving and aesthetic incentives to householders in one single package. This will minimize the cost of the whole project due to the integration of the retrofit and decoration by the same organisation as well as doing the renovation on a mass scale which can reduce the costs by half [4,95]. It is important to provide clear information about SWI energy-saving benefits, costs, and available subsidies and funds as well as support in the application process as part of the services offered by the industries to gain customers' trust [2,94,108]. It is also beneficial to provide customer service for all the steps of the project such as design, material selection, supervision of the project and after care service [109]. Following on from the results of this study, it is important to clarify all factors of aesthetic, energy saving, cost, in the retrofit project to maximize the attractiveness of the package for the customers, and to minimize the disruption time of the retrofit process for homeowners and deliver projects according to schedules suitable for customers. Furthermore, it is recommended that retrofit industries invest in creating the aesthetically appealing insulation products and consider the option of aesthetic customization in their products to facilitate the variety of customers' tastes. All of these improvements would help in making a very clear path for householders to engage and benefit from internal aesthetic wall insulation. These are often a relatively cheap intervention, but they complement each other within one work package and would help towards removing the barriers for householders.

Recommendations for policymakers: As the results indicated,

Table 5
Importance of aesthetic, energy-saving, cost, and time frame factors in internal house retrofit according to gender categories for all participants.

			Aesthetic	Energy saving	Cost	Time frame
Gender	Male	Count	117/135	123/136	124/136	83/135
		Expected Count	117.0	123.0	124.0	83.0
		% Within gender category	86.7%	90.5%	91.2%	61.4%
	Female	Count	128/137	123/137	126/137	94/137
		Expected Count	128.0	123.0	126.0	94.0
		% Within gender category	93.5%	89.8%	92%	68.6%
Total		Count	245/272	246/273	250/273	177/272
		Expected Count	245	246.0	250.0	177.0
		% Within gender category	90.1%	90.2%	91.6%	65%

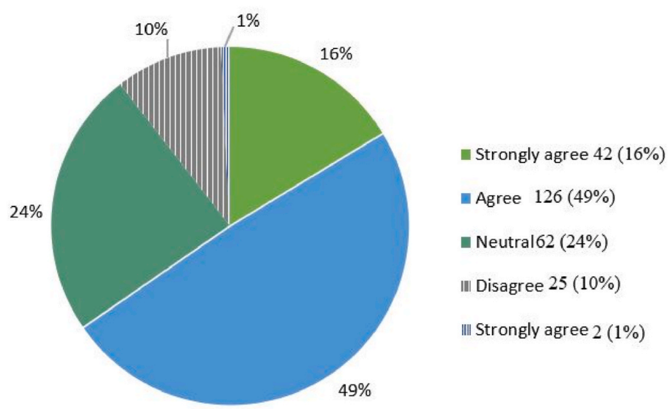

Fig. 6. Impact of aesthetic on internal space reduction concerns.

aesthetics can play a critical role in promoting the internal solid wall insulation but currently no policy exists to support such an approach. More attentions to the social dimension of renovation in new policies is essential and policy measures should recognize the role of householders and their preferences in renovation process [31]. Policymakers should develop policies in support of the integration of aesthetical householders' demands in implementing the SWI. In such policies, the financial support available for energy retrofit may include the redecorating cost. Furthermore, these new supportive policies about SWI should be communicated widely and clearly to the public to minimize the hassle and complexity [108]. Advertisement and publicizing the new attractive approaches for SWI is crucial for a better understanding of the service by the public and informing householders about the existence of the offers available to them. All these are necessary because successful energy policy for the buildings require educational and training initiatives and eliminations of the bureaucratic processes [110]. Policymakers should support the collaboration between home improvement, energy retrofit industries, and the householders, for integrated approach for the renovations of the UK old dwellings where Government can ensure the most positive outcome. Similar efforts were applied in different countries. Kalmar project in Sweden, for example, provides a successful example of collaboration between different actors and local inhabitants [111] with respect to the corporate strategies and citizens' desires

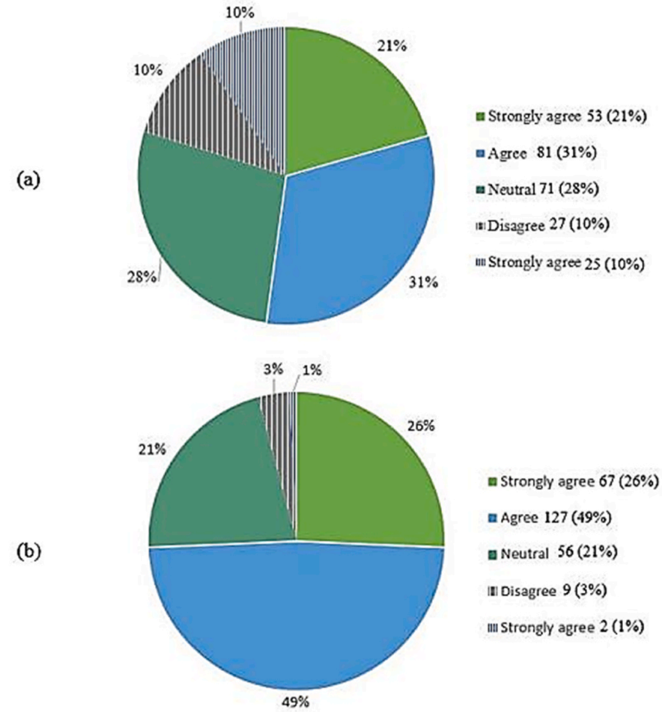

Fig. 7. Participants' valid responses about a) internally appealing wall insulation and b) establishment of organizations to deliver user-appealing retrofit packages.

[112].

Recommendations for designers: The role of designers is critical in facilitating the engagement of householders in SWI implementation for their old dwellings. Interior designers who work for the home improvement industry should consider the environmental impacts of their design [113]. A proper energy advice can positively impact the household's decision to adopt an energy retrofit measure [15]. Interior designers, as intermediate, should direct customers to designs and packages for a positive sustainable outcomes [88]. They should encourage IWI for old dwellings where possible, as beside saving more energy and cost compared to EWI [3,114], the aesthetic improvement of internal spaces is more of a priority for householders [72], and both can be achieved in an integrated approach. Designers and developers should continuously seek their customer's views about aesthetical demands to integrate them into energy retrofit projects and discuss the benefits with customers. Product designers should also improve the design of insulation products, not only to be energy efficient but also to be aesthetically appealing. Creating such products for internal spaces should be the priority as the research results showed that the aesthetic aspect of the internal spaces has a high priority for the tenants.

This study has used a convenience sampling method and the findings and recommendations of the survey study were based upon a sample of 273 staff members of the University of Salford. The future researchers can expand the boundary of this current research by adopting probability sampling methods with more diverse sample population. Furthermore, the survey was designed to suite UK solid wall housing and population. The level of importance for energy saving by retrofit might be different in different countries because of the climate condition. The aesthetic inclusion could be considered in promotion of internal wall insulation in countries with cold climates in old housing stock. For other countries with more favourable climatic conditions, but still in need for home insulation, the level of awareness for energy saving might be less. This could further increase the importance of provision of an attractive package to occupants on uninsulated houses. However, the results of this survey study can be country specific due to political, economic, social, and cultural context, and therefore, country-specific questionnaires may be needed in future studies for different countries. But notwithstanding these limitations, this study offered an insight into importance of aesthetics in renovation for householders and its potential in uptake of solid wall insulation.

CRediT authorship contribution statement

Mahsa Seifhashemi: Writing – review & editing, Writing – original draft, Visualization, Software, Project administration, Methodology, Formal analysis, Data curation, Conceptualization. **Hisham Elkadi:** Supervision.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The authors do not have permission to share data.

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