AN APPROACH TO SUSTAINABLE REFURBISHMENT OF EXISTING BUILDING

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The climate change challenge in built environment is complex as on one side there is a pressure to reduce carbon emissions from energy consumption, on the other side energy consumption trends are moving upwards and performance of the existing housing stock is degrading. As the majority of the existing housing stock will still be standing in 2050 there is need to address its energy consumption if CO_2 targets are to be met. This challenge forms the basis refurbishment, offers a huge potential to improve the performance of existing housing to the meet climate change and sustainability. Although the technical approaches to low carbon refurbishment are well known; deep retrofit uptake is currently very low. Through a review of literature, review of theoretical areas under which social landlord operate this paper will explore possible reasons for the low uptake and present a theoretical model of the key decision points that influence the refurbishment process in social housing in UK. The paper will identify the importance of economic and social drivers alongside technical solutions in designing effective refurbishment interventions. The paper will present the model in the form of a decision tree which will help built environmental professionals better understand the refurbishment process and develop effective business models that contribute towards sustainability by reduced energy consumption, improved thermal comfort. The study will help closing the performance gap by balancing the adaptation and mitigation measuring impacts.

Keywords: decision tree, energy efficiency, refurbishment, sustainability, social housing.

INTRODUCTION

Energy efficiency and climate change are topical issues over the world. The building sector accounts a significant percentage of national energy consumption: 37% for EU, 39% for the UK (Perez-Lombard *et al*, 2008). With the Climate Change Act in 2009, the UK has committed itself to an 80% reduction in all greenhouse gases by 2050 over 1990 levels (H M Government, 2008). The scale of the challenge, to achieve at least 80% cut in carbon emissions by 2050, is somewhat daunting. Paul King, chief executive of the UK Green Building Council said: ‘‘We drastically need to cut emissions from all sectors, but the built environment offers the best cost effective opportunity to do that. We have the technology and the know-how in the industry, but we haven’t managed to mainstream these yet. So the drive to cut carbon emission, quest for sustainability has put new challenges to engineers (i.e. doing more with less).

From 1994 to 2004 building energy consumption in UK and North America has increased at a rate of 1.5 to 1.9% per annum respectively (Perez-Lombard, 2008). The high level of building energy consumption, the steady increase in building energy

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demand and the legislative obligation to cut carbon emission necessitate low energy houses either by newly built or refurbishing existing building. The rate of new buildings that are being added to the current housing stock is nearly 1% per year (Power, 2010). At this rate it will take several ages to get a significant percentage of new houses of the total stock. Demolishing housing, taking the debris to the site, preparing the site for the new build involves high embodied energy. At this rate of new built and demolition, about 70% to 87% of the current existing stock will still be standing in 2050 (National Statistics, 2012). Therefore, refurbishing offers the most potential in making the existing building stock energy efficient.

Although a wide range of software tools and retrofit technologies are readily available, methods to identify the most cost-effective retrofit measures are still a major technical challenge. There is still a lack of implementing quality and performance management techniques. Through literature review, review of theoretical areas under which social landlord operate this paper describes the business cases and theoretical model for refurbishment and a decision tree for alternative measures to be identified through multi-criteria decision technique for a more rational and realistic assessment of technical, economical, social, and environmental issues. Findings of the ongoing research will help formulating a framework that asset managers can use to evaluate and plan technical interventions over a 10 years timespan from the many available to a build (or stock) depending on the building archetypes, future climates, socio economic conditions and occupant's preference.

WHY REFURBISHING?

According to BSI (1993) *"refurbishment is a combination of any actions required to retain an item in, or restore it to an acceptable condition"*. The above mentioned definition is solely true for physical condition of the building or its elements under the current refurbishment practices. But a building's functional performance is different from physical state, which can be improved to more than its original state. In Jones's (2007) model, refurbishment as an activity can be partial or total. Repeated partial refurbishment cycles are carried out until the point at which a building fails to satisfy the occupier's demands. Even after full refurbishment some residual obsolescence may remain and grow over repeated refurbishment cycles. Obsolescence means a building no longer meeting its requirements, which could occur for a number of reasons. Details of refurbishments are available in Jones and Sharp (2007).

The basic question of undertaking refurbishment can be simplified as when to refurbish and how to refurbish. Different buildings will have different business cases to instigate refurbishment. Householders can be motivated to refurbishment for physical, functional or both requirements.

Physical requirement includes space – extending the house to make more space, provide privacy, security from intruders, better use of existing space, easy access, kid's room; technology integration – integration of innovative technology such as green roof, led light, heat pump; repairs – damaged features of the home such as floor, walls, roofs, windows, leaning, corrosion of fixing, mould growth.

Functional requirement includes discomfort –draughts, overheating, noise attenuation, visual comfort; efficiency – improving heating systems or insulation to reduce energy consumption, CO_2; indoor environment quality- provide fresh air, light, remove odour, reduce NOx and VOCs (volatile organic components). Functional requirement also includes economic consideration- low maintenance cost, increase asset value, avoid

void period, long lifecycle; intrinsic factors – personal satisfaction, gaining a sense of achievement or relaxation, pride in restoration and a high standard of workmanship; social dimension - alleviate fuel poverty, stop anti-social behaviour, crime, environmental dimension - care for environment and wild life, less burden on fossil fuel, improved health; optimal use of resources –water, land, minerals, reduction of waste, less dependency of fossil fuel, exploitation of renewable energy; waste minimization – use less water, energy, produces less waste, use recycled product more; and overcome obsolescence – political, technical, aesthetic, societal changes, environmental aspect, climate change. Mostly these are microenvironment drivers. Though it is said micro-environment but it is hard to separate many issues from macro to micro environment as they are inter-related to each other. For the larger society of macro environment the drivers are low NHS cost, improved health condition, tree planting and beautification, low carbon society, increasing social equity, creating employment, and increasing energy security. So there are many business cases that drive refurbishment but under current refurbishment practices little emphasis is put on to improve the sustainability performance profile.

CURRENT REFURBISHMENT PRACTICE

The current refurbishment practice in social housing in UK is governed by stock condition survey putting physical condition, service life of the building or building component, and weatherproofing at its core taking into consideration of budgets, legislation and a time frame for a service life of generally 20 to 30 years for social housing. It also depends on the economic status and their attitude such as refurbishment is sometimes treated as a burden and waste of money (Moua and Russel, 2001) in the organization. In the past social housing refurbishment was carried out to meet the targets imposed by the local or central government under different schemes such as warm front, decent housing schemes etc. The social housing management was busy in meeting those targets only (eg. replace kitchen older than 20 years, replace inefficient boilers). So, effectiveness and efficiency of the refurbishment under previous approach was questioned as it did not do more than it was asked to. It is good that under current amendment social housing have been given the power to develop their own targets and act accordingly – a shift from regulatory prescribed housing management to a proactive style of asset management. It means that they have now more freedom to include sustainability at micro and macro level in their asset management strategy. Nevertheless, uptake of refurbishment is very slow.

THE BARRIERS AND CHALLENGE OF REFURBISHMENT

One of the most challenges of refurbishment as opposed to new built is the high cost, higher tax on refurbishment and lack of incentives. Though there are some incentives available under the schemes of green deal or renewable heat incentives, they are split by nature. Moreover the framework has its own problem. Another big challenge is the lack of enough information and uncertainty in the building structure to be refurbished (Azlan-Shah., 2010) such as physical condition of load bearing members, cracks, infiltration, or uncertainty in the whole construction project which may cause contingency cost allocation (Rayers and Mansfield, 2001). The drive to increase new housing also minimises the fund needed for refurbishment. Though cost is a big factor for refurbishment, social housing sector is less impacted by it as it is met through revenue budgets which are largely derived from rental income (Housing Corporation, 2008). Moreover public ownership under social housing allows a greater degree of

control, making it easier to coordinate and carry out refurbishment (Waide, *et al*., 2006).

Barriers within the asset management are - lack of top level commitment, skilled person to take the lead with regards to sustainability, lack of co-operation between departments and support from external organisations. Building Regulation in UK is less strict than Scandinavian countries (Balaras, *et al*., 2005). The Passivhaus standard of Germany is even almost three times stricter than the current Regulations in UK. Construction industry only meets the standard in force at the time of construction; they never go beyond building Regulation whereas the standard gets stricter day by day. Social housing sometimes lack in consistent stock condition data as stock condition data varies due to subjectivity, poor links to business cases.

Social housing works in partnership with third parties who are mostly SMEs (small, medium enterprises). In cases, SMEs lack knowledge in best measures; present poor quality of work. Sometimes the supply chain within SMEs is fractured and the holistic concept of sustainability is not known to them. Critical components for refurbishment are even often shipped from overseas increasing embodied energy. Sometimes installers don't like to take the risk with innovative solutions as complexities might arise later. Measures such as solid wall insulation are viewed as unattractive as outside appearance of the house is changed and disruption is involved. Housing stock with Hard to treat (HTT) or Hard to heat (HTH) may not be suitable for refurbishments at all. Though renewable energy can play a vital role to decouple HTT or HTH housing stock from the fossil fuel and minimize carbon emission, renewable energy is unpredictable, costly and pay back periods are sometimes very long.

Barriers at the downstream are age of tenants (particularly if elderly), habitual aspects- occupants do not understand how to operate most efficiently. Due to rebound or take back effect no improvement in energy saving might be seen from refurbishment. Obsolescence is less observed in dwellings or social housing but it is clear that if tenants don't accept changes due to the refurbishment, their preference is ignored, holistic approach to sustainability is not taken; expected performance will not be achieved. It becomes complex while integrating broad contextual issues in a holistic approach.

CONTEXTUAL FACTORS OF REFURBISHMENT

Before attempting to describe the context of refurbishment it is important to define *"Healthy housing"*. A healthy housing means a quality housing itself which necessarily need not to be designed with special care in residential setting but meets the occupants preference and expectation. According to World Health Organization, (2010) housing will have four characteristics- physical entity, provide facilities and feeling of home to occupants, its surrounding environment, a feeling of neighbourhood. The above issues are correlated and have serious impact on physical and mental growth of an occupant. The contextual factors affecting the social house refurbishment in UK has been described below and shown in the conceptual sustainable refurbishment model of figure -1.

Technologies: Based on supply and demand the refurbishment technologies providing facilities can be categorised into three groups -supply side, demand side and change of energy consumption patterns, i.e. human factors. The supply side refurbishment technologies include solar PV, gas, electricity, biomass, oil, solar hot water, heat pump or other efficient sources of energy. Technologies for demand side include

strategies to reduce building heating and cooling demand (insulation, heat recovery, windows, shading, etc.), the use of energy efficient equipment and, low energy or zero carbon (LZC) technologies. Human factor can be managed by the application of controls, sensors or by habits. Mitigating climate change effect will require innovation in sustainability, technology, procurement and industry capacity in energy constrained world. However, the procurement and penetration of LZC in market is slow.

Environment or ecology: There are five major areas in which the built environment can interact with the environment. They are in the form of land fill, release to air in the form of gas (CO_2, CO, CH_4, NOx and VOCs), release to water (waste generation), use of natural resources (water, fuel, metal, wood), use and release of energy (electricity and gas consumption, light, bulbs, ventilation fan, noise, heat). So, be it existing or new building it has its impact on the environment. Details of impact on environment can be found in introduction section and also in Michaityte, *et al*., 2008. According to the National commission of the Environment (1993, pg 2) sustainable development mandates that the present generation must not narrow the choices of the future generation but must strive to expand them by passing on an environment and an accumulation of resources that will allow its children to at least as well as, preferably better than the people today. Unfortunately in practice, only energy and CO_2 reduction target is considered in refurbishment decision.

Social: The refurbishment does two important tasks. On the one hand, it preserves the design qualities and socio-cultural values of a building, a street atmosphere, or a neighbourhood. On the other hand, after experience with architectural ideals and urban concepts, today's planners are able to revise older concepts and repair mistakes of previous generations. For example, poorly designed urban surroundings, vacancy, which often occurs when buildings do not fulfil the current demands, and misuse of properties lead to a lack of acceptance by neighbours, vandalism and social problems. Furthermore, technical decay in the estates is connected with social decay. Groups of users with socio-economic strength leave the estate and weaker groups replace them. This mechanism often results in high turnover, vacancy, lack of control, and in general in *"unfavourable"* living conditions. Hence, social drivers such as education, awareness, culture, labour market can reverse this problematic social environment. However, social aspect is hardly considered for refurbishment in decision making.

Political: The setting of carbon reduction targets, although informed by the scientific research on climate change, is undoubtedly also a political process which is poorly aligned to sustainabilty. Political issues are likely to have a direct influence on social landlords through either Regulation or Government legislation affecting the housing sector. Different political government introduced many programmes such as warm front, decent homes, CERT (carbon emission reduction target), CESP (community energy saving programs) Housing Health and Safety Regulation, EPC (energy performance certificate) and SAP rating to bring the households to a certain standards and alleviate fuel poverty. More details on the changes of policy and its impact of on housing refurbishment can be found in Baek and Park (2012).

Stakeholders: Stakeholders are those people or organisations who influence, or are impacted by the business of the organisation, its programmes or projects (Jensen, 2001). For social house refurbishment the stakeholders are Government, local authority, tenant services authority (TSA), occupants, other social landlords and support networks. According to Jones and White (2008) *"stakeholder's satisfaction is central to effective asset management"*. Project type, duration, budget and type of

technology to be used are shaped by preferences and expectations of stakeholders. Government plays an important role in social house refurbishment through Regulations and incentives. Occupants reflect current emerging issues of refurbishment. Local authorities influence carbon reduction interventions through devising and implementing spatial planning rules (DECC, 2009; GLA, 2007). SMEs play an important role by sourcing workers and materials from the local areas, using materials with less embodied energy and using innovative construction technology.

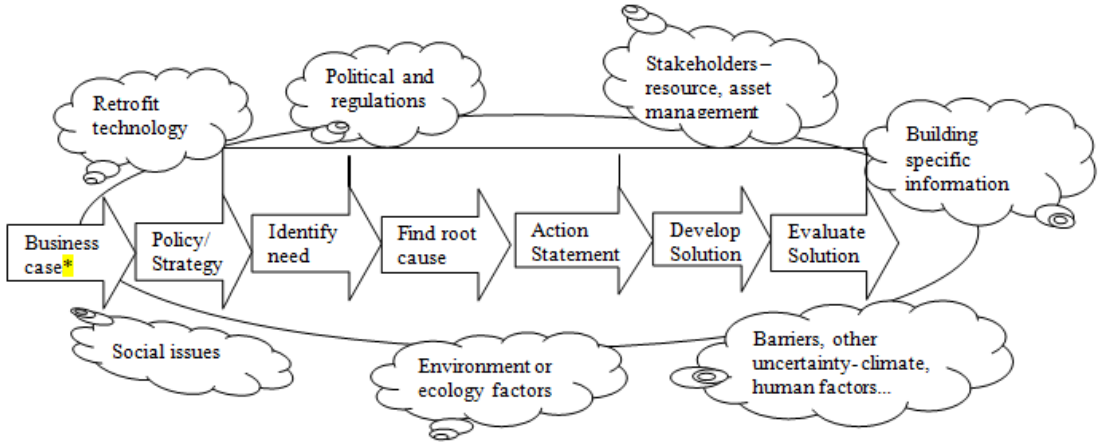

Figure 1: Contextual factors impacting building refurbishment (adapted from Jones and Sharp, 2006; Ma, et al., 2012)

Asset management: Refurbishment in social housing is carried out by social landlord under specific asset management strategy. The culture and attitude nurtured within an asset management is very important. Willingness of all operational, non-asset managers, stakeholders to achieve the service needed, standards to be set, priorities to be given and external and internal context (often termed environment) (Capon, 2000) to be considered is critical for a successful refurbishment.

Organisational strategy, approach: Refurbishment is also influenced by change in organisational strategy. According to Elrod II and Tippett, (2002) *"planned approach"* works on three phases. - firstly, unfreezing current behaviour to welcome new changes; secondly, roll on the modified strategy and get used to and, finally refreeze the modified new strategy. The limitation of this approach is, it does not unfreeze and accept any changes required in the last stage. So, an alternative approach was developed called 'emergent approach' to overcome the problem. Emergent approach assumes that rapid change might be needed due to change in internal or external issues, and it gets complicated if needed to manage from the top down approach. Rather it allows a buffer mechanism to adjust any change from top down or bottom up approach, and treats it as a process of learning. However, little use of planned and emergent approach is observed to keep in pace with the new situations in refurbishment.

It is understood, issues such as the variability of the climate, habitual aspects of people, unmeasured construction constraints (e.g. size and distribution of enclosure openings); design and construction deficiencies (thermal bridge, improper work); the unpredictable nature of renewable energy can influence refurbishment but they are outside the scope of this research. So by literature view and theories in contextual issues it is obvious that the cause of slow uptake of refurbishment are a loop of barriers, the poor business cases that fail to map the contextual factors influencing

sustainable refurbishment model and to convey and bring forward the social, economic and environmental benefits. The following section describes a strategy in a decision tree for refurbishment which can be used to integrate social, economic and environmental issues in decision making.

DECISION TREE FOR REFURBISHMENT

Decision-making tools can be defined as tools, which help decision makers to make (or even propose a decision for the user) on the basis of data about the alternatives to be selected from the multiple conflicting criteria (Leitch, *et al*., 1992). The main advantage of the decision making tool is, it breaks the whole complex process in simple phases, minimize risks in advance and establish a balance between the expectation and achievement. The decision tree shown in figure 2 has been built on performance based built asset maintenance process model developed by Jones and Sharp (2007) under participatory research in UK, following a series of development and review cycles. It is adapted but seeks to the address the weakness that is prevalent under current approach (physical condition based refurbishment). The steps are

Identify need:
Through this phase detailed information about the problems in the building, building component, building system or surround environment to be resolved are obtained. The problems might be high energy consumption, thermal discomfort, physical deterioration, failing to satisfy user's need. Through this phase information about priority, values, aspirations, budget and resources for the project are also collected. The information is collected by diagnosis, survey and questionnaires.

Find root cause:
Problems reported through above phase might be due to a single cause or a number of issues related to them. As an example, a building is not getting warm, does not mean that there is a problem in the heating system. It could be due to occupant's behaviour, draught, leaky building fabric or others. Auditing and survey can be used to find the cause of the problem under this phase. Data collected for modelling are building type, layout, physical status- leaky, single glazing, presence of insulation, status of building system, subsystem (Boiler, PV) and so on. Both of these phases are iterative and cyclical.

Action statement:
In the literature concerning multi-criteria decision- *"criteria"* can be called key point indicators (KPI) or key success indicators (KSI) that represent the social, economic, environmental and whole contextual factors in construction industry. Designers can decide the KPIs through several meetings or with the help of tools such as Design Quality Indicator, Housing Quality Indicator. KPIs vary from one case to another, one measure to another. Based on the root cause, action statement should be made through the use of KPIs.

Develop solution:
KPIs are organised in a hierarchical tree structured model where the aim gets the top, criteria and sub-criteria are represented in branches and sub-branches until it captures the whole view of the refurbishment. To form a comparison matrix quantitative KPIs such as energy consumption, CO_2 emission reduction from different refurbishment measures are scaled through energy simulation and modelling; and qualitative KPIs are scaled by survey or questionnaire. To simultaneously quantify the weight of qualitative and quantitative KPIs, a number of methods exist - Analytical Hierarchy

Process, Analytical Network Process and so on. The more alternative measures are investigated before making a final decision, the greater the possibility to achieve a more rational end result.

Evaluate solution and implementation:
Once multi criteria optimization is done, the cost benefit analysis should be carried out. A variety of economic analysis can be carried out- simple payback period; benefit cost ratio (BCR) based on tax, maintenance cost, insurance, consultancy fees. If value for money is expected to be achieved, depending on the situation partial or full refurbishment strategy can be developed and implemented. Otherwise, it should be demolished or called for auditing, survey again. At the end, commissioning and post occupancy evaluation is needed to ensure it operates as it is intended to, and justify the overall satisfaction of the occupants which gives room for improvement that can be implied for next refurbishment.

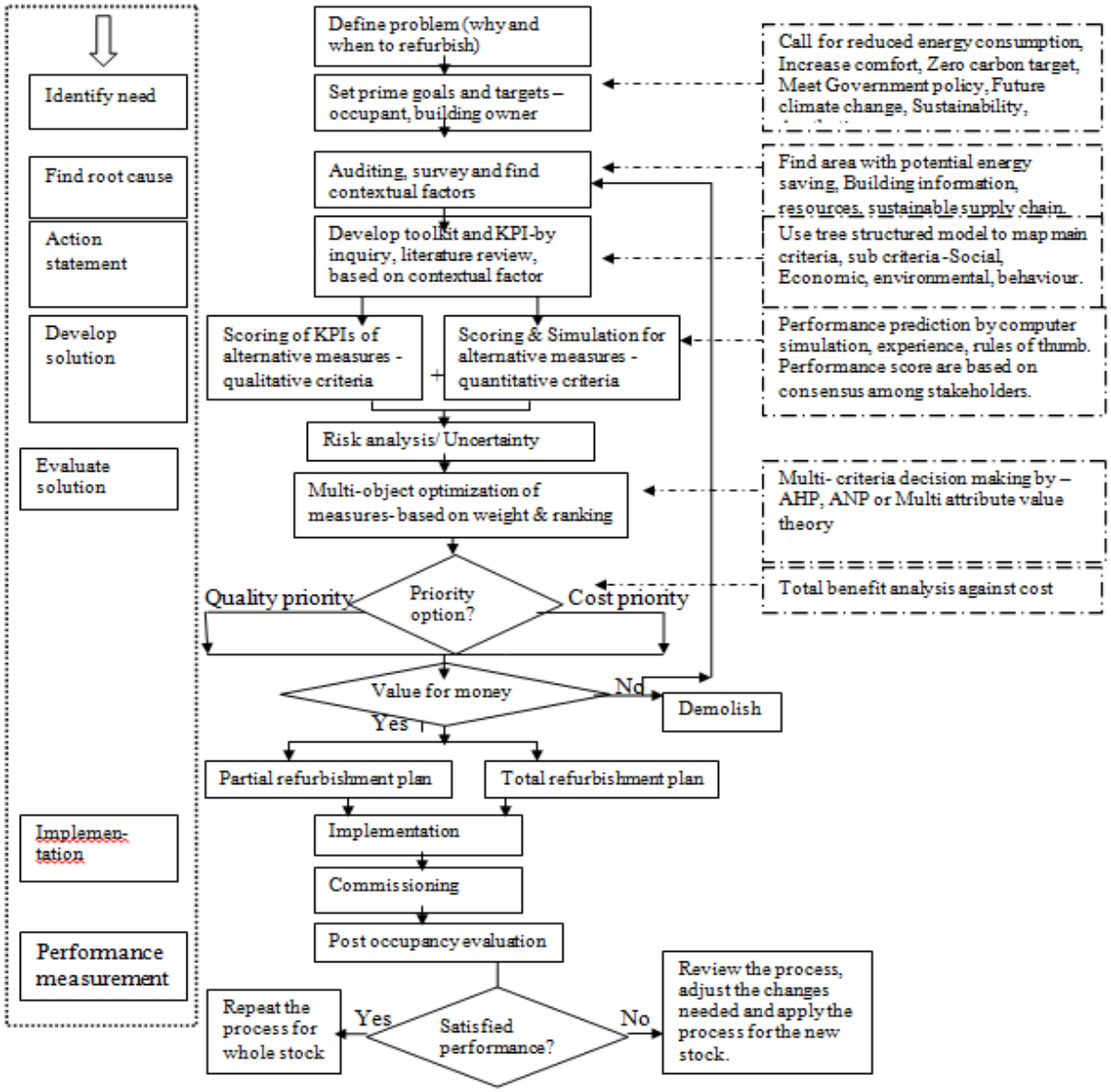

Figure 2: Decision tree for social house refurbishment (adapted from Jones and Sharp, 2007)

CONCLUSIONS

The paper presented theoretical conceptual model of sustainable refurbishment and factors that influence the refurbishment. Through literature review and review of

theoretical areas under which social landlords operate this paper identified the poor business cases as the reasons of slow uptake of building refurbishment. To overcome the weakness a decision tree was developed from the literature that is based on business cases. It integrates physical and functional performance of a building- a shift from a traditional condition based to performance based refurbishment. Quantifying the weight of the KPIs for different refurbishment measures and optimising the measures against cost, optimal measures for different house archetypes can be derived from the decision tree. Identification of the order of best retrofit measures by the decision tree can be used and extrapolated by asset managers to refurbish their whole housing stock to meet zero carbon targets, climate change issues and improve sustainability performance profile. Further research is needed to select the KPIs wisely that are specific, attainable, measurable and reflects the business cases properly.

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