Existing Healthcare Facilities, Refurbishment, and Energy Simulation

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Short description: The research relates to post-refurbishment reduce energy consumption of existing hospitals in the UK. This paper discusses a range of different refurbishment types for healthcare facilities.

Longer description: In recent years, various experts and organisations have emphasised the need to improve existing facilities to meet targets imposed by government related to energy consumption and carbon emissions. Demolishing existing facilities and constructing new facilities is not always the best solution to achieve government targets and modernise existing healthcare facilities. Also, the National Health Service's (NHS) focus on new construction in the past has contributed towards the deterioration of existing building stock up to certain extent. Research in the area of refurbishment of existing hospitals has been neglected despite the fact that existing facilities still account for a major proportion of NHS healthcare building stock. To accomplish the research aim and goals, a mixed methodology was used which include a literature review, web-based case studies, questionnaire survey, interviews and site visits to hospitals. A brief study of healthcare refurbishment indicates that a specific framework for existing buildings is required because their characteristics are different to new facilities. The function of this particular framework should be to integrate modelling and assessment tools, and to reduce existing building energy consumption throughout the life-cycle.

Key words: BIM, energy, existing facilities, refurbishment, simulations, tools.

1. INTRODUCTION

The design development in NHS was studied during late 1990s by Boswall, 2007 showed that despite development and dissemination of design guidance, the rate of the NHS response was slow compared to the rate at which its facilities were being developed. Further, a need for patient centred healthcare facilities was clearly identified. During the investigation it was found that refurbishment of existing hospitals is often considered from a narrow perspective; for example, work only related to mechanical systems and re-decoration. Nevertheless, other than improvements to mechanical systems and re-decorations there are many other factors which need to be explored in existing facilities, such as orientation of buildings, layouts, envelope, etc. Consideration of all these factors in existing hospitals will help to achieve an improved indoor environment and reduced energy consumption. This reduced energy consumption will result in a smaller carbon foot print. Effective consideration of refurbishment of existing facilities can extend their life-cycle significantly, perhaps even into a second life-cycle or a long term life-line for existing facilities. Also, various researchers and experts have proposed and developed several concepts related to hospital design resulted in a changed approach in the design of recently constructed hospitals. During refurbishment of existing facilities, concepts related to decentralised hospitals, multicentre hospitals, and nucleus hospitals should be considered, if possible. For example a '*decentralised hospital planning'* approach during refurbishment will propose nurses' stations at various points which can help them to focus more on patients and spend less time travelling to and fro in large scale healthcare facilities. Although, these concepts are for new hospitals, considering them during refurbishment can help to reduce nurses' and doctors' travel time and distance within healthcare facilities.

Based on data collected refurbishment can be divided into several types, such as with consideration to approach towards refurbishment or future requirements of facilities. The size, age, conditions, and requirements of existing facilities, refurbishment often involves part-new construction and part-renovation of existing areas within the facilities. Also, during primary data collection (a questionnaire survey and interviews) several terms were identified associated with construction of operational facilities such as renovation, retrofit, remodelling, modernisation, refurbishment, extension, etc. However, as it was clear that refurbishment can be divided sensibly into three types: cosmetics; mechanical systems; and (re)designing of facilities. Also, the approach towards refurbishment can vary with the type of existing facilities' layouts such as a *'shallow plan'* (7-10 metres deep) or a *'deep plan'* (10 plus metres deep core from external facade). For example with a deep plan building features like larger windows or glazed facade, central stack, atrium, mechanical ventilation, etc. should be considered to maximise penetration of natural day light into the facilities to reduce energy consumption and improve indoor environment quality (IEQ). For a shallow plan facility there may be a need to extend the existing floor plate to accommodate new medical technologies or demands.

The subject of this paper is to propose '*a refurbishment framework for existing healthcare facilities'*. The research relates to the refurbishment of healthcare facilities especially those built from the late 20th century and a key focus of the research is energy consumption of these facilities. As part of this, facilities considered for refurbishment and/or extension are discussed. The research phases comprise a review of existing literature followed by a questionnaire survey along with interviews with face-to-face healthcare facility experts and site visits to hospitals.

2. RESEARCH METHOD

The detailed review of literature related to methods and tools such as Building Information Modelling (BIM), energy simulation, and data collected through the interviews and a questionnaire survey was done. This paper is based on data collected from: literature; 43 questionnaire responses; seven face-to-face interviews; and five observation site visits to existing (operational and/or under construction) healthcare facilities in UK. The experts involved with development and/or implementation of a proposal for new and/or existing facilities were identified and selected for the questionnaire survey and interviews. The interview participants and the survey respondents were involved exclusively with healthcare projects and most of them working at least in two countries (UK and USA) and had more than 10 years of experience within the healthcare construction industry.

The combination of all this data has helped to define the types of refurbishment projects within existing healthcare facilities. Data collection and analysis was based on the principles of qualitative research methods, for example, all the questions used for the questionnaire survey and interviews were 'open ended' type questions. The analysis of the data helped to: propose a refurbishment scale (see Figure 1); develop a framework (see Figure 2); and formulate a refurbishment planning and implementation (see Figure 3) process. Furthermore, modelling and simulation were considered within the scope of the research to understand their benefits and limitations; the framework's emphasis is on integration of modern tools related to modelling and energy simulation. Importantly, the aim of this research is not to develop another certification tool, but to interface and/or integrate modern tools.

3. TYPES OF REFURBISHMENT PROJECTS

The review of literature directly related to refurbishment patterns in healthcare construction revealed that little effort was made to categorise types of refurbishment projects. However, it is necessary to classify existing refurbishment projects typology to understand their scope of work and limitations. Thus, the early phases of the research, efforts were made to categorise the major types of refurbishment projects observed commonly in healthcare. The collected data helped to propose a refurbishment scale indicated in Figure 1. All refurbishment projects can be divided into one of three main categories: minor; average; and major. The key aim behind the development of the scale is to provide a sensible way in which refurbishment can be considered during the design stages of a project.

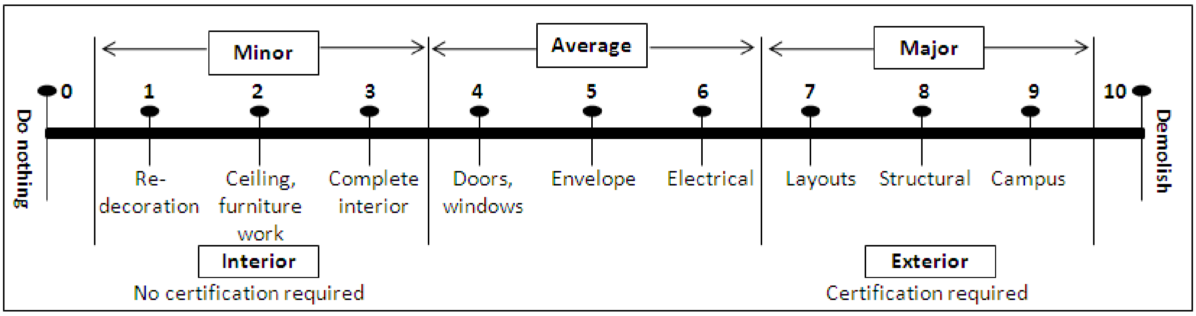

Figure 1. The proposed refurbishment scale

In Figure 1, Type 0 means '*do nothing'*, Type 5 being '*refurbishment of envelope'* including other activities for Type 1-4 on the scale, and Type 10 means '*demolish' or* to change the use of a facility considered for a refurbishment. The proposed scale is based on the characteristics of a project and not the size or quantity of the work, therefore, even though Figure 1 indicates that minor refurbishment works are usually interior and major works deal with exterior of facilities, sometimes minor works can be associated with exteriors and vice versa. Also, after a visit to a facility, the project team can decide on the type of the project, based on the above scale; this should help to establish overall project objectives and scope of work. Due to rapid changes in medical technology and service delivery, in more than three years old larger healthcare facilities there is little probability that the project will fall under '*do nothing*', (Type 0) on the scale.

There are several certification schemes available that measure and assess the sustainability of new and existing healthcare facilities. However, due to a number of reasons it is not feasible or practical to consider such assessments for refurbishment projects under Type 1-3 (even though these projects are the most common and can be of large scale in terms of quantity). This kind of projects provide very limited opportunity to save energy, improve IEQ and have less impact on social and economical sustainability of facilities, which is the focus of most 'green' certification schemes. Whereas, in major refurbishment projects (Type 7 and above), almost the entire building is new apart from structural systems and foundations, where the project team and clients will choose to pursue certification, if projects goals and budget permit.

Sometimes existing buildings are refurbished to support the physical extension of existing facilities. In these types of projects, the scope of the buildings' refurbishment could be anywhere on the scale between Type 0-10, in addition to extension of facilities. The type of refurbishment project will depend on the approach towards refurbishment and the need for an extension project.

Later in this paper, the scale will be developed to describe the typical scope of a project, e.g. scope for a Type 5 project on the scale, refurbishment of envelope. Also, types of software, tools, standards, and experts to be engaged for any specific level of projects will be specified. Table 1 describes the types of refurbishment projects from *'Type 0 to 10'* and will be enhanced further in due course.

Table 1. Discussion of refurbishment projects Type '0 to 10'

Level on scale	Types of project	Description
	0 Do nothing	Due to rapidly changing medical technologies there is very little probability that any medium or small scale healthcare facilities will fall into this category three years after construction. Although refurbishment will not commence at this stage it can give an indication of when there will be a need for refurbishment.
Minor	1 Re-decoration	These types of projects are classified as redecoration and involve *'cosmetic refurbishment'*. They have very little impact on energy consumption, but can result in improved 'look and feel' of facilities and so enhanced environmental quality overall.
	2 Ceiling, furniture work	This work type involves partial interior work. Sometimes furniture/ergonomics is considered. These projects generally involve work related to lighting fixtures, maintenance of detached furniture, plumbing works, curtains, louvers, etc.
	3 Interior	Mostly, these projects deal with the indoors of the buildings but can be minor or major work in terms of quantity. This kind of works can reduce energy consumption significantly compared to works Type 1 and Type 2.
Average	4 Doors, windows (Partial envelope)	This work involves partial improvement of the building's envelope. The work will reduce air leakage and heat transfer through windows and doors. Also, improvements to roof and signage within hospitals are considered within these types of projects.

	5 Envelope	The building envelope has a major role to play in reducing energy consumption and to improving IEQ in existing facilities for example if the existing envelope is in a poor condition then another layer of envelope along with peripheral circulation pathway can be added to control air leakage through existing envelope.
	6 Electrical and mechanical	Most of this work deals with Heating, Ventilating, and Air Conditioning (HVAC) of buildings. Current trends show that this kind of work accounts for most refurbishment proposals in the industry.
Major	7 Layouts	This involves improving building's layout usually due to a change in service delivery, an improvement in service delivery or efforts to minimise complexities within existing layouts.
	8 Structural	This kind of work can significantly extend a building's life-cycle. Here, almost the entire building is new including work related to structural improvement and stabilisation, and the existing foundations remain mostly untouched. These projects will include almost all the above mentioned types (scope) of work.
	9 Campus	These types of projects mostly deal with outdoor areas. The scope of the projects generally includes onsite parking, landscaping, entry and exit roads, storm water drainage etc. The projects are implemented in conjunction with above mentioned projects or sometimes executed individually.
	10 Demolish	If buildings are in a dilapidated condition and difficult to maintain then buildings will be demolished. Sometimes, these types of building provide an opportunity for a change of usage (convert into warehouse or for archives) with some restoration work. This is end of building's life-cycle as a healthcare facility.

Considering the above types of projects, including Type 0 and Type 10 there are several factors, which need to be emphasised during refurbishment. Before commencing any work, facilities should be checked for following conditions to decide type of refurbishment projects and scope of work.

Overall quality of the work: before commencing or finishing any work it is important to check overall quality of the work and space within the building. The quality of work has to be approved by experts or of approved standards. Even decisions related to '*do nothing*' or '*demolish*' will relate to existing work quality and space.

Energy consumption: except in Type 1 and Type 2, it is important to assess energy consumption and to have targets related to it. Also, targets related to energy will have a beneficial effect on IEQ and carbon foot-print of facilities.

Building conditions: in existing facilities this is important and must be considered during refurbishment of any type. Before adopting new technologies or new programs related to medical science it is important to check building height, strength, circulation spaces, etc. because insufficient floor to floor height, weak structure, or lack of proper circulation spaces are common challenges associated with existing facilities.

Indoor environmental quality (IEQ): this should be assessed in all types of refurbishment projects and all proposals should demonstrate the ability to tackle IEQ in existing facilities. Indeed much of the healthcare industry's money is spent on staff salaries, and IEQ can have a significant impact on staff performance. Improved IEQ along with minimum energy consumption can reduce operational costs and improve performance of facilities by a significant amount.

Re-planning: this is important to improve overall quality and to reduce complexities within existing hospitals for example, improved ward layouts, or circulation to reduce staff and nurse travel time within facility.

Sustainability: this should be considered because of an increasing demand from the industry to address environmental, social, and economical impacts. During refurbishment projects, sustainability should be considered irrespective of the scale of a project. Though there will be probably limited impact on social sustainability, refurbishment can improve economical and environmental sustainability significantly.

4. REFURBISHMENT FRAMEWORK

With fast-moving and changing regulations and developments in medical equipment, a refurbishment project executed over a six to seven year span can be expensive and ineffective. In this type of projects, the existing refurbished space will appear on completion to be already outdated because of changing regulations. Also, during those years of refurbishment a part of a building under construction will remain out of use. Nevertheless, during the interviews, it was revealed that although refurbishment is a time consuming and a lengthy process, but can be very effective if executed in well-planned phases. Also, collaborative planning along with well planned refurbishment can speed up the process. There are various reasons why refurbishment is time consuming and sometimes lengthy, as identified during the data collection, as follows:

- Existing occupancy
- Hidden/unseen conditions
- Dependencies of and/or on adjacent areas
- Construction noise and vibration
- Site restriction (less availability of space for construction related activities)
- New regulations
- Existing building conditions
- Reduced or more floor to floor height
- Structure/envelope performance is very poor

The refurbishment process is classified into three major categories: pre refurbishment; refurbishment; and post refurbishment. The resulting classifications and support systems for each category are shown in Figure 2. Also, the focus of the framework is on the development of refurbishment and thus, some of the construction related activities such as tendering, bidding, etc. are not a part of the framework.

The framework is divided into three columns: '*phases*'; '*purposes*'; *and* '*tools/process*'. The left hand column helps to define a phase and a stage of the project, the middle column denotes the purpose of that phase and right hand column (tools/process) contains objectives and purpose for that specific stage. To understand the relation between three phases for example, if a project is in *Phase II*, stage 1 '*detailed survey*' then '*purpose*' of that stage will be to compare the project status with the proposal and '*tools*' to fulfil the '*purpose*' is modelling which is a '*support system*'. A '*support system*' in detail for '*Phase II to IV*' is been presented in Figure 3 which describes the types of inputs required and type of outputs to be expected during the process.

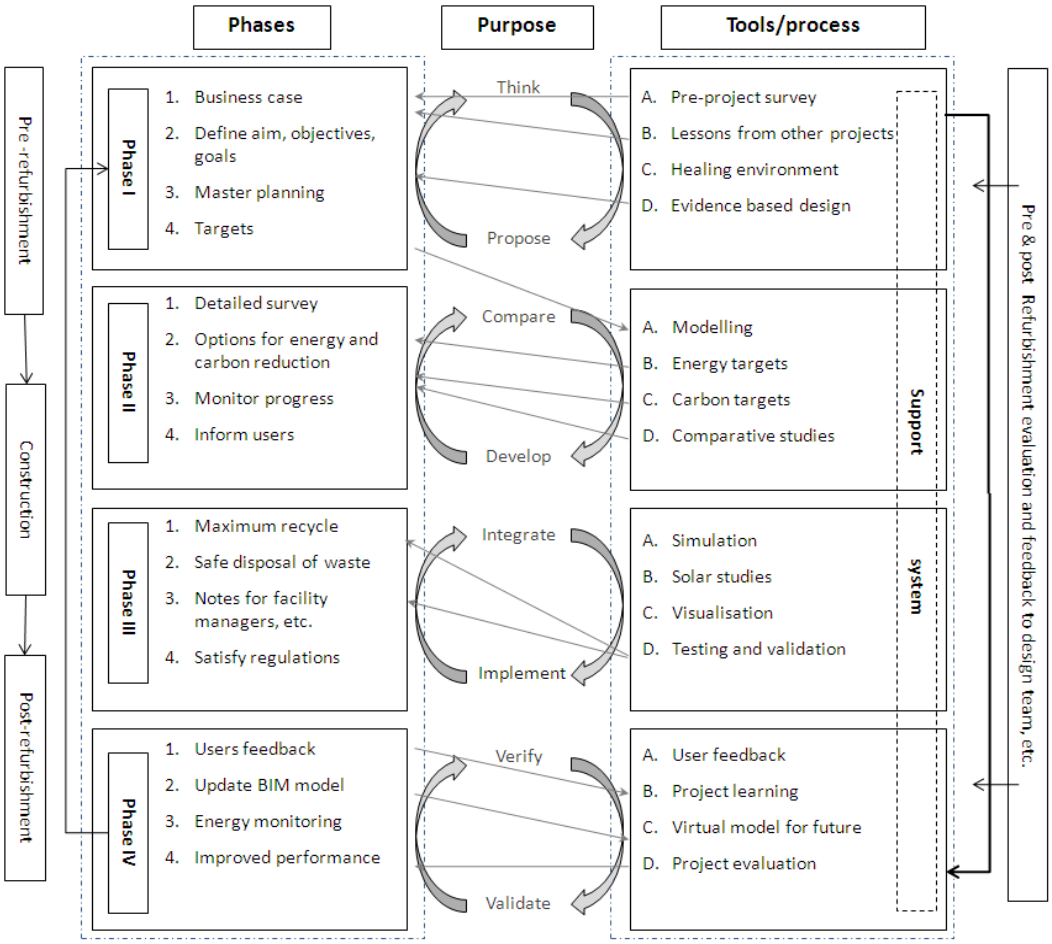

Figure 2. The conceptual framework for refurbishment

The arrows connecting the *'phases'* and the *'processes'* in Figure 2 are indicative, and as the study progresses, the connections will be developed further to make them stronger. Moreover, the brief list of activities and tools will be developed further during the process to make it more exhaustive and to develop a comprehensive framework.

The suggested process ('support *system'*) does not aim to prescribe the order in which they should be used because of the highly collaborative nature of the process. During refurbishment, collaboration is important not only amongst the construction team but also with users. It is important because in almost all healthcare refurbishment projects, users might have occupied existing space around or near to construction activities. Also, the occupied space in existing facilities might be required for future expansion (via refurbishment or new construction). Moreover, adoption of the refurbishment scale (see Figure 1) will help to decide engagement of the framework within refurbishment process. The '*support system'* can be employed simultaneously by several team members throughout the process. The '*purpose*' mentioned in Figure 2 is interfacing of '*phases*' with the '*support system'* and will help to promote a well-integrated process. Also, a properly documented '*purpose*' can give partial output (see Figure 3) to be used in the next phases or for future projects. For example, the purpose in the Phase II *'compare and develop'* can provide a comparison of various options considered for projects. Also, it can give a base to develop an approach for refurbishment in future.

Phase I: is a pre-construction design phase, where most of the decisions related to end product will be taken. This is a primary phase, which will serve as guidance during construction. In this phase, various opportunities are available to consider different options, which can have impact on the overall life-cycle of facilities. The design team members are the key actors in this phase.

Phase II: is an early construction phase where most of the decisions taken in the previous stages will be developed further and implemented. During this phase, there will be a need for physical data (such as solar heat gain based on the actual site location) to be used for further development of the project. During this phase, most of the activities will happen on the site however, there will be some scope to explore different energy saving features, measures in this phase. At this stage most of the activities will be taken over by the construction team from the design team.

Phase III: is the late construction phase before handing over the facility to the client/users. Most of the proposed ideas are implemented during this phase. There are very few possibilities to propose/make any changes at this stage because they could lead to delays in the completion of the project. During this phase most of the activities will be lead by the construction team leaving no room for design team to make design related decisions.

Phase IV: is a post-construction phase and will help to justify the refurbishment proposal (Phase I) and can assess, verify the strengths and weakness of the proposal. Moreover, the phase will help to provide lessons learnt to be used while developing a proposal in the future for the same facility or other facilities with similar characteristics. During this phase the facility manager takes the lead and will corroborate the design proposal.

5. REFURBISHMENT PLANNING AND IMPLEMENTATION

The process indicated below in Figure 3 will generate various outputs throughout the process such as project brief, execution brief. The objective behind partial outputs during the project is to review projects to learn and avoid mistakes in the later stages as well as during development of similar projects in future. The quality of the outputs will depend on the types of inputs received in the form of site analysis, client's inputs, and business case. Figure 3 shows Phase II to IV in greater detail.

Inputs in the form of site analysis by the site team will be actual site data, physical conditions of buildings and surroundings. Inputs given by the client/stake holder and end users may be related to their requirements and the type of end product they are expecting, whereas, the business case will include almost the entire project brief including financial and other issues. In any project, the business case plays a vital role, which can decide the refurbishment need, approach, type, and scale of construction. Also, all the briefs generated during the above process will validate the business case. Moreover, Project Brief and Execution Brief are important parts of the Phases II and III.

Project Brief: this will help to explore the early stages of projects. The brief will provide a ground on which a preferred refurbishment option can be selected or rejected. The brief should contain detail on the type of options considered, assessed and any learning during the process. The design team will be the major contributor to generate a Project Brief.

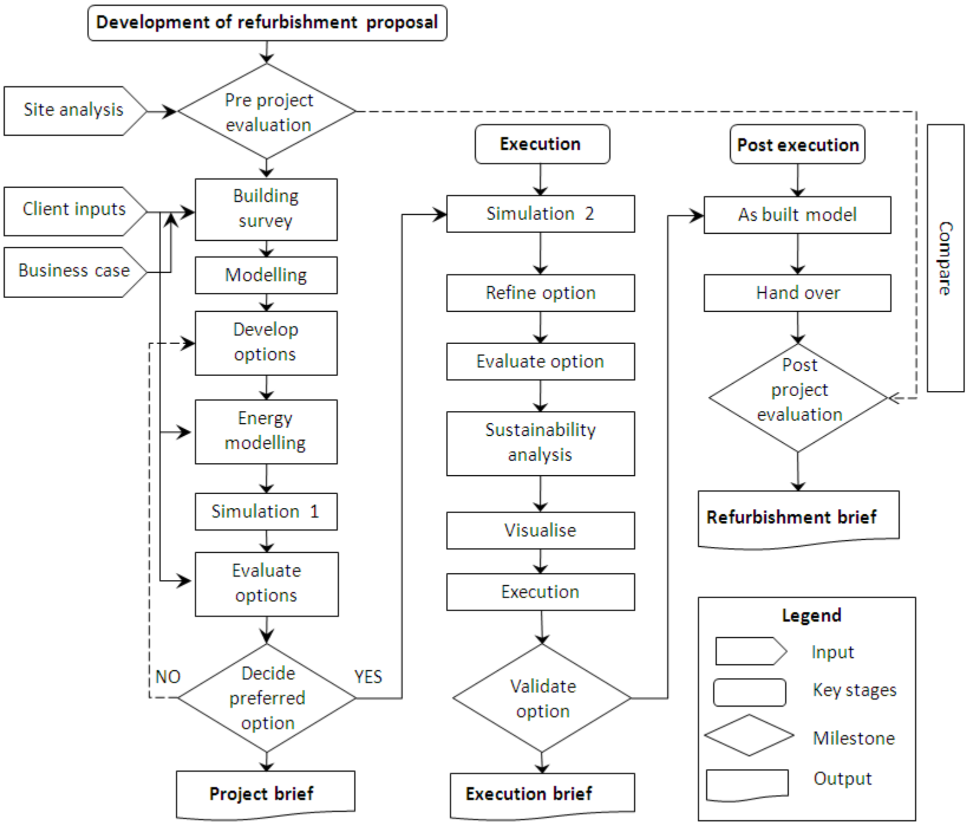

Figure 3. Refurbishment planning and implementation (Phase II to IV)

Execution Brief: will provide a brief about the execution of refurbishment proposal. This will contain most of the data related to site activities, which can have influence on success of the projects and designing of future projects. An Execution Brief should provide a sound analysis of proposed operations in the context of the existing facilities. In this phase a major contributor will be the site team and it will be useful for design team in future.

Refurbishment Brief: will carry all the details from '*project brief*' and '*execution brief*'. The brief will be a part of Phase IV of the proposed framework (see Figure 2). This will help to validate the initial refurbishment proposal and refurbishment project and can prove to be very helpful with future development of similar types of projects.

6. BUILDING INFORMATION MODELLING (BIM) AND SIMULATION

Implementation of 3D modelling demands critical inputs related to projects during the design phase. This promotes involvement of the engineer and consultant early on projects which minimises clashes/conflicts between architects, designers, contractors, consultants, etc. during later phases. Barista (2007) reported that *"BIM is a perfect fit for healthcare because of the complex nature of these buildings, the repetitiveness of the activity within the building and the need to really nail the process".* Another option could be to study the morphology of a building and add an external layer of a building envelope to reduce the energy consumption by controlling air leakage through the existing buildings' envelope. Ren (2007) reported that a performance based design and simulation approach can offer an improved and comfortable indoor built environment, lower carbon emissions, and additional value to the client. But Cooper (2007) asks *"why do we create our most critical facilities using antiquated tools and based on data that may be years out of date?"* To explore this issue, the benefits as well as limitations of BIM and simulation are highlighted below. The review of literature and the investigation revealed that BIM and simulation offer particular benefits for refurbishment and construction projects.

6.1. Building Information Modelling (BIM) for refurbishment projects

The need for more information during the design stage has attracted the attention of research communities, industries, and experts. As a result, the construction industry has started adopting 3D tools over 2D Computer Aided Design (CAD) based tools for designing. Also, recent developments of 3D models to include project information related to building (known as BIM) has been observed, but the process of designing buildings in BIM is complex compared to traditional CAD based approaches. However, there are several benefits of BIM over CAD; Table 2 gives the key benefits and limitations of BIM from a healthcare and refurbishment perspective.

Table 2. Benefits and limitations of BIM

Benefits of BIM	Limitations of BIM
Rich in data, object oriented, intelligent, giving a parametric digital representation.	A large amount of data input is required.
Provides comprehensive set of building knowledge related to form, materials, context, and technical systems of buildings.	Detailed modelling in BIM is reported as time consuming.
Easier to integrate data from and for different players involved in the project.	Difficult to interpret and apply outputs in design decision making.
Manages the essential building design and project data in a digital format throughout construction and buildings life-cycle.	Need experts to embed the information in designing process.
Provides appropriate data for users from different disciplines for various analysis purposes.	Because more data is incorporated based on assumption at initial stages, difficult to ascertain level of accuracy.
It is a building design and documentation system for all phases of design and construction.	Hard and frustrating to learn many tools.
Offers a level of management control typically ignored by conventional CAD based construction processes.	Geometric inputs required during the process are tedious task and error prone.
Helps to apply additional technologies to the building design process.	There is lack of clarity about who is responsible for these additional technologies among stakeholders.
Can facilitate the very complex process behind sustainable design.	Widely accepted BIM based tool to assess and promote sustainability is not available.
Can optimise construction time by highlighting bottlenecks and site constraints in advance of construction.	Need expert construction manager who can utilize tools related to 'clash detection' and 'conflict resolution.'

Reduces costs related to development of model to be used for energy and sustainability simulation.	But not always the same model can be used for energy and sustainability simulations, as industry is still dealing with the issue of interoperability.

6.2. Simulation from energy point of view

Fewer than 20 per cent of energy saving building components are selected with consideration to an alternative option (De Wilde et al, 2002). Application of computer based simulation is the most effective if applied at conceptual design phase to compare and optimise the best design solution (Lain and Hensen, 2009), so offers an opportunity for healthcare refurbishment.

Some of the key benefits and limitations of simulation are discussed in Table 3.

Table 3. Benefits and limitations of simulation

Benefits of simulation	Limitations of simulation
Enables comparison of a range of design variants, leading to more optimal design.	Minimum level of accuracy and validation because of several tools and team members involved in a project.
Provides a better understanding of the consequences of design decisions, which promotes the engineering aspects of the design process.	Sometimes it is difficult to interpret the results obtained from simulations.
Helps designers to explore complexities between design options in the early phases of the building design.	Does not support integrated, concurrent design process during early stages.
Reduces the gap between design and analysis.	Difficulty in transferring data from a tool/software to another.
Climate responsive design of high efficiency and optimum combination zones is possible to achieve with the help of simulation.	Difficulty in conducting parametric analysis.
Helps to predict the future performance of buildings during design stage.	Process is costlier because of cost of tools and experts required to operate.
Can extend life-cycle of buildings.	If facility management is willing to use the same BIM model they are expected to be a good user of BIM.
Helps to achieve improve indoor environment quality.	There are other better tools available only in relation to indoor environment quality check.

7. PILOT STUDY

A pilot study was run to understand the basics of the proposed software in Figure 3 (Simulation 1 and Simulation 2). A small hypothetical healthcare facility was developed with the help of Revit Architecture, a modelling tool provided by Autodesk. Revit has been widely accepted as a BIM based tool useful for modelling. A plug-in for Revit supplied by Integrated Environmental Solution (IES) for quick analysis of buildings from energy and carbon point of view was used. A small structure with windows, doors, walls, floor, and roof was modelled in Revit. The structure with two multi bed wards, a toilet block, and a staff room was developed and used for energy and carbon analysis with different characteristics of exterior envelope. Details of the hypothetical structure have been presented below in Table 4.

Table 4. The facility details considered for the pilot study

Type of facility	Inpatient, healthcare facility
Location	London. Latitude $51^0.5'$ N, Longitude $0^0.12'$ W
Operational hours	Day and night, 7 days a week (168 Hrs/week)
Exterior walls	Light weight concrete 200 mm (U value 0.8108)
Ground floor	Un-insulated solid (U value 0.7059)
Roof	Light weight 100 mm (U value 1.2750), 30 degree slope and 750 mm overhang on all sides.
Windows	Double-glazed (U value 2.9214)
Mechanical System	Central heating radiators
Option 01	Windows on all four sides
Option 02	No windows on the West facade
Option 03	100 % glazing on the North facade with no windows on West facade.
Option 04	100 % glazed East facade and normal windows on North facade.

Table 5. Comparison of options considered during the pilot study

Details	Option 01	Option 02	Option 03	Option 04	Units
Total Glazing Area	26	19.6	63.2	71.9	M^2
Total floor area	136	136	136	136	M^2
Volume	544.6	544.6	544.6	544.6	M^3
External solid wall area	475.4	481.8	438.2	429.5	M^2
Proposed energy use	**59.76**	**58.84**	**66.53**	**66.64**	MWh/yr
Proposed carbon emissions	**17.1**	**16.9**	**18.3**	**18.6**	Tonnes CO_2

During the study, with Option 01, windows were provided on all the sides of the structure and performed a simulation. Furthermore, with Option 02 windows on the West facade were removed to reduce the solar gain before simulating the structure. Ahead, in the process for Option 03, before running the simulations, windows were removed from the South facade to minimise solar gain and entire North elevation was replaced by glazed facade. Finally, in Option 04, walls on the East facade were replaced by glazing in order to maximise utilisation of available day light and reduce the need for artificial light during day time. In all the options daylight had been considered to reduce the need for artificial light during day time. The results of the simulation studies for Option 01-04 are presented in Table 5.

In Table 5, Option 02 clearly indicates that removing windows from the West facade can have impact on energy consumption as well as carbon emissions. Also, in all the options the total floor area, and volume is constant with varying glazing area and thus changing external solid walls area resulted in changing energy consumption and carbon emissions in every option. Considering the small area of the structure, there is a difference of two tonnes of CO_2 and 7.8 MWh of energy per year between Option 02 and Option 04. Which shows that in existing buildings, small changes and careful consideration to characteristics of existing envelope can give major savings in terms energy and carbon emissions.

Nevertheless, there are many ways to control solar gain by controlling daylight penetrating inside the buildings from West and South direction such as adding fins, louvers, curtains, etc. In the next stage of the research, all such options will be explored with the help of simulation tools and a more detailed model will be developed and tested using Ecotect, IES-Virtual Environment (VE).

There are some limitations to the pilot study with size and complexity of healthcare buildings being major issues. In future, a large scale healthcare facility might impose unexpected challenges such as more time, more information during modelling and analysis. However, it is assumed that large scale hospital models will provide significant savings and opportunities in terms of reduced energy consumption with different combinations of energy saving features such as fins, louvers, and light shelf.

8. DISCUSSION AND CONCLUSIONS

To perform energy simulation of a building, a rich data and inputs are needed which can be easier to gather from existing buildings as compared to proposed or the buildings under construction. A survey of existing facilities before refurbishment can elicit various details related operational hours, number of visitors, staffs and patient occupancy, existing indoor environmental quality (IEQ), need for lighting, etc. However, in case of new construction most of the above factors are assumed or forecasted and can change drastically on completion. Also, the levels of accuracy of the assumptions made during design are based on the experience of design team and experts involved in the project. Investigation reveals that often, modelling and simulation based approaches are not commonly considered during refurbishment of existing buildings. Compared to traditional tools such as CAD, BIM can help to plan for future refurbishment as well but various tools developed on the principles of BIM and simulation lack wide approval. This investigation has defined a need for a framework or a process to implement these kinds of modern tools into the construction of existing facilities.

In the healthcare construction industry it was observed that, refurbishment is considered from a narrow perspective with emphasis on improved mechanical systems and re-decoration. However, opportunities provided by refurbishment to reduce energy consumption and carbon emissions are often missed.

It was observed that in existing facilities very less importance is given to: Post Project Evaluation (PPE), any formal comparison between two refurbishment projects or between pre and post refurbishment project. However, PPE can help to improve and speed up the refurbishment process in the future and to validate refurbishment proposals as indicated in Figure 2 and Figure 3. Another aspect of PPE is to analysed the results and generate knowledge for refurbishment.

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