DELIVERING A RE-LIFE PROJECT

Preliminary Literature Review & Methodology

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Table of Contents

List of tables

EXECUTIVE SUMMARY

The purpose of this report is to review and discuss the earlier work done on tools that have been developed for decision making on refurbishment of buildings (office, residential and hotels) and the assessment criteria being used by these tools. This report starts with a historical background of retrofit projects and the reasons for retrofitting instead of grassroots construction. The tools and their methodologies are discussed individually and then summarised in the matrix which also shows the assessment criteria used by these methodologies.

The most common criteria for building retrofits addressed by previous researchers include:

- Assessing residual life using deterioration & functional obsolescence/ residual life of more than fifty different elements including windows, roof covering, façade finish, boiler, electrical installations etc. using degradation and functional obsolescence codes.
- Assessing building sustainability using:
    - Energy consumption by comparing current energy bills to the standard and best value of the country to illustrate the saving potential and
    - Indoor environment quality by using a questionnaire distributed to the building occupants with questions on indoor environment and building facility quality.
    - For office buildings and hotels there are additional modules for solar heating, central air-conditioning, pools etc. that need to be assessed.

In most cases the tools used by previous researchers use a radar graph to summarise the building deterioration state of the building elements. The same graph can also visualise the retrofit cost and identify the most expensive actions. The software calculates the scenario cost element by element. The first rough estimate helps the expert user to converse with the owner to decide on retrofitting or new build, taking into account budget limitations.

There is no doubt about the usefulness of these tools but they fail to address some other important issues such as waste management, floor space optimisation and use of efficient structural strengthening schemes like FRP composites.

It is also evident from the literature review that due to the nature of retrofit projects the need of proper risk assessment including risk identifying, risk assessment, risk reduction and contingency planning and a structured scheme to choose a proper procurement method need to be part of an assessment scheme that evaluates retrofit projects.

The ‘Re-life’ project is looking towards developing a holistic, robust and structured tool for retrofit projects that addresses the issues of residual life, sustainability, risks management, floor space optimisation etc. and operates in scientific way, instead of depending on information that has been gathered haphazardly.

A mind map was used to present the findings of the literature review. After reviewing the literature and discussions with the members involved in the Re-life team it was decided to use ‘Delphi technique’ to augment the issues identified in the mind map. Interrelationships between these issues will then be investigated using statistical data analysis. The outcome would then be validated using real-life retrofit projects.

1.0 Introduction

A review of literature was undertaken to identify tools and or criteria that can help in the decision making process of retrofitting and re-using existing buildings rather than demolition and new build. An international approach was adopted for literature, the majority coming from Australia, UK, Europe and USA. A Matrix is used to summarise the methodologies and the assessment criteria used by these methodologies. Some construction management issues in relation to project delivery are also identified through the literature search. The literature review then becomes the basis of development of the project methodology.

2.0 Historical Background

"A retrofit is the modification or conversion (not a complete replacement) of an existing process, facility, or structure. Such modification may involve additions, deletions, re-arrangement or not in kind replacements of one or more parts of the facility. Changes may alter the kind, quantity, cost or quality of the products or services being produced by the facility.(Sanvido, 1991)

The significant growth in the construction of new commercial office buildings over the past thirty years means that we now have a large stock of ageing buildings providing an opportunity for retrofit or re-life. Furthermore Caccavelli (2002) identifies that although in Europe 70% of total stock of buildings at 1200 million square meters of conditioned floor space is less than 25 years old which implies that they are relatively new buildings, but the retrofitting market has seen a considerable growth over the past 5 years.

Several reasons can explain this paradox:

- User requirements have considerably changed during the last decade (in terms of office equipment, communications, automation, quality of use and comfort).
- The property crisis, which has affected many European countries, has amplified the stock of not rented office spaces: buildings that do not offer all the amenities for comfort and flexibility, are difficult to sell or rent.

- Retrofitting a building costs is more or less half or one third of the cost of demolition and reconstruction
- Office buildings in particular are classified amongst the buildings presenting the highest energy consumption (e.g. annual energy consumption in European office buildings averages 100-1000KWh/ m^2 of conditioned floor space).

This implies that there is a new market developing which requires specific application tools that can help in making decisions on:

- Sustainability issues including indoor air quality, energy saving, Waste handling, disposal, potential recycling and Occupational Health and Safety (OH&S).
- Condition of existing building and the residual service life.
- Associated risk and project delivery.

3.0 Literature review

A new generation of European methodologies and software tools is in use or under development that enables architects and engineers to make an accurate first assessment of a building's existing structural conditions, energy performance and other criteria with a final estimate of the total cost. These decision aid tools provide a global view of a building's renovation and refurbishment process and enable a user to make well targeted decisions and to assess different scenarios. Some of these tools and other research being carried out in USA and Australia are discussed next.

3.1 EPIQR

EPIQR is the result of a European research project in the IIIrd framework program. A multidisciplinary team with research institutes and private consultants from Switzerland, Germany, France, Netherlands, Denmark, UK and Greece participated in the project of developing a residential building refurbishment decision aid tool in 2002. The main objective of the project was to develop:

"a software with a structured diagnosis scheme covering the state of degradation of building of existing residential buildings, energy performance and indoor air quality and help users to make informed decisions. Also to construct a coherent refurbishment scenario and calculate a reasonable investment in the early stages of the refurbishment projects." *(Flourentzos et al, 2000)*

The EPIQR method starts at the very beginning of a refurbishment project and ends by providing the user with enough information to set-up a successful refurbishment strategy. This structured diagnosis scheme enables architects and engineers to simultaneously handle the entire complex process of retrofit using the following criterions:

Physical state of degradation of building elements: the assessment was based on building objects and types. This assessment is used as a knowledge base for the probable residual life span of building elements and to decide whether to be replaced or not.

Sustainability

Energy consumption: the assessment is based on energy calculations for service hot water, heating and cooling energy, calculating energy saving potential and identifying suitable retrofit actions.
Indoor environment quality: the assessment was based on thermal comfort, indoor air quality (humidity, pollutants and ventilation), lighting and noise.

The building is decomposed into discreet objects and elements e.g. the object roof covering is divided into types tiles, roof membrane etc. The diagnosis is performed during a building audit. The auditor observes the elements and objects and decides which of the degradation or deterioration codes a, b, c or d best fits the observed state of the building where 'a' representing good condition, 'b' representing some degradation or deterioration, 'c' representing degradation or deterioration that requires repair and 'c' representing service life is over requires immediate repair. In addition to the detailed description a number of pictures and sketches illustrate the four possible degradation states. A total of about 500 photos and sketches have been populated in the tool to help the user in this assessment. The actions for retrofitting are defined for each object with four intervention codes. The program then uses a few (7-10) dimensional coefficients such as façade areas, built area, area of foundation etc. to calculate each intervention. The actions are detailed in a way to allow costs to be classified according to elements as well as trades. Costs are calculated from unit prices and quantities. The cost include Actions based on include professional fees, incidental costs, value added tax are laid out. A similar coding system is used for functional obsolescence.

Energy calculation modules are then used to estimate the building energy balance and assess the energy conservation potential for space heating and cooling. Energy bills show the current state of the building energy consumption. The state is compared to the standard and best practices values of the country to saving potential.

For Indoor Environmental Quality (IEQ) EPIQR system uses questionnaires to collect data on occupant complaints and after analysis different possible actions of improvement are selected. The software performs a statistical treatment of the questionnaire and relates complaints with refurbishment work and energy retrofit measures.

A clear distinction is made between the diagnosis and decisions to be made which do not depend on diagnosis. The software allows the user to build different scenarios and each scenario shows different levels of improvements to the office building and all have variations in the projected budget cost. A radar graph summarises the building deterioration state and on the same graph the auditor can visualise the refurbishment cost and identify the most expensive actions. The software allows the user to select the most suitable refurbishment actions comparing which actions promote the greatest energy savings, increase indoor environmental conditions for occupants and is within the budget constraints of the building owner. The program calculates the scenario cost element by element and the first rough estimate can help the expert to converse with the owner to decide the retro fit strategy taking into account budget limitations. The users can modify the calculated cost and give their own estimate. The interface of the software is programmed in Microsoft Visual Basic 5 and the databases in MS Access. About 350 European residential buildings were used as case studies and audited in order to collect the input data for the work that was performed.

3.2 MEDIC

This tool is intended for use with EPIQR and is based on subdividing of the element into 50 elements. The remaining life span of the building elements is an important piece of information for financially and ecologically coherent refurbishment decisions. The aim of MEDIC is to:

"Calculate the remaining life span of a building element not as a deterministic unique value but as a probability distribution. The remaining life span can be used as a decision criterion refurbishment scenarios and life cycle energy or ecological assessments."

(Flourentzou et al, 2000)

The decision making is based on the combination of the priori probability based on the experience from a large number of previous investigations.

3.3 TOBUS

The European Commission (EC) launched a two year research program entitled TOBUS involving eight European Institutions in 2002. The main objective of the project was to:

"develop an evaluation tool and software for the assessment of retrofitting needs of office buildings in European countries and for estimating the costs to meet these needs in compliance with sustainable issues improved energy performance and indoor environment. The software can then be used to define the most cost effective actions, to elaborate consistent refurbishment scenarios and calculate a reasonable investment budget in the early stages of a refurbishment project."

(Caccavelli et al, 2002)

This software uses the same philosophy as EPIQR but with additional features to handle the complex installations of office buildings. TOBUS methodology involves description of each building element, a description of deterioration and corresponding refurbishment work, including costs, potential upgrading work, as well as related national standards and guidelines. The new features include additional element and types for the electromechanical installations air conditioning and ventilation, central heating, fire protection, Hydraulic systems and low current systems.

The residual life assessment of building envelope and electromechanical is diagnosed in a similar manner as EPIQR. Additional calculation modules are included for air handling units, ice and chilled water storage, low energy office equipment and sanitary water savings. There is an additional *Functional obsolescence of building services* criteria in which the assessment is based on user needs, Flexibility, Divisibility, Maintainability and Compliance with regulations. The auditor assesses the obsolescence for each project and each criteria and the tool offers a description text to assist the auditor. Hellenic office buildings were used as case studies to evaluate the potential energy savings and cooling.

3.4 Hotel refurbishment tool

A tool is being developed for the hotel building scenario with the main goal to prepare:

"a multimedia software for carrying out a hotel audit, supported by the necessary tools for making a first assessment of where and how to integrate the most cost effective energy efficient renovation practices" *(Balaras et al 2004)*

The methodology and elements were similar to EPIQR and TOBUS but new modules that were important to the hotel industry were also included e.g. central solar systems, water and swimming pools etc.

3.5 Miscellaneous

The Cambridge Architectural Research (CAR) in UK did a scoping study for Energy Saving Trust (EST) in 2003 to explore the question of "when it makes more sense to to demolish housing and build new than to refurbish and upgrade an existing housing?" CAR ran a workshop to canvass expert opinion on issues that can facilitate the decision making on refurbishment. These issues included energy efficiency, remaining functional life and health and technological constraints.

A similar tool called the Office Scorer was developed by the Building Research Establishment in UK in 2002 and funded by the dti (Department of Trade and Industry) to promote more sustainable construction. The tool compares major or complete re-development, and redevelopment within an existing façade. It enables the user to systematically compare and test the environmental and economic impacts of different building design concepts for offices. BRE has modelled a number of buildings over a 60 year life and evaluated the economic and environmental impacts of a range of factors including building elements degradation, ventilation and cooling system energy saving.

Software called the Facility Energy Decision System (FEDS) was developed by Pacific Northwest National Laboratory and funded by US Energy Management Program designed to help inform decisions on energy-saving retrofit projects.

"FEDS determines the optimum set of cost-effective retrofits from a current data base of hundreds of proven technologies. These include retrofits for heating, cooling, lighting, building shell, and hot water. Replacement or modification of the equipment for a retrofit

operation varies from complete replacement to functional enhancements to fuel switching." *(FEDS website)*

In Brisbane, Australia Qbuild uses an MAR to carry out maintenance or refurbishment on their buildings.

"The Maintenance Assessment Report (MAR) provides an objective technical assessment of a buildings maintenance needs. It contains advice on how to best address those needs, and is an important reference when developing maintenance strategies, plans and subsequent work programs for buildings"

(QBuild, 2003)

The report compares the assessed conditions with the pre-specified conditions. The report also identifies non urgent maintenance situations and proposes solutions in the form of planned maintenance tasks. The assessment is done by teams undertaking the site inspection phase but special instructions by clients in relation to specific assets can also be included in the assessment. The maintenance categories used in the assessment are Planned (condition based and mandatory or non-mandatory servicing) and Unplanned or Responsive (Routine & Breakdown and Incident related)

The maintenance task list contains details about each maintenance task including building identification, defect description, rectification tasks, calculated priortisation ranking, timeframes and indicative costs.

The assessment is made using a Maintenance Scorecard. This comprises of 4 graphs. The first two graphs indicate the facility's overall condition. The graphs use comparative results from specified and assessed condition of each element in the element groups. The conditions compared are actually the aggregated (i.e. rolled up) weighted averages of the specified and assessed conditions of the individual elements within each element group. The comparison is represented through a series easy to read symbols (ticks and crosses) with descriptions ranging from 'well exceeds specified condition' to 'substantially below specified condition'. The third graph indicates the spread over time of the financial demand of recommended planned tasks. The fourth graph (pie chart) shows the distribution of recommended maintenance costs over the next three years. Each segment of the graph represents the portion of the planned maintenance costs attributable to specific building groups.

The building elements groups used for the maintenance assessment for all the above buildings include:

- Air Conditioning
- Building Structure
- Communications and data
- External finishes
- Electrical Services
- External Structures
- Fixed Equipment
- Fire Protection System
- Furniture and Fittings
- Gases
- Hydraulic Services
- Internal Building Fabric
- Internal Finishes
- Loose Equipment
- Refrigeration and Environmental Control
- Security and Safety Systems
- Site improvements
- Transportation
- Mechanical Ventilation

However the MAR technique does not address some of the issues in relational to residual life and sustainability and risks associated with refurbishment projects.

Some of the issues that have not been addressed by the above tools and have been identified as being for important for retrofit projects by previous researchers are discussed next.

3.6 Demolition waste

One of the elements identified as challenging for preparing estimates for retrofit projects identified in the ECI (2003) workshop on 'The Engineering and Management of Retrofit Projects' was refurbishment waste removal or recycling. Demolition waste is increasingly being seen as a valuable source of engineering materials in the UK (Lawson, 2001). The government of New South Wales, Australia is also proposing waste management reforms that prioritise waste management options into 1. avoiding waste, 2. re-using waste, 3. re-cycling waste and disposing waste. (Faniran, 1998). For refurbishment projects the last three options are more likely to be considered for developing an estimate on managing waste.

Lawson et al (2001) identifies that waste materials from new construction are usually clean and relatively uncontaminated whereas demolition waste materials are often dirty or contaminated and are mixed with other materials. These create specific challenges for waste reduction and involve risk assessment, remedial measures and risk management. This includes: hazard estimation, hazard assessment, risk evaluation and risk estimation.

In order to have a robust tool for making decisions on a retrofit project it would be useful to integrate these criteria with other issues identified above e.g. the information on material degradation and functional obsolescence on building elements may be helpful for developing the costs associated with retrofit waste management and recycling.

3.7 Sustainable building structures

The decision making on material deterioration identified in the above tools may enable the decision makers to utilise the most efficient structural strengthening scheme using FRP composites. Current annual expenditure on structural maintenance is around two billion dollars in Australia. Overseas experience has shown that by using advanced composites, the cost of structural strengthening can be reduced by 17% (Thomas at al, 1996). Some of the benefits on using composites in structural retrofitting identified in the literature are:

- High chemical resistance to acids and bases
- Reduction in corrosion related problems

- No increase in the dead weight of the structure
- Ease of handling
- Little interruption in the use of the structure

The estimating of residual life and estimation of construction costs will have some measures of commonality with structure strengthening techniques. The matrix in table 1 summarises all the above discussed methodologies and tools.

Table 1: Matrix of assessment criteria and methodologies used for building retrofits

No	System/ Tool	Authors	Methodology	Residual life criteria		
				Building element degradation including residual life	Functional Obsolescence of building	FRP structure strengthening
1	EPIQR	(Flourentzos et al, 2000)	Decision tool using a degradation coding system for residential buildings	✓		
2	MEDIC	(Flourentzou et al, 2000)	Residual life assessment of building elements using a probability distribution	✓		
3	TOBUS	(Cavacalli et al, 2002)	Decision tool using a deterioration coding system for office buildings	✓	✓	
4	Hotel Buildings Tool	(Balaras et al, 2004)	Decision tool using a deterioration coding system for hotels	✓	✓	
5	Refurbish or Replace - Context report	(CAR, 2000)	Report to identify criteria for making decisions on refurbishment	✓		

6	Office Scorer	(BRE, 2002)	Compares refurbishment with re-development	✓		
7	FEDS	FEDS website	Determines the optimum set of cost-effective retrofits			
8	MAR	(Qbuild, 2003)	Technical assessment of building maintenance	✓		
9	Minimising waste	(Faniran, 1998)				
10	FRP composites	(Thomas, 1996)				✓
11	Recycling & demolition waste model	(Lawson, 2001)				

No	Sustainability				
	Indoor environmental quality	Energy consumption	Electromechanical installations (Additional modules for energy consumption and other assessment)	Solar system and desalination installations (Additional modules for energy consumption and other assessment	Waste recycling and management
1	✓	✓			
2					
3	✓	✓	✓		
4	✓	✓	✓	✓	
5		✓			
6		✓	✓		
7		✓			
8					
9					✓
10					
11					✓

The main objective of doing the background research up till now has been to identify the criteria that previous projects have used to make decisions on building refurbishment. These and other measures can help in preparing a reasonable investment budget in the early stages of a refurbishment project. However to be able to make a holistic decision on the delivery of a refurbishment of a building project a back ground research on of construction management primarily project risks associate with a retrofit project is discussed next.

4.0 Risk Assessment of key project risks

As identified in the ECI (2003) workshop on retrofit projects the elements that need to be considered to in estimating and budgeting for retrofit projects are:

- Identify what exists on site and what condition is it in. Are there any modifications required, status of existing control and other equipment. These have been covered in detail in the form of residual life of elements, functional obsolescence, energy performance and indoor air quality.
- Dismantling, removal and recycling have also been discussed above.
- Total risk assessment – check original scope definition, assesses risks and decide how to deal with cost implications. The past and present research on risk assessment etc. is discussed next.

Refurbishment projects potentially contain more technical and economic uncertainties and risks than new build schemes, reflecting the nature of works within, and the increasing demands placed upon existing property (Reyers, 2001). To deal with this the most important issue with retrofit projects is risk management which is a set of methods and activities designed to reduce the disturbances occurring during project delivery (Skorupka, 2003). The aim of the risk management is to achieve project objectives that may include delivery within schedule and budget and in line with all quantitative and qualitative standards.

Gray (1999) pin points that the risk management system includes the following consecutive phases:

- Identifying risk,
- analysing and
- assessing risk and responding to risk.

Identifying risk begins by making a list of all the area that might cause the retrofit projects to delay or fail and their respective outcomes. The entire management team participates in this task and brainstorming can be used to ensure all aspects of the risks are covered.

Assessing and analysing risk

The next step of risk assessment selects potential foreseen risk events that need attention because they exhibit a high probability of occurrence and have consequence of loss (Gray, 1999). Risk analysis starts with a matrix that summarises the chances, severity and the time the event is likely to occur. The matrix also identifies whether the project team would be able to detect that the event was going to occur in time to take mitigation action. A number of techniques have been used to identify and assess the impact of a risk event, a few of the most recognised techniques are Scenario Analysis, Ratio/ Range Analysis, Hybrid Analysis, Probability Analysis and Sensitivity Analysis. The risk assessment methodologies for retrofit projects are the same as for the other projects except that it is essential to recognise the additional risks associated with refurbishment projects (Cox, 2004).

Responding to risk:

When a risk is identified and assessed, a decision must be made concerning which response is appropriate for the specific event. Responses to risk can be classified as:

- Avoiding risk: pre-emptive action is required, including if necessary changes to the project plan or implementation strategy.
- Mitigate risk: reduce risk by limiting the exposure to them.
- Distribute risk: Transfer the risk to the party most capable to quantify and manage it.
- Absorb risk: strengthen your position so you can cope with the shock associated with some events.

Some of the risks identified by Cox (2004) that are specific to retrofit projects are:

- Resources with required specific knowledge are not available when needed to carry out feasibility and development phase work
- Documented information relating to existing services is not available.
- Risks associated with the use of unproven technology.
- Availability of construction
- resources for fixed date works.
- Construction productivity is less than budgeted.
- Issuing of permits to work may cause significant delay to construction works.

Other project risks identified by Reyers et al (2001) are:

- Health and Safety: an increased use of temporary works such as scaffolding, shoring systems and safety issues that would be expected in new build.
- Design constraints: there are often unique combinations of alternative design solutions and varying levels of specifications coupled with restricted component and material choice have different risk implication (Raftrety, 1994).
- Decanting and existing occupants of the building.
- Schedule risks identified at ECI (2003) workshop are
    - Realistic shutdown and schedule planning. The resources involved to manage this.
    - Understanding the business drivers.
    - Building contingency into shutdown.
    - Delivery of equipment.
    - Other projects and their influences on strategy.
    - Operational constraints.
    - Allowing for accidents.
    - Adverse weather/timing.
- Cost risks (Gray, 1999) are:
    - Time cost dependency link
    - Cash flow decisions
    - Final cost forecasts
    - Price protection risks
- Adequacy of Definition – Risks are:
    - In-valid estimate/budget.
    - Impact assessment.
    - Adequacy of utilities.
    - Infrastructure required to support the project and its resources.
- Key Project Risks (Cox 2004) are:

- Unknowns/emergent work.
- Resources.
- Scope changes.
- Operating environment.
- Quality of information supplied.
- Plant condition.
- Material availability.
- Compatibility of materials.
- Adequacy of definition.
- Support from original equipment manufacturers.
- External influences.

A contingency plan is an alternative plan that will be used if a possible foreseen risk event becomes a reality. The contingency plan is used to mitigate the adverse impact of a risk event. Reyers (2001) identifies that contingency allocation for retrofit projects tended to be 70-80 percent higher than new built. In a study conducted by Reyers (2001) the provisional sums were reported to make 8-12 percent of the project cost for retrofit projects. This was up to 50% for higher than a new build project. There is reluctance to provide the project with a large contingency fund but failure to do so may end up in a situation where additional funding needs to be acquired.
Due to above list of significant uncertainty and risks it may be prudent to allocate specific contingencies to each element in addition to the provision of general contingency. These elements can be those aspects of the project where there is a perceived high degree of cost uncertainty. These may be a high as a percentage of the base cost but reduce the overall project contingency. These however need to be assessed as part of the risk assessment. As the estimate of the retrofit project is likely to have some additional cost vulnerabilities then effective cost control is even more important than new build.

Cox (2004) identifies that has potentially all the above features which make accurate estimation a challenge and makes it highly unlikely that the available quality will be better than 90% probability of being within plus/minus 20%.

5.0 The choice of right procurement method

A report published by CIRIA (2004) on refurbishing buildings identifies that the procurement method determines how much an input the client and members of the construction team have at different phases, who has the overall responsibility and who carries the major risk. There are two important considerations first project planning to minimise the disruption for existing occupants and secondly cooperative site operation between the project team and occupants. Hence when choosing a procurement method let it be traditional or DNC these two considerations should be taken into account. The existing value alignment tool outcome is also aimed at selecting the most appropriate project delivery approach.

6.0 Effective use of design and management contractors

Cox (2004) makes the following recommendation for efficient development and implementation of projects, in terms of effective use of design and management contractors:

- Agree and define the roles and responsibilities between the contractor and the client.
- Examine competency levels – use historical experience.
- Look at the availability of the resource – can we get the right people at the right time?
- Transfer the experience and learning from other retrofit projects.
- Ensure that access can be gained to experienced retrofit project people and organisations.
- Consider constructability during the early stages, i.e. once the contract has been selected.
- Ensure that an appropriate contract, procurement and execution strategy is in place.
- The selection of the appropriate contractor. They must fit the size and complexity of the project.
- Undertake pre-qualification procedures – look at experience, track record, competencies, and key personnel.
- Make use of joint ventures – share the gain/pain.
- Look at the compatibility of the client and contractor culture – ensure that the "soft issues" are considered.
- Is access to senior management possible?
- Ensure the early involvement of the contractor.

7.0 Methodology

8.1 Introduction

The literature review identifies a number of tools and criterion's being used by them when making decisions on refurbishment rather than building from grassroots. The most commonly addressed issues shown in table 1.1 are residual life of building elements and objects including deterioration / degradation, functional obsolescence and Structural strengthening techniques, building sustainability including Indoor Environment Quality (IEQ), energy saving, and waste management and recycling, analysing & managing risks associated with refurbishment projects including the selection of right procurement methods. In the quest to have a robust tool previous researchers employed various methodologies ranging from developing a coding system to identify building degradation and comparing existing energy bills to best practice to identify the energy saving and using structured questionnaire targeted at building occupants to identify issues with indoor air quality and using un structured interviews to identify risk issues associated with retrofit projects. However most of these tools only address individual issues and in some cases lack a scientific and holistic approach to decision making on retrofit projects.

The aim of the Re-life project is to incorporate all these issues into one holistic tool and provide a structured scheme instead of collecting haphazard in formation on retrofit projects.

Based on the literature review findings the proposed methodology for the development and validation of the tool is discussed next.

8.2 Development of the tool

Based on the literature review the proposed methodology for the criteria's identified in the literature is as follows:

Construction Management:
Most of the tools identified in section 1 to 3 do not address the issues related with the construction management and project delivery of a refurbishment project. However a

review of literature from UK, USA, and Australia as summarised in section 4 identifies that issues such as risk management and procurement method selection are absolutely paramount for project delivery especially refurbishment projects where there are more technical and economic uncertainties than new build.

To incorporate risk as part of the tool a risk management model is proposed.

- The first step involves identifying all the risks associated with retrofit project. The rational behind addressing some of the risks identified in the past is provided by the in depth literature review. However the next step is to validate these issues by conforming their importance and relevance. This is where an established research method like 'Delphi Technique' that has been rigorously analysed over the years for its application is used.
- The second step is to analyse and assesses risks using quantitative or semi quantitative analysis.
- The third step is to develop a framework to identify the appropriate to respond to a certain event.
- The final step is to develop the appropriate contingency plan that correctly represents preventive actions that will reduce or mitigate the negative effect of risks.

Procurement method

- Use and extend value alignment tool to assess this criteria.

Effective use of project team

- Identify roles and responsibilities at an earlier stage
- Involve teams from an earlier stage.

Residual life:

- Identify the building elements and objects of an existing building using the pilot case studies.
- develop a degradation code for these based on their existing condition e.g. 'a' = good condition to'd' = repair required. The knowledge base may be summarised in the form of probability curves for each element. The remaining life span can then be calculated as a probability distribution.
- Develop corresponding set of 'actions' or intervention codes may be proposed and the cost associated with each action can be used to produce the cost estimate required for refurbishment. Similarly costs may be linked with the actions required to deal with functional obsolescence. The structure

strengthening techniques like FRP may be one of the possible actions required for upgrading, repairing or maintenance of reinforced concrete, timber, masonry and stonework elements. Thus these can be linked to the residual life assessment of these elements. This process can be performed by using a case study and using it as a pilot to identify elements, objects, degradation and the actions required to deal with the degradation. Sketches or photographs of these elements can be used to populate a database that may be required when the tool is used for decision making.

- Identify any overlaps with other issues.

Sustainability:

Energy saving:

- Investigate energy bills of the pilot case study showing the current state of the building energy consumption can be compared to the best practices in the area to find the saving potential.
- Carry out energy balance calculations and identify actions for energy saving retrofit measures and the cost associated with these actions.

Indoor Air Quality

- Develop a questionnaire for the case study occupants with questions on the indoor air quality and apartment facility quality.
- Analyse the complaints of the occupants and
- Identify possible actions and the associated costs with these actions e.g. if the occupants complaint of rusty water a possible action may be the replacement of hot water distribution system.
- Identify any overlaps with other issues.

A radar graph may be used to summarise the degradation state and link it to different actions to identify the most cost effective scenarios.

Waste Management and Recycling:

- To develop appropriate ratio indicators of eco efficiency using the data from the case studies and
- Look at sustainable management of demolition waste from the environmental, social and economic point of view.

- Identify any overlaps with other issues.

Most of the tools identified in the literature that used for an overall decision making on refurbishment projects have not addressed the issue of waste management and recycling. However there has been a lot of work on developing assessment tools only for waste management. The challenge for the re-life project is to integrate this issue with the other issues to come up with a holistic decision making tool.

It is important to address any other issues that the industry partners think are important and need to be included in to the tool. It is also important that inter linkages or information overlaps between the different criteria are identified as part of the development of the tool.

8.3 Validation of the tool

The next step is to validate and refine the complete tool using the same (that were used during the tool development) or different case studies. The data collected can be used to check the robustness of the tool and to validate the linkages that have been developed at the development stage.

Risk Management

As discussed the risks identified during the development stage are validating using Delphi Technique. A panel of experts including the industry partners involved with the re-life project are selected. A few rounds of questions are then conducted in which the expert panel is asked to rate the relevance/non relevance of the risks identified from the literature and also add new ones based on the pilot case study existing conditions. The model reliability and sensitivity can then be tested for suitability and validity using concordance coefficients and sensitivity analysis. The case studies data may also be used to validate the other steps in the risk assessment model. Similarly the procurement methods selection may be validated by using and extending the value alignment tool.

Residual life and sustainability

The tool developed for residual life and sustainability assessment may be validated using the data from the pilot case studies or new case studies.

8.4 Conclusions

A world wide literature review of work on building retrofits was undertaken for this project. The issues identified included residual life, energy saving, indoor air quality, waste management, floor space optimisation, risk assessment, choice of procurement method. Most of the tools in place through out the world only address some of these issues and there is an urgent need to develop a more integrated, robust and holistic tool.

The ultimate aim of this research is to develop a tool that can assist client's in the decision making process of investing in retrofit projects, especially when the investment budget is limited. The tool will also be useful for contractors bidding for refurbishment projects as it will address construction management issues including risk assessment, project procurement etc. and help reduce the uncertainty associated with refurbishment projects.

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