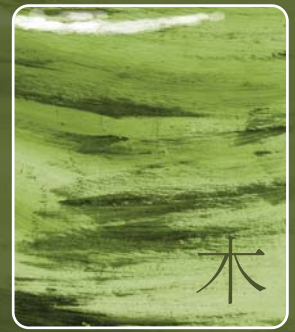


2 section two

An Intelligent Rule-Based System for Whole-Life Cost and Sustainable Building Decisions

- Adopting the CP 80 : 1999 Standard



The Singapore Government has launched a Green Building Master Plan in 2006 to encourage more building owners and developers to own and develop more environmentally-friendly buildings. From April 2007, all new public-sector buildings and those undergoing major retrofitting works will have to be environmentally-friendly. In view of the industry trend, the research aims to develop a rule-based system that contains decision-support rules pertaining to the assessment of (whole-life) cost implications of new building projects having to meet the criteria of the BCA Green Mark Scheme. The system adopts the building elemental classification of the Singapore Standard Code of Practice No. 80 (i.e. SS CP 80 : 1999) as a framework to structure the mapping of the rules to be extracted from the BCA Green Mark Assessment Criteria onto a set of cost and risk factors. The proposed intelligent rule-based system will serve as a support tool for clients of the construction industry in the public and private sectors in making capital investment and operation decisions.

Goh Bee Hua

Senior Lecturer, Department of Building
National University of Singapore
Member, Construction Industry IT Standards Committee

1 Introduction

The Singapore Economic Review Committee, set up in December 2001, had envisioned to remake Singapore through "new challenges and fresh goals", with the aim of transforming her into a dynamic global city [1]. Among the goals set for the construction industry to upgrade capability, a new possibility was identified for its domestic enterprises to develop niches in eco-efficient design, environmental technologies, and green products and services. These areas come under Singapore's Green Plan 2012, which is a blueprint for achieving environmental sustainability. In view of the strategic plans, the signal was clear that in order for Singapore to achieve and maintain its position as a global city, the construction industry must among its other goals be able to produce and offer quality and environmentally-friendly buildings to illustrate sustainable development.

Responding to the calls for the construction industry to build up expertise in environmental and ecological technology, the Building and Construction Authority (BCA) had developed the Green Mark scheme as a strategic programme to encourage property developers, building owners, designers and contractors in Singapore to adopt "green building" practices. The scheme was launched in January 2005 and it would apply to new and completed buildings. In 2006, the Green Building Master Plan was launched to encourage more building owners and developers to own and develop more environmentally-friendly buildings. From April 2007, all new public-sector buildings and those undergoing major retrofitting works would have to be environmentally-friendly.

2 The BCA Green Mark Scheme

Broadly intended, the scheme was developed to promote sustainable development by raising environmental awareness among all participants in the construction industry, particularly, property developers, designers and contractors. In essence, it is a green building rating system used to evaluate a building, new or completed, for its environmental impact and performance. In each case, the assessment is based on five key criteria looking at levels of energy efficiency, water efficiency, site or project development and management (for new buildings) or building management and operation (for existing buildings), good indoor environmental quality and environmental protection, and environmental innovation. A point scoring system is used to quantify and ascertain the extent of environmental friendliness of the new or existing building. Details about the assessment criteria and points allocation can be found on BCA's website [2].

3 The Whole-Life Cost Concept

The whole-life cost of an asset is defined by Addis and Talbot [3] as "the present value of the total cost of that asset over its operational life. This includes initial capital cost, finance costs, operational costs, maintenance costs and the eventual disposal costs of the asset at the end of its life. All future costs and benefits are reduced to present-day values by the use of discounting techniques". In essence, the main components of whole-life costs are shown in Figure 1.

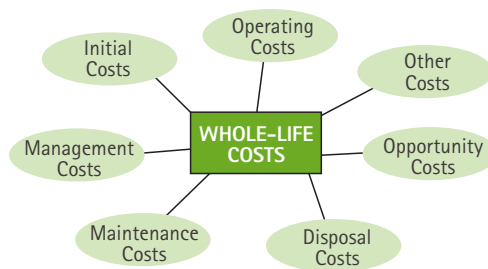


Figure 1: Components of whole-life costs of an asset [3]

The application of the whole-life cost concept within the construction industry is rapidly increasing and more recent studies have involved examining the importance of improving the data collection process during the design stage, developing enhanced models to aid in capital investment decision-making, as well as re-engineering the life-cycle costing process to encourage use [4] [5] [6]. Kirkham [6] remarks that the industry's acknowledgement of benefits that whole-life costing based decisions can bring to the design and operation of building assets marks a definitive shift which underlines the commitment to clients that industry stakeholders have to be delivering products that demonstrate value for money over the long term. He notes that perhaps it is indicative of the wider desire of the industry to aim for sustainable design and construction.

4 Singapore's Code of Practice for Classification of Construction Cost Information (SS CP80 : 1999) [7]

The SS CP80 : 1999 was developed to serve the key purpose of allowing the exchange of data and information to enable communication of design, construction and contractual matters relating to cost via a uniform classification format. The development of the national standard in 1999 involved a review of international standards and an adaptation of a few international standards to suit local use. The main components of the national standard are:

- i) an elemental classification;
- ii) a work-section classification;
- iii) a mapping dictionary for elements and work sections; and
- iv) a set of guidance notes.

Users of this standard are property developers, architects, mechanical and electrical engineers, civil and structural engineers, quantity surveyors and contractors. The long-term benefits for users include efficient information exchange between different parties, reduction in duplication of work between the different disciplines, increased familiarity with a uniform standard leading to an overall increase in productivity for the company as well as the industry.

5 Intelligent Rule-Based System Development

5.1 Aim and Purpose of the System

The proposed rule-based system contains decision-support rules relating to the assessment of (whole-life) cost implications of the development of environmentally-friendly buildings. The system is primarily based on a two-fold purpose that it intends to serve and, they are:

- i) to aid in the general understanding of value (versus cost) in relation to the design, construction and operation of buildings; and
- ii) to serve as a support tool for clients of the construction industry in the public and private sectors in making capital investment and operation decisions (e.g. budgeting and design).

5.2 Mapping Framework

The proposed system adopts the elemental classification of the SS CP 80 : 1999 as the framework to design the rule-based system. The rules will be mainly derived from the assessment criteria of the BCA Green Mark scheme. As an illustration, a partial framework to be used to guide the development of the system is shown in Table 1.

5.3 Fuzzy Inference System

A proposed fuzzy inference system implementing a real-valued function $f(\cdot)$ of n input variables has the following form [8]:

\rightarrow *fuzzifier* \rightarrow *fuzzy inference* \rightarrow *defuzzifier* \rightarrow
knowledge base (fuzzy rules & membership functions)

Here $\mathbf{x} = [x_1, x_2, \dots, x_n]$ is a (crisp) multivariate input vector and y is a (crisp) univariate output. The knowledge base contains fuzzy rules encoding a priori knowledge about the function $f(\cdot)$.

| SOME GROUP ELEMENTS AND ELEMENTS (SS CP 80 : 1999) | WHOLE LIFE COST IMPLICATIONS | RELEVANCE TO 'GREEN MARK' ASSESSMENT |
|---|---|--|
| SITE PREPARATION: - Demolition - Site clearance - Earthworks - Soil investigation | Minimal. | Moderately relevant to 'Site and Project Management'. |
| SUBSTRUCTURE: - Piling - Foundation - Basement - Ground Slab | Yes, in order to select the most cost efficient structural design. | Minimal. |
| SUPERSTRUCTURE: - Columns and structural walls - Upper floors - Roof - Staircases - External walls and cladding - Internal walls and partitions - Doors | Yes, mainly for the roof, external walls, internal walls and doors. | Yes, mainly for the roof system, external walls and cladding. |
| SERVICES INSTALLATIONS: - ACMV - Sanitary and plumbing - Electrical installations - Transportation - Communications installations - Security systems - Fire protection systems - Gas installations - Maintenance equipment - Pool and water feature installations - Special installations | Yes, operating, management and maintenance costs considerations. | Yes, for systems that require 'Design for Energy Efficiency', 'Design for Water Efficiency', and 'Indoor Environmental Quality'. |

Table 1: A proposed mapping framework to design the rule-based system

5.4 Occurrence Likelihood

A set of standard terms for quantifying likelihood has the following description [9]:

| <u>Likelihood</u> | <u>Description</u> |
|-------------------|---|
| Very very high | Expected to occur with absolute certainty |
| Very high | Expected to occur |
| High | Very likely to occur |
| Medium | Likely to occur |
| Low | Unlikely to occur |
| Very low | Very unlikely to occur |
| Very very low | Almost no possibility of occurring |

The assessment of the likelihood of occurrence can be complex as it is highly subjective and the decisions taken are influenced by a management's view of the future based on knowledge from past experience.

5.5 Rules Development

The rule-based system will be developed using the ILOG *JRules* software. This software is able to manage rules throughout their life cycle, that is, from creation through testing, deployment and retirement to allow for greater flexibility to rules developers and managers, especially in the rapidly changing business environment.

The generic if-then structure of a rule is illustrated for the building envelope design as shown in Figure 2. It involves applying a set of pre-established vocabulary (see the underlined words) to define the rule's conditions and actions, as well as present the rule in a readable language.

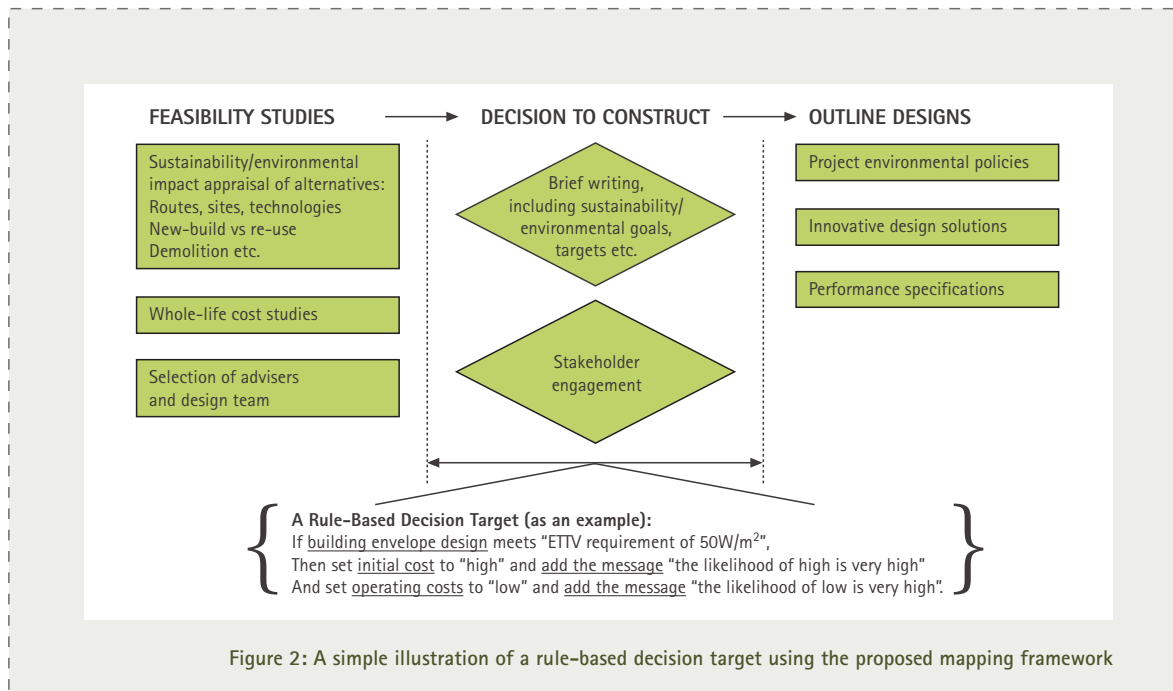


Figure 2: A simple illustration of a rule-based decision target using the proposed mapping framework

6 Testing the Developed Rules

The different sets of rules developed for the main elements of a building will be verified against the process or product used in those buildings that have been awarded the Green Mark. Essentially, such Green Mark buildings would have adopted energy efficient features, water conservation measures, made substantial use of greenery in their projects and ensured a good indoor environmental quality for their users, setting them apart from other buildings. Therefore, the rules will be adjusted or modified according to the best practices adopted for the Green Mark buildings.

7 Conclusion

In the global marketplace, it is highly crucial that businesses know the importance of managing knowledge in order to sustain their competitive advantage. With the use of information technology, various information systems can be set up and integrated with knowledge gathering and analysing tools for data analysis and dynamic end-user querying. Essentially, enterprises must gain in-depth analytical capabilities needed through the creation and adoption of knowledge management tools especially those that can offer intelligent business solutions to aid them in making better strategic decisions.

Hence, to begin with, it will not be difficult to anticipate that most developers of buildings can be very concerned about cost and risk issues when they are deciding on critical features or measures which can promote energy savings, water savings, healthier indoor environments and greenery for their projects. And, the proposed intelligent rule-based platform can serve as a means to contain and manage key knowledge, in terms of decision rules, relevant to the area of sustainable design and construction in order for building developers to attain long-term cost and image benefits for the business.

8 References

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