COBRA2009

10th -11th September

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COBRA 2009

The Construction and Building Research Conference of the Royal Institution of Chartered Surveyors

Held at the University of Cape Town, 10-11 September 2009

ISBN 978-1-84219-519-2

12 Great George Street
London SW1P 3AD
United Kingdom

www.rics.org/cobra

September 2009

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The construction and building research conference of the Royal Institution of Chartered Surveyors held at the University of Cape Town, 10-11 September 2009

The RICS COBRA Conference is held annually. The aim of COBRA is to provide a platform for the dissemination of original research and new developments within the specific disciplines, sub-disciplines or field of study of:

Management of the construction process

- Cost and value management
- Building technology
- Legal aspects of construction and procurement
- Public private partnerships
- Health and safety
- Procurement
- Risk management
- Project management

The built asset

- Property investment theory and practice
- Indirect property investment
- Property market forecasting
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- Urban development
- Planning and property markets
- Financial analysis of the property market and property assets
- The dynamics of residential property markets
- Global comparative analysis of property markets
- Building occupation
- Sustainability and real estate
- Sustainability and environmental law
- Building performance

The property industry

- Information technology
- Innovation in education and training
- Human and organisational aspects of the industry
- Alternative dispute resolution and conflict management
- Professional education and training

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The Organising Committee for the RICS COBRA 2009 Conference consisted of:

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Keith Cattell	University of Cape Town
Kathy Michell	University of Cape Town
Stephen Brown	RICS

The doctoral students' session was arranged and conducted by:

Monty Sutrisna	University of salford, UK
Les Ruddock	University of Salford, UK

The CIB W113 Law and dispute resolution session was aranged and conducted by Paul Chynoweth of the Univeristy of Salford, UK

Peer review process

All papers submitted to COBRA were subjected to a double-blind (peer review) refereeing process. Referees were drawn from an expert panel, representing respected academics from the construction and building research community. The conference organisers wish to extend their appreciation to the following members of the panel for their work, which is invaluable to the success of COBRA.

Rifat Akbiyikli	Sakarya University, Turkey
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In addition to this, the following specialist panel of peer-review experts assessed papers for the COBRA session arranged by CIB W113, Law and dispute resolution:

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A knowledge-based decision support system for roofing materials selection

Sazzadur Rahman[1*], Srinath Perera[2], Henry Odeyinka[1] and Yaxin Bi[3]

[1] School of Built Environment,

[3]School of Computing and Mathematics

University of Ulster, Shore Road, BT370QB, United Kingdom

[1*]*Email: rahman-ms@email.ulster.ac.uk*

[2]School of Built Environment,

Northumbria University, Newcastle, NE18ST, United Kingdom

Abstract:
Varieties of materials are available for roof housing construction but selecting the appropriate material is a complex and ponderous task. In order to choose the right material, a multitude of performance criteria would need to be considered. This research aims to develop a knowledge-based decision support system for material selection (KDSMS) to facilitate the selection of optimal material for different sub elements of roof design. This model consists of a knowledge base and databases to store different types of roofing materials with their corresponding performance characteristics. Knowledge is elicited from domain experts and extensive literature review. The proposed system employs the use of TOPSIS (Technique of ranking Preferences by Similarity to the Ideal Solution) multiple criteria decision making method, to solve the materials selection and optimisation problem where initial cost, maintenance cost, thermal performance and sustainability criteria are considered among others. The proposed system is currently being developed for the housing sector in Northern Ireland. This paper presents and explains the framework of the proposed system.

Keywords: TOPSIS, knowledge-based system, decision support system, roofing material selection

1 Introduction

Different types of materials and technologies are available for roof design and construction while new materials and advanced technologies are continuously being introduced into the market (Wong and Li 2008). It is acknowledged that the selection of appropriate materials may reduce the energy consumption and maintenance cost of buildings (Papadopoulos and Giama 2007). It is documented that buildings are responsible for significant impact on the environment; hence eco-friendly materials are becoming popular (Hymers 2006). As the selection of materials is always a complex procedure, it is a problem to match materials based on design requirements (Ashby et al. 2004). Architects and other members of design team need to consider several factors in order to select the more suitable materials to meet clients' requirements. In order to solve this problem of material selection in a way that meets design and clients' requirements and results in sustainable construction, it is required to analyse and synthesise multitudes of criteria.

Different approaches regarding materials selection have been devised for different purposes. Moreover, knowledge-based or expert systems have been developed to select materials for different purposes. Mahmoud *et al*. (1996) explain a method for selection of finishing materials that covered floors, walls and ceilings. Mohamed and Celik (1998) propose a knowledge-based method regarding materials selection and cost estimating for a residential building where users could be able to choose their preferred one from a list of materials without evaluation and synthesis of multiple design criteria and client requirements. Instead of expert or knowledge-based systems, Perera and Fernando (2002) propose a cost modelling system for roofing material selection where several factors are identified and considered in the selection process. Soronis (1992) proposes a method for the selection of roofing materials where several factors have been taken into consideration to assess durability.

It is identified that very few approaches have been developed for roofing materials selection. This clearly indicates that there is a research gap with respect to selecting the appropriate roofing materials and technologies that analyse and synthesise multitude of design and client's requirements that are cost effective and sustainable. But the information overload may exacerbate this appropriate material and technology selection. Hence, this research aims to bridge the current knowledge gap by developing a Knowledge-based Decision support System for Material Selection (KDSMS) that helps to optimize the selection of roofing materials and technologies. This research identified and validated the performance criteria through an expert forum by conducting structured interview and extensive literature review. Material information has been collected from catalogues, technical booklets, price guide books and other literature. The architects, quantity surveyors and self builders are the potential users of this system. This system assists the users in selecting materials according to its importance of pre-defined criteria. This system also educates the users about new materials by providing relevant information. Although the proposed system facilitates cost estimating process, this paper only presents the material selection process.

2 Methodology

Extensive literature review and structured interviews for knowledge-elicitation have been carried out in this ongoing research to build a roofing material selection system. The following section explains the steps of the methodology in chronological order.

2.1 Knowledge Elicitation

Roof structure, roof coverings, roof lights, roof drainage and roof features sub elements have been considered based on BCIS definitions (BCIS 2008). The selection process has been conceptualized from domain experts by conducting a series of structured interviews. Performance criteria have been identified from literature and validated through domain experts. The performance criteria for roof insulation have been considered separately as it has a significant impact on internal comfort and energy consumption. Linguistic variables (very high, high, medium, low and very low) have been used for the importance weights of criteria (client requirements). Table 1 illustrates the identified criteria and it also shows which criterion is used for which roof sub element with performance mapping for each roof sub element related to materials selection.

Table 1: Criteria for selection of Roof sub elements

Performance criteria	RS	RC	RI	RL	RD	RF
Strength and stability	√			√	√	√
Fire resistance	√	√	√	√		
Life span	√	√	√	√	√	√
Maintenance cost	√	√	√	√	√	√
Initial cost	√	√	√	√	√	√
Life cycle cost	√	√	√	√	√	√
Sustainability	√	√	√			
Ease of installation	√	√	√	√		
Freedom from maintenance	√	√	√	√	√	√
Sound resistance		√	√	√		
Thermal performance		√	√	√		
Weather resistance		√		√	√	
Weight		√	√			
Security				√		
Thickness			√			

[RS= Roof structure, RC= Roof coverings, RI= Roof insulation
RL= Roof lights, RD= Roof drainage, RF= Roof features]

Four domain experts were chosen among architects and quantity surveyors from industry and academia. These Experts enabled the capture of the materials selection procedures that are used in practice.

2.2 Analysis of Criteria and Materials Information

The linguistic variables used for importance weights of criteria have been converted to positive numbers as Table 2.

Table 2: Linguistic variables for importance weights of each criterion

Linguistic variable	Values
Very High	0.30
High	0.25
Medium	0.20
Low	0.15
Very Low	0.10

Selection criteria of each roof sub element have been considered based on the importance weights given by the domain experts. It is a rigorous task to find the values of different performance characteristics because different sources can be considered to obtain these values. Per unit price rate of materials have been considered based on SPON price guide book. Other performance characteristics of similar materials based upon the identified criteria and the associated value of these characteristics have been collected from technical literature, catalogues, technical documents and manufacturers' websites. Sustainability rating has been considered according to BRE green guide (Anderson *et al.* 2009). As sustainability rating for all materials are not available in BRE green guide, the green building handbook (Woolley, et al. 1997) and hazardous building materials guide (Curwell, et al. 2002) have also been used for environmental and health & safety issues. But these sources provide different rating system for environmental and related issues. Thus, a common numerical value system, as shown in table 3, has been used to consider the various ratings and these converted values have been used against existing sustainability or environmental ratings to build a database of roofing materials.

Materials name, numerical values of performance characteristics and associated unit price rate have been collected from product catalogues and SPON price guide book. Moreover, numerical values of sustainability or environmental criteria have been considered by using the above table and documented in Microsoft Excel formats to build in to the database. The building regulations and other selection factors are identified and documented for production rules to control the selection of materials.

Table 3: Sustainability rating with associated numerical values

Source	Rating	Converted values
BRE Green Guide	A+	0.26
	A	0.22
	B	0.19
	C	0.15
	D	0.11
	E	0.07
Green Building Handbook	0	0.26
	1	0.19
	2	0.15
	3	0.11
	4	0.07
Hazardous Building Materials	0	0.26
	1	0.19
	2	0.11
	3	0.07

2.3 System Development

Data modelling was carried out using SELECT SSADM 4.1.2 software to model business processes, information flow and relationship among roof sub elements. The decision making process is illustrated in figure 1 below and it explains how the system processes the user input to perform an evaluation of materials in order to select the top ranked materials for each roof sub element.

The proposed knowledge-based decision support system for material selection (KDSMS) model is illustrated in figure 2 and its components are explained in the following sections.

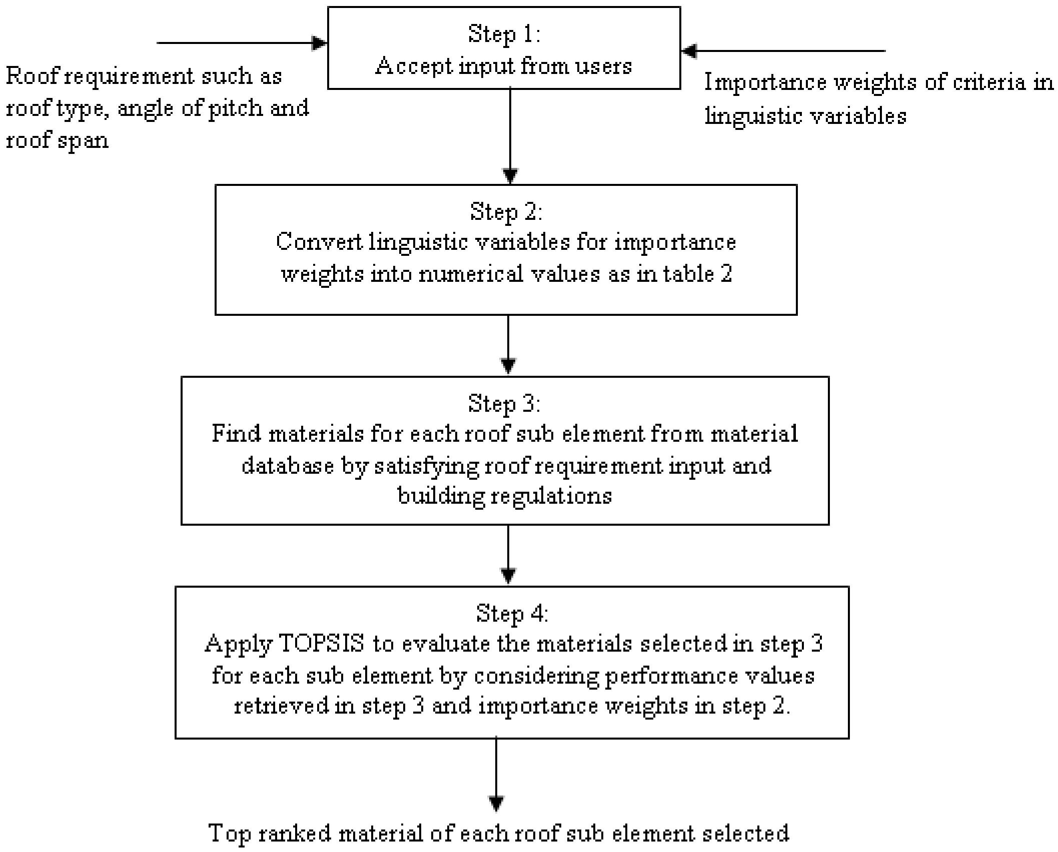

Figure 1: Decision making process of KDSMS

2.3.1 User

The potential users are the architects, designers, quantity surveyors and self builders. Expert forum comprises of the architects and quantity surveyors who have the required knowledge about building design requirements and selection of materials.

2.3.2 User Interface

It interacts with the users and processes. It accepts input from users, supplies it to the inference engine to validate and activates the processes to produce the output to the users. Oracle Form 10g has been used to develop the user interface.

2.3.3 Inference Engine

It queries the knowledge base and provides the information to users through the user interface. It also helps to narrow down the search space of the database. Oracle 10g database engine and Form 10g have been used to implement inference engine concept as illustrated in Figure 2.

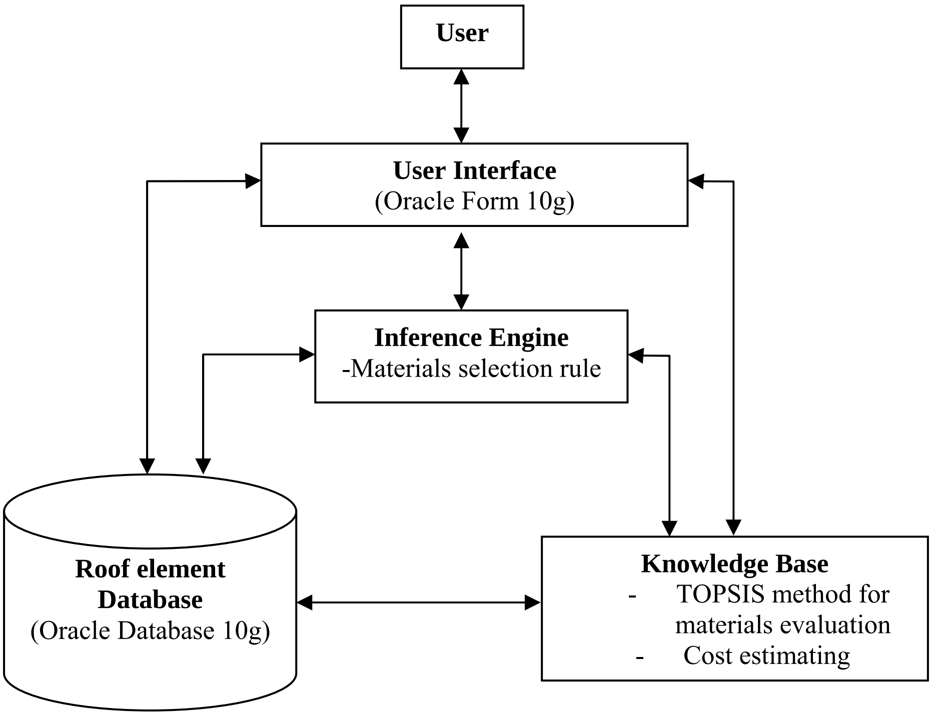

Figure 2: KDSMS model

2.3.4 Roof Element Database

The roof element database stores all information available about roofing materials of each roof sub element along with the values of performance characteristics that are considered to choose materials. Oracle 10g database has been adopted to build the database. Data has been collected from documented Microsoft Excel files.

2.3.5 Knowledge Base

This consists of the material selection and cost estimating processes. As selection of materials is associated with multiple criteria, TOPSIS has been incorporated to solve decision making problem (Rahman *et al.* 2008). It also contains building regulations and other selection factors that may influence the type of materials or technologies selected. It consists of a decision support shell that can facilitate reaching a decision in selection of the optimal material by using TOPSIS. Oracle database and Form 10g have been used to implement TOPSIS decision making mechanism. TOPSIS decision making mechanism needs complex analytical tasks. As Oracle supports complex analytical tasks, the system has adopted Oracle to implement decision making mechanism.

3 Analysis and Discussion

The screen shot of the KDSMS user input is illustrated in figure 3.

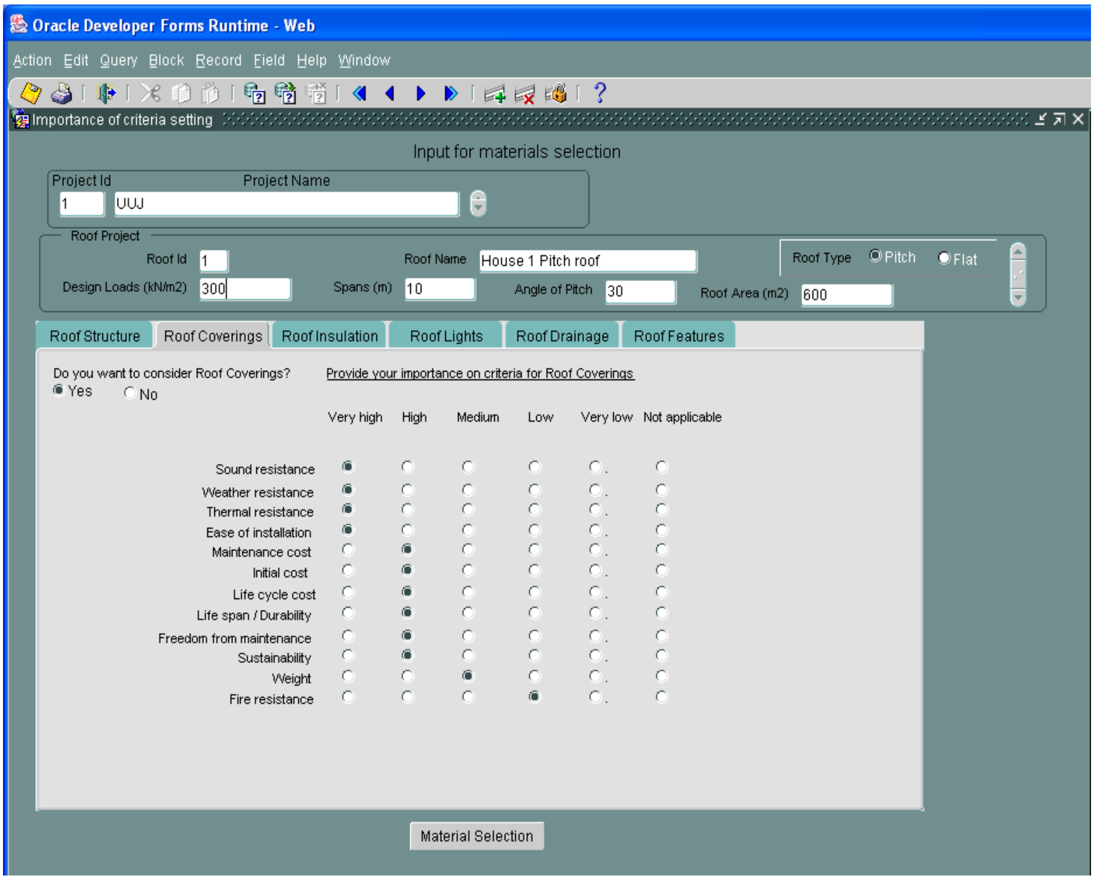

Figure 3: KDSMS user input

The users provide information such as roof area, roof type, angle of pitch, roof span, design loads and roof area as design specification and importance weights of criteria for each roof sub element as input. Since importance weights of criteria vary from user to user, the system prompts the user a set of default weights for the level of importance attached to the criteria to select the required materials. These can then be changed by the user as required. Linguistic variables are used for importance weights of criteria and user can choose importance of weight by using radio buttons. The user can choose all sub elements or individual sub element for materials selection. If the users do not wish to consider any of the roof sub element or other criteria, it can be ignored. The system will use default values in such instances. When the user selects 'Material Selection' option, the system retrieves materials information from roof element database by satisfying the user requirements. For example, if the user only considers selecting roof coverings materials, the system searches the roof element database based on angle of pitch and roof type and then performs TOPSIS multi criteria decision making operation. The system facilitates the users to maintain the database by adding or updating materials information.

As multiple criteria decision making technique can evaluate and synthesise multiple criteria simultaneously, it is an effective way to select optimal material in a knowledge-based system. An optimal material is quantified by its performance that is assessed by defined requirements. The appropriate material is one that is most favourable for the given requirements. The requirements are considered as selection criteria of materials. It needs to consider multiple criteria simultaneously to select the appropriate material. The proposed KDSMS model facilitates to consider multiple criteria and asses the performance of materials by ranking them. Hence, KDSMS provides an effective methodology for roofing materials selection.

4 Conclusion and Further Research

This paper presents a knowledge-based decision support system for roofing materials selection (KDSMS). Appropriate materials are always preferred not only for environmental reasons but also cost effectiveness, ease of maintenance and many other criteria. More sustainable materials contribute to the reduction of the carbon footprint and help the environment. This requires to simultaneously considering a multitude of criteria to select higher quality sustainable materials. New innovative materials and technologies are frequently introduced to the market, but may not be used due to lack of information and experience. Therefore, building designers are often confronted with the problem of information overload and pressures on innovative and sustainable design. This research hypothesised the use of a knowledge-based system to overcome this problem. If information related to materials along with the performance characteristics is stored in a knowledge-based system, it is possible to efficiently retrieve the details of appropriate materials and its performance when required. Several research projects have attempted to develop knowledge-based systems solutions to this problem but none have been successfully initiated in roofing materials selection within the house design domain. Furthermore, there is no evidence of the use of multi criteria decision making techniques to resolve this problem. This research fills this gap and proposes a knowledge-based model as the decision making tool. The KDSMS model and concept can be effectively expanded to cover all elements of a building facilitating the effective use of innovative and sustainable building materials and technologies.

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