Development of RP^{3}CA-EMP, a Knowledge-Based System for Applying Environmental Management Plan (EMP) in the Malaysian Construction Industry

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Abstract. The Environmental Management Plan (EMP) is a tool for preventing environmental pollution from a proposed construction project. EMP development requires specialized construction site data and information from multiple sources. Recently, knowledge-based system (KBS) has been used extensively in the environmental field, especially in cases where human expertise and data are limited. In this study, a KBS computer application was developed to guide the application of EMP for housing and new township development projects in Malaysia. This system, called River Pollution Prevention Plan during Construction Activity- Environmental Management Plan, or "RP^{3}CA-EMP" was developed in the Microsoft Visual Basic environment. RP^{3}CA-EMP predicts the impacts of housing and new township development projects on surface water and details necessary mitigation measures. Additionally, RP^{3}CA-EMP is an educational tool for individual developing EMP for housing and new township development projects.

Keywords: Water Resources Protection, Construction Industry, Knowledge-Based System, Microsoft Visual Basic.

1 Introduction

The rapid urbanization occurring in most developing countries presents major environmental problems due to city expansion, conurbation development, and population growth. The problems that are typically associated with such large urban centres are expected to appear in developing countries [1, 4]. In most major cities in Asia , Africa, and Latin America, a significant proportion of the population lives in shelters and neighbourhoods lacking both adequate access to clean water and system for the safe disposal of solid and liquid wastes [9, 14]. Although water is a critical natural

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resource that plays a vital role in national progress and development [2], surface water quality may be adversely affected by construction activities [13] such as trenching, surface preparation, demolition, pouring concrete, and material and waste management [8]. Construction projects also require managing labour and materials, preparing the land and foundation, installing mechanical and electrical systems and appliances, erecting and enclosing the walls and roof, applying interior and exterior finishes and trimming [10, 16]. Typical pollutants resulting from these activities include displaced soil, sediment, debris, wood products, concrete slurry, hazardous materials, and recyclable materials [8].

Urban development is particularly rapid in Malaysia and has caused adverse environmental effects. Specifically, construction sites, especially those that have been cleared of vegetation but have not yet been developed, frequently lose excessive amount of soil. In some cases, this has caused deterioration of water courses [5, 6]. In Malaysia, the high mean annual rainfall and frequent intense storm make water erosion the most significant cause of soil loss, and the rate of this erosion increases when vegetation disturbed or removed [21]. Malaysia experiences more intense and frequent rainstorms than most developed countries and therefore requires more stringent control measures with both structural and non-structural components [6].

Environmental study is a time-consuming process that requires special tools or support systems because a wealth of dependent and independent variables must be considered. Various computer-assisted systems can help to meet the challenges of collecting, processing, analyzing and reporting this complex environmental information [15, 19]. Knowledge-based systems or expert systems have been used for environmental planning, impact assessment, regional environmental impact analysis, environmental assessment, and environmental management since the 1980s. These systems provide advice and support for decision makers based on a database of expert knowledge in combination with heuristic (rule of thumb) reasoning, [3, 19]. Expert systems are promising technologies for enhancing data, and information management, and access to specialized expertise. Therefore, they appear to be well suited for many of the tasks associated with environmental management study. In this application, they could provide structured approach to environmental studies and help users cope with large volumes of environmental management studies [12, 19].

In this study, a KBS called the River Pollution Prevention Plan during Construction Activities (RP^{3}CA) was developed with a particular emphasis on housing and new township development projects in Malaysia. RP^{3}CA has three sub-systems: Environmental Management Plan (EMP), River Water Quality Monitoring (RWQM), and Construction Site Inspection (CSI). The EMP described in this paper has the capacity to advise the end-users regarding Environmental Management Plan for the construction industry, especially related to housing and new township development projects in Malaysia.

2 Methodology

RP^{3}CA-EMP was developed according to standard KBS development methods. The KBS design and development process is guided by a five-step process: task analysis, knowledge acquisition, system development, expansion and refinement, and verification and validation [11, 7, 20, 22].

2.1 Knowledge Acquisition

The Best Management Practices (BMPs) identified in this study were drawn from multiple sources of expertise in the field of construction engineering in order to minimize river pollution during construction activities. Pre-requisite basic knowledge was acquired from textbooks and manuals and served as the basis for the development of the initial prototype modules [1]. Journal publications and conference proceedings were used as recent and more specialized data sources within the domain. Current research publications facilitated a more practical approach to various environmental concerns, including technological considerations, legislative enforcement, and finances aspects [1]. Experts in the field were contacted directly to obtain additional information. This interaction consisted of a series of systematic consultations, over a period of a few months. According to Yialouris [24], two meetings were organized with three experts to elicit opinions about developing an integrated expert geographical information system for soil suitability and soil evaluation. In this study, three meetings were organized with ten experts to discuss construction management, soil erosion, sedimentation, environmental management, and BMPs. After the third meeting, the experts were asked to provide their recommendations on the following topics:

- The construction stages and activities that should be considered during the development of the KBS,
- The properties of construction sites that are most important for preventing river pollution,
- BMPs that should be considered for construction sites, and
- BMPs and construction sites that should be inspected.

Expert responses to these questions are summarized in Table 1, 2, and 3.

Table 1. Recommended stages of construction activity

Construction stages	Substage
Site construction facilitie	Access road and stream crossing, Temporary building, Site utility
Site clearance	Demolition, Site clearance
Site formation	Earth work, Import and export of fill, Drainage work, Road development
Infrastructural work	Operation of heavy equipment, Construction of building and utility

Table 2. Recommended construction site characteristics for pollution prevention

Construction site information	
Season condition	Dry, rainy
Slope of streambed for entrance the site	< 1:3, ≥ 1:3
Flow condition of site upslope	Concentrate, Non-concentrate
Drainage area	< 0.4 , 0.4-2, 2-4, > 4 ha
Soil type	C, D, F, More than one type
Waste type	Steel, Aluminium, Gypsum plasterboard, timber, concrete, bricks and tiles, plastic, glass, carpet
Flow condition at site	Sheet, rill, gully, channel
Duration for soil stabilization	< 3, 3-12, ≥ 12 months
Slope range for soil stabilization	≤ 1:4, 1:4 – 1:2, ≥ 1:2
Flow velocity of surface runoff	< 0.6 m/s, ≥ 0.6 m/s
Slope of streambed within the site	< 15°, ≥ 15°
Slope range of cut and fill area	< 1:2, ≥ 1:2

Table 3. Recommended Best Management Practices (BMPs) for construction sites

BMPs	
BMPs for contractor activities	Construction practice, Material management, Waste management, Vehicle and equipment management, Contractor, employee, and subcontractor training
BMPs for erosion and sedimentation	Site planning consideration, Soil stabilization, Tracking control, Velocity reduction structures, Sediment trapping structures

The primary goal of this stage of the study was to acquire expert knowledge based on information obtained during the previous stage and a series of structured interviews. Ten distinct sets of expert questionnaires were designed in order for the experts to share answers or other information, and interviews were organized separately with each expert.

In general, knowledge acquired from experts includes some conflicting information. Conflicts were resolved by applying Certainty Factors (CF), which quantify the confidence of an expert's belief. The minimum value for the certainty factor was -1.0 (definitely false), and the maximum value was +1.0 (definitely true). A negative value represented a degree of disbelief, and a positive value represented a degree of belief. CF values are interpreted as "Definitely not" (-1.0), "Almost certainly not" (-0.8), "Probably not" (-0.6), "Maybe not" (-0.4), "Unknown" (-0.2 to +0.2), "Maybe" (+0.4), "Probably" (+0.6), "Almost certainly" (+0.8), and "Definitely" (+1.0) [17].

In KBS, the knowledge base consists of a set of rules that have a common syntax of conjunctive and disjunctive rules. Conjunctive forms are written as follows: IF <evidence E_1> AND <evidence E_2> … AND <evidence E_n> THEN <hypothesis H> {cf}. The net certainty of hypothesis H is established as shown in Equation 1. Disjunctive rules are written as follows: IF <evidence E_1> OR <evidence E_2> … OR

<evidence E_n> THEN <hypothesis H> {cf}. The certainty of hypothesis H is established by Equation 2 [17].

$$cf\,(H, E_1 \cap E_2 \cap \ldots \cap E_n) = \min\,[cf\,(E_1), cf\,(E_2), \ldots, cf\,(E_n)] \times cf \quad (1)$$

$$cf\,(H, E_1 \cup E_2 \cup \ldots \cup E_n) = \max\,[cf\,(E_1), cf\,(E_2), \ldots, cf\,(E_n)] \times cf \quad (2)$$

2.2 Task Analysis

EMPs for housing and new township development projects incorporate many distinct tasks in diverse subject areas. Each of these tasks defined a knowledge base module that contributed to the system. The tasks used to organize BMPs are as follows:

Task 1: access road and stream crossing
Task 2: temporary building
Task 3: site utilities
Task 4: demolition
Task 5: clearance
Task 6: earth work
Task 7: import and export of fill
Task 8: drainage work
Task 9: road development
Task 10: operation of heavy equipment
Task 11: construction of utilities and buildings

2.3 Design

Microsoft Visual Basic software (VB) was used to develop the RP^{3}CA-EMP and a rule-based technique was used to represent knowledge. The RP^{3}CA-EMP reasoning process was controlled by a forward-chaining control strategy which represented collections of facts. In this control strategy, rules are formatted to read "IF 'condition is true', THEN 'perform action'." If the conditions are true within the context of the available knowledge base, they will be stored in the fact portions of the system knowledge engine to perform procedure [18].

A pilot prototype system was built to validate the project [11] and to provide the guidance for future work. Initially, it was used to solve one of the domain tasks in order to test and explore the concepts of problem definition, scoping and domain representation [1].

Next, the system was further refined to meet the project objectives. Expert knowledge was acquired and codified in the form of production rules. The overall RP^{3}CA-EMP system consists of the BMPs module, data input, and accessories. The BMPs module consists of eleven sub-modules that contain specialized knowledge bases for the system. The data input object facilitates collection of the input that is required to begin the RP^{3}CA-EMP process, and the accessories object provides support features for the system. Interface development began with RP^{3}CA-EMP prototype development. A standard Microsoft Windows interface was used so that the users familiar with similar programs could easily adapt to the interface [1]. VB provides a Session Window in which the system developer can create images that allow the end-user to interact with the knowledge base. VB also permits user interaction through forms. The Windows dialogue box guides the user through system operation [18], by presenting the user with a series of questions. The answers provided by the user are used to determine the factor or element [23]. System development was guided by information obtained through knowledge elicitation sessions and tests.

The basic organizational structure of the computer-assisted EMP system is given in Fig. 1.

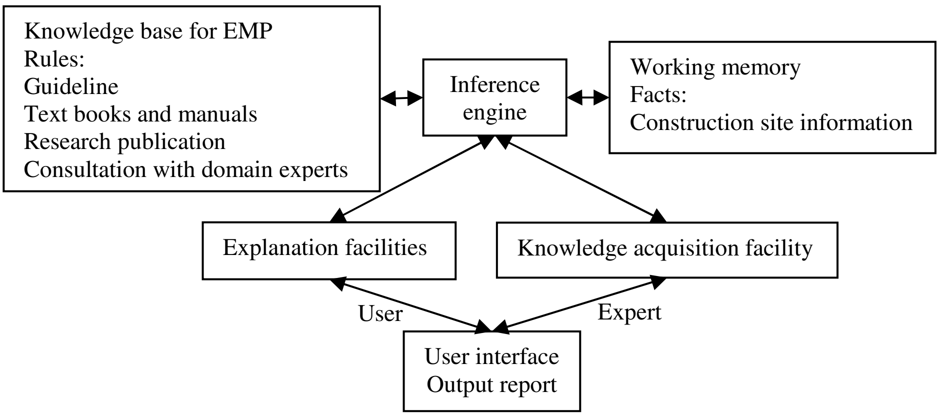

Fig. 1. Basic organizational structure of a computer-assisted EMP system

2.4 Testing and Validation

A construction site in Malaysia was used as a case study for testing and validating modules of the RP^{3}CA-EMP. The objective of the case study was to evaluate the performance of the RP^{3}CA-EMP consultation process when it was applied to a construction site. An Erosion and Sediment Control Plan (ESCP), and EMP must be submitted to Malaysian Drainage and Irrigation Department (DID) by a qualified consultant for all housing and new township development projects. The results of the RP^{3}CA-EMP were found to be comparable and similar with the project ESCP, and EMP, indicating that the RP^{3}CA-EMP performed as well as the human experts.

Finally, the user-friendliness of the user interface was evaluated. The main screen of the RP^{3}CA-EMP consists of several buttons with images similar to other software applications for the user to select with a mouse. Therefore, very few computer commands are involved, and the user is only required to perform a minimum amount of work with the keyboard. The RP^{3}CA-EMP also provides a teaching feature that is designed to aid an inexperienced engineer by guiding him or her through the process of selecting BMPs, preliminary design steps, and explaining inspection and maintenance requirement associated with BMPs. These features are available to the user through the *User Guide*, and *General Information* menus. Furthermore, the user is able to access the help features if he or she is having difficulty at any stage during the consultation process [11].

3 The RP^{3}CA-EMP System

System output is primarily intended to provide engineers, consultants and EMP decision-makers with the following information:

a. General information about appropriate EMP content,
b. Potential environmental impacts of housing and new township development projects on surface water,
c. Information about mitigation measures for minimizing river pollution during construction activities,
d. BMPs for different stages of construction activities based on construction site characteristics,
e. A BMP checklist for site inspection, and
f. Locations for BMPs in a Geographical Information System (GIS) map

The user is advised on project steps through a series of choices from RP^{3}CA-EMP. At each consultation step, the user can choose any of the construction stages presented in Figure 2, which illustrates the temporary building stage. After receiving data, the system delivers immediate results as shown in Figures 3, and 4. The system then presents all results and a preliminary design of the recommended BMPs in a report form.

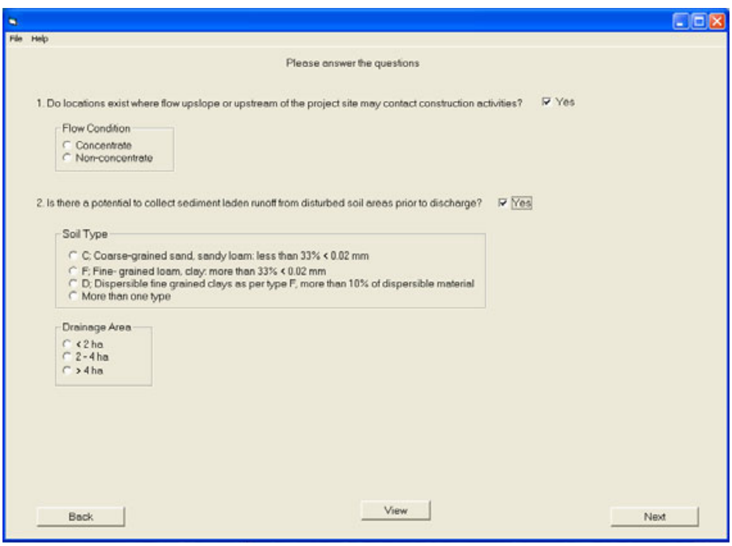

Fig. 2. Data input for the selected construction stage

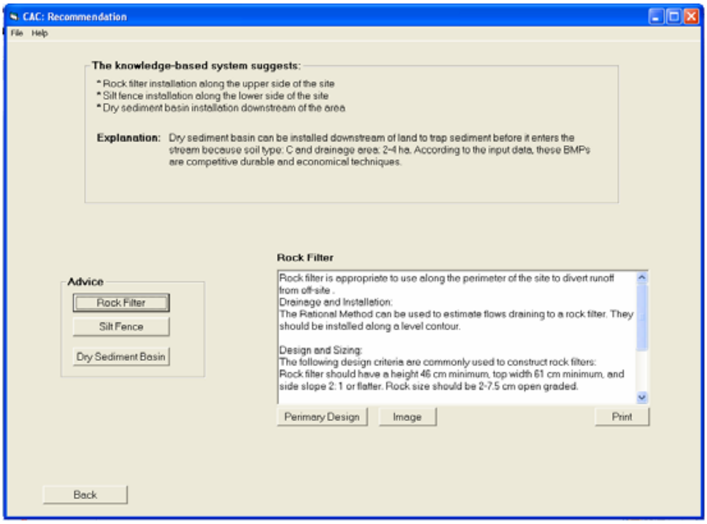

Fig. 3. RP[3]CA-EMP recommendations for selection of BMPs

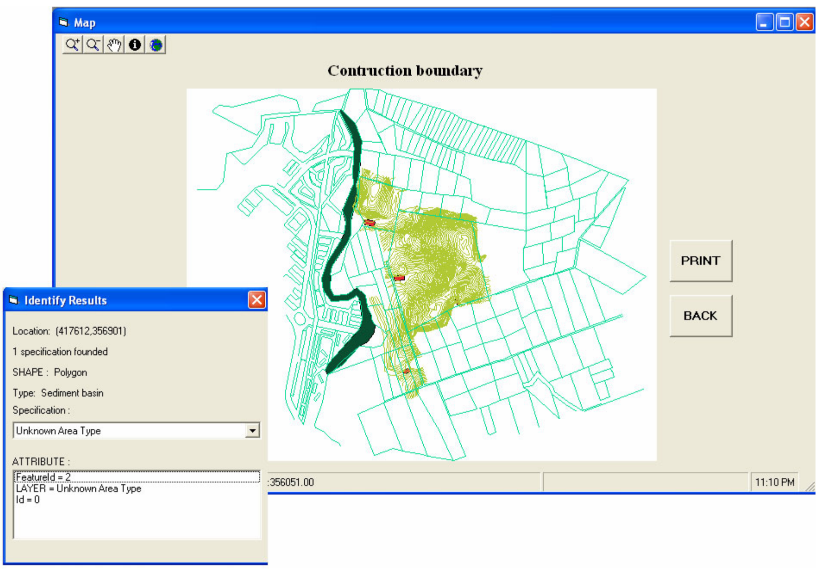

Fig. 4. Locations of BMPs in GIS format

4 Conclusions

The construction industry contributes significantly to river pollution. Therefore, it is essential to apply the most appropriate techniques and BMPs at construction sites to minimize river pollution. This paper presented a knowledge-based system, called the

RP^{3}CA-EMP that was developed to minimize river pollution during housing and new township development projects in Malaysia. This system provides advice based on input data and, together with its “help” feature, serves as useful educational tool. The system database compiled texts, expert knowledge about common BMPs, figures, GIS maps, potential environmental impacts, mitigation measures, and site inspection procedures. All of this information can be applied by both experts and non-experts during housing and new township development projects. The system accounts for relevant properties of the project area in order to generate site-specific recommendations and to guide the selection of appropriate BMPs. This system will be encourage the creation of EMPs in the construction industry and will thereby help relevant agencies make more accurate and objective decisions that will reduce river pollution during housing and new township development projects.

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