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Knowledge Based Expert System for Minimising Stormwater Erosion and Sedimentation in Malaysian Construction Sites

Ibrahiem Abdul Razak Al-Hadu#, Lariyah Mohd Sidek#, Mohamed Nor Mohamed Desa#, and Noor Ezlin Ahmad Basri*

Department of Civil Engineering, Universiti Tenaga Nasional

Jalan IKRAM UNITEN, Kajang, 43009, Selangor, Malaysia

Tel.:+60146437715, E-mail: ibrahiem.moadmawi.ak@gmail.com

**Department of Civil & Structural Engineering, Universiti Kebangsaan Malaysia*

UKM, Bangi, 43006, Selangor, Malaysia

Tel.:+60123417687, E-mail:ezlin@vlsi.eng.ukm.my

***Abstract*— Construction activities generate enormous amount of erosion and sediments that are the result of soil disturbance during construction activities, thus, will pollute the adjacent water bodies and make it unfeasible for different uses. This paper aimed to develop and create the main features of an expert system prototype (ESCES) for minimising erosion and sedimentation due to stormwater generated from the construction activities by recommending a feasible BMPs. Multi criteria Analysis (MCA) technique has been integrated so as to select the best control measure among many stormwater control alternatives. A questionnaire has been distributed to the relevant experts so as to rank the stormwater control measures to be used in the MCA technique. Using Visual Basic 6, Graphical User Interfaces (GUIs) were developed. The knowledge and experience were acquired from various textural sources (i.e. guidelines, manuals, literature, and human expert). Results from this study showed that the Best Management Practices (BMPs) recommended have good suited the site characteristics as the relevant experts have showed their convenience to the developed prototype since they asked to fill in simple questionnaire after developing the system and presented to them. The conclusion drawn from this study indicates that the ESCES can be considered as "Green Technology Tool" since it helps in protecting the environment and preserve good quality of water adjacent to the construction sites in Malaysia.**

***Keywords*— Expert system, construction sites, best management practices, multi criteria analysis, pollution control.**

I. INTRODUCTION

People like living around water, this joint with the omnipresent of surface water bodies all over the nation, many times construction activities essentially occurred adjacent to water bodies. Construction is not typically a source of conventional pollution such as chemical and biological contaminants, on the other hand, for the reason that the large amount of land disturbed as a result of the construction activity, construction sites are one of the largest contributors of sediment loading to our nation's surface waters. During construction phase, large areas of soil are exposed to the erosive forces either by wind or flow or by both. This erosion may result in a significant increase in sediment loads to the receiving water thus, will degrade the quality of the receiving water. Construction site usually exposes large areas of bare soil to water erosion, increasing the soil erosion rate to 2-40000 times to preconstruction levels [1] and results in approximately 80 million tons per year of sediment supplied to US lakes, rivers and watersheds.

Before 1960, mining, agriculture, logging, and so forth were the essential disturbances participating to sedimentation to the adjacent water systems. Nevertheless, within the past two decades, construction activities have played an increasingly important role in this process and may currently equal to or exceed all other sources. [2]. Furthermore, harmful compounds may be involved in the runoff that has derived from the construction sites. From past and recent studies, sediment indicated to overcome all other pollutants in both quantity and total economic and ecological impact. In Malaysia, Kuala Lumpur and in the neighbouring urban centres of the Klang valley, urban development was particularly rapid in the late 1970s and 1980s. The rapid growth of urban development in Kuala Lumpur area has the effect of excessive soil losses from construction sites and from sites cleared and awaiting development. Construction sites in Malaysia usually involve bare eroding slopes and drains chocked with sediment. Observation has been made and indicated that huge amount of this sediment transported from the development sites. Areas subjected to construction usually experience sediment yields 2 to 3 folds of magnitude greater than those under natural land cover conditions [3].

The sediments that results from the erosion process will result in a significant cumulative impact downstream and over a longer time periods [1]. The sediments will cover stream bed and will dramatically alter stream ecosystems, reduce light transmission, which limits in-stream photosynthesis and diminishes aquatic food supply and habitat, nutrients associated with sediments contribute to the development of algal blooms, erosion of stream banks associated with increased frequency and magnitude of runoff events destroys riparian systems, and loss of topsoil from construction areas leaves behind less fertile subsoil which hinders re vegetation of disturbed areas.

Multi Criteria Analysis technique is a structured framework for investigating, analysing and resolving decision problems constrained by multiple objectives. It is used to apprise a discrete number of alternative options against a set of multiple criteria and conflicting objectives [4]. A key feature of MCA is its emphasis on the judgements of the decision making team, in establishing objectives and criteria, and the relative importance weight, and to some extent, in judging the contribution of each option to each performance criteria. The MCA is emerging as a popular approach for supporting multi stakeholder environmental decisions [5]. Ref. [6] describes a web-based Multi Criteria Analysis approach that have been developed within the EU 5th Framework DayWater project so as to support the decision making and solve the conflict between the stakeholder and facilitate negotiation between them. Ref. [7] have utilised the multicriteria process for evaluating the flood control options for the catchment of Livramento creek in Portugal. Recent research that applied the MCA in water resources field involves reservoir operations [8]; planning or irrigation [9]; water quality and ecosystem impacts [10]. Ref [11] have evaluated three common alternatives, they are: sodding natural channel, lined natural channel, and box culvert for the Malnichara channel in Bangladesh because this channel is responsible for stromwater runoff conveyance to the downstream Surma River. This river is found to be encroached at many locations of the city and found to be very vulnerable. The evaluation process has been conducted by the application of the Multi Criteria Analysis by adopting nine criteria which have been categorized under four main criteria (Technical, Environmental, Economical, and Social). The channel has been divided into two parts: the upper portion and the lower portion. Small groups of stakeholders were interviewed for the selection of the criteria, assigning weights, and scoring the options against the criteria. Results have shown that the sodding natural channel is the best alternative for both portions of the channel. However, the choice is very sensitive to the social criteria. The aim of the this study is to minimise erosion and sedimentation due to stormwater in Malaysian construction sites by adopting a stormwater Best Management Practices (BMPs) that are suitable to a specific site characteristics. Section 1 of this manuscript has provided an introduction and a brief literature regarding the current study. Section 2 involved the methodology adopted during this study accompanied with illustrative Figures. Section 3 presented the results obtained from this study. Sections 4 and 5 represent the overall evaluation of the ESCES and the conclusion respectively.

II. METHODOLOGY

The methods adopted in this study have been commenced from the task analysis till the expert system prototype development. Figure 1 presents the overall methodology adopted in this study

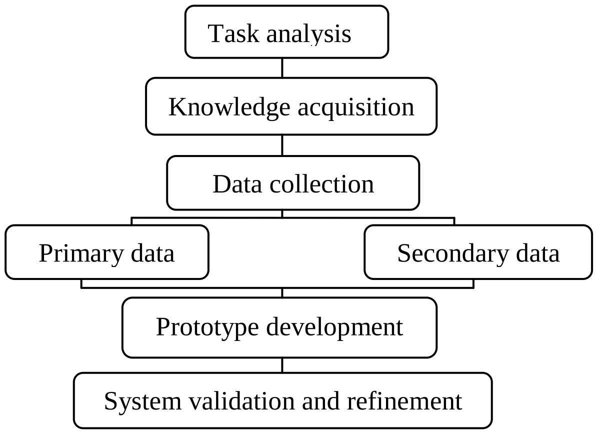

Fig. 1 Overall study methodology

As shown in Figure 1 above, the methodology of this study has started from the task analysis which means the adaptability of the current statement of problem to the expert system type approach. Following the task analysis, is the knowledge acquisition which is the most difficult and time consuming step in expert system development. The current knowledge has been acquired from various manuals, and human experts.

The data needed to be collected involves two kinds of data, the first set is the primary data that represented by the questionnaire. The questionnaire has been distributed to the relevant experts of erosion and sediment control for getting the necessary ranking of various control measures so as to be as an input to the Multi Criteria Analysis. The second set of data involves the secondary data that represented by the data needed to validate the prototype. The latter set of data have been obtained from the Environmental Management Plan (EMP) reports, Environmental Impact Assessment (EIA) reports for any ongoing or completed projects in Malaysia.

The prototype development have been accomplished by using the Visual Basic 6 (VB6) [12] which is proved to be very powerful and safe programming language tools, further it is especially well suited for dealing with complex knowledge. Moreover, VB6 was chosen because of its proven reliability and knowledge engineers' familiarity of working with this language. Afterwards, some secondary data obtained from a construction site which is located in Cameron Highland District in Pahang for validating the developed prototype.

A. Multi criteria Analysis (MCA) Technique

MCA technique can be used to find the optimum solution available among many other alternatives by depending on some criteria and criteria weight. The criteria that are adopted in this study were environmental (water quality impact, water volume impact, and TSS control), economical (construction cost, removal cost), technical (BMP durability and performance, BMP construction material availability), and social (risk of BMP failure, public health and safety risk, stakeholder acceptability)

This paper have adopts and extended the basic structured classificatory methodology by [4] to the evaluation and selection of stormwater erosion and sediment control measures. There are many methods used to standardisation of the ranked values collected from the experts. The most common one is to adjust criterion scores based on their distance to a maximum and or/minimum value. For example the top performing alternative for a given criterion is given a score of 1 and the worst performing alternative is given a score of 0. The following approach to standardisation has been used in this study:

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$$s1_{ij} = \frac{x_{ij} - x_{j\min}}{x_{j\max} - x_{j\min}} \quad (1)$$

Equation (1) above can be used where a higher criterion score indicates better performance. (i.e. when the criteria is benefit criteria).

$$s2_{ij} = \frac{x_{j\max} - x_{ij}}{x_{j\max} - x_{j\min}} \quad (2)$$

Equation (2) above can be used where a higher criterion score indicates lower performance (i.e. when the criteria is economic/cost criteria)

Where:

s_{ij} = the standardized performance measure for x_{ij}

x_{ij} = the performance of the i^{th} alternative against the j^{th} criterion in real units of any type

x_j max = the maximum performance score under the j^{th} criterion

x_i min = the minimum performance score under the j^{th} criterion

For ranking of alternatives (options), a great many techniques exit to obtain a ranking of alternatives once the weights and performance measures have been entered into the MCA matrix. The techniques primarily differ in how they handle qualitative and quantitative data, and decision maker preferences. One of the most widely applied and most easily understood techniques is weighted summation. Using weighting summation, the performance measures are multiplied by the weights, and then summed for each option to obtain performance score. This is the approach taken here. The overall performance score can be calculated by:

$$v_i = \sum_{j=1}^{m} s_{ij}.w_j \quad (3)$$

Where,

v_i = the value (or utility) of the i^{th} alternative relative to the other alternatives

s_{ij} = the standardized value of x_{ij} (the performance measure for the i^{th} alternative against the j^{th} criterion)

w_j = the weight of the j^{th} criterion

B. Production Rules of the Acquired Knowledge

Knowledge acquisition is the transfer and transformation of knowledge from some knowledge source to an expert system program. Potential sources of knowledge include human experts, manuals, guidelines, reports, and one's own experience. The information included in this rapid prototyping expert system ESCES knowledge based are acquired from many sources that were written by experts and related professional institutions [13], [14], [3], [15], [16]. Acquiring knowledge from such sources was felt to be the most difficult and time consuming task in this rapid prototyping ESCES.

The knowledge acquisition was performed by classifying and summarising information needed for the erosion and sediment control in construction sites and by incorporating the authors experience in this field. Knowledge representation is a method of organising and representing the knowledge. By far, the most popular knowledge representation technique is ruled based. It uses an if-then statement to represent a production rule.

The operation of the ESCES consists of a series of selections linked by if-then logic. Its control system supports a forward-chaining procedure. This rapid prototyping runs on typical personal computer configuration, requiring a run-time version of VB6 (for windows XP and above).

III. RESULTS AND DISCUSSION

The result of this research is the output of the Erosion and Sediment Control Expert System (ESCES) which has been presented via GUIs and integrated with well illustration for each. Figure 2 shows the first window of the ESCES. To start formal consultation, the user needs to press on the **OK** button (Figure 2). Initially, the basic water quality parameters (i.e. the water quality parameters before construction commenced) has to be inserted as shown in Figure 3. The parameters involved in this study are the Total Suspended Solids (TSS) and turbidity as they are the two essential indicators for water pollution due to erosion and sedimentation in construction sites. Afterwards, the user has to identify the duration of need (i.e. how long does the user need the BMPs to be in place) and has to select the objective of stormwater control (i.e. does the user wanted to control erosion only, sedimentation only, or erosion and sedimentation simultaneously). The user has to identify the type of area whether it is urban, semi urban, or rural. Identification/selection of the duration of need, erosion and sediment control objectives, and type of area were illustrated in Figures 4, 5, and 6 respectively. Whenever the user inserted the site characteristics which are represented by the drainage area extent, slope steepness and length, and other site characteristics, the ESCES produces recommendations by comparing the monitored water quality parameters that the user have entered into the system with the existing values. A typical output of recommendations for the input data is presented to the user as shown in Figure 7.

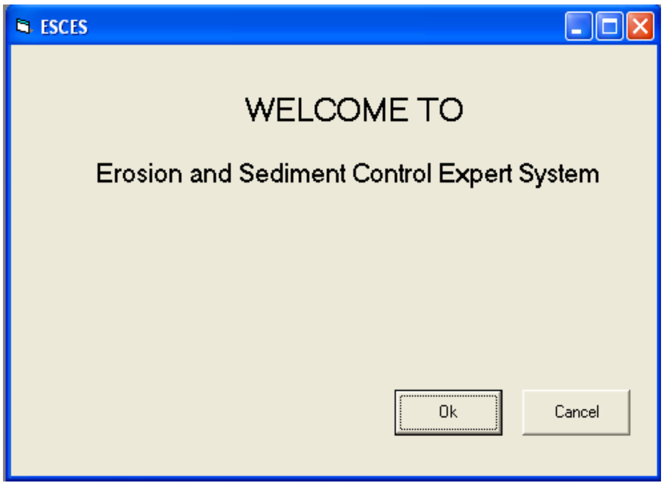

Fig. 2 The first window of ESCES

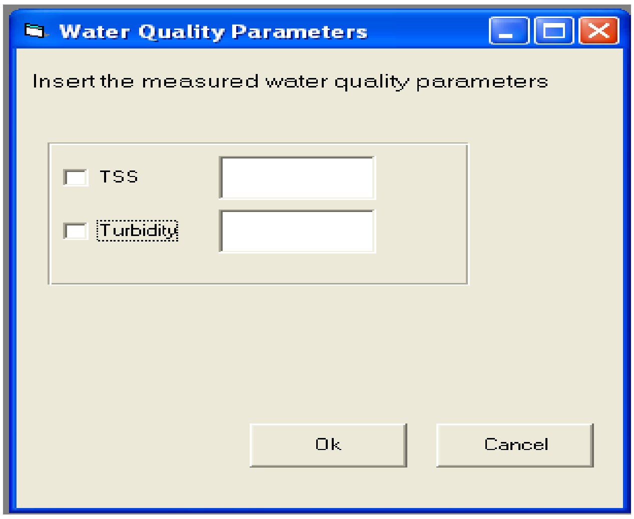

Fig. 3 Water quality parameters

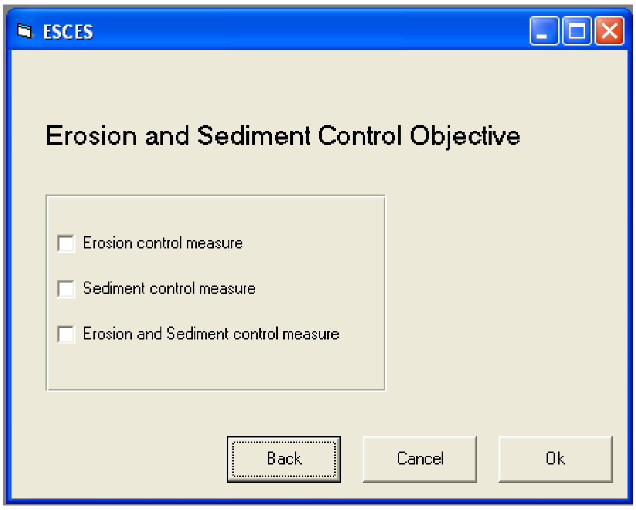

Fig. 4 Erosion and sediment control objective

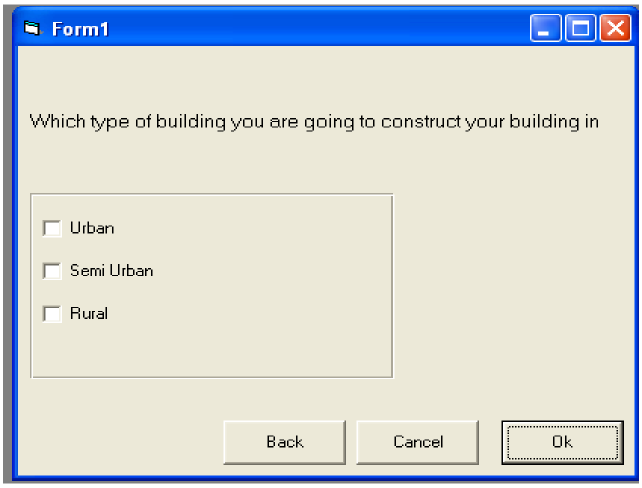

Fig. 5 Type of area

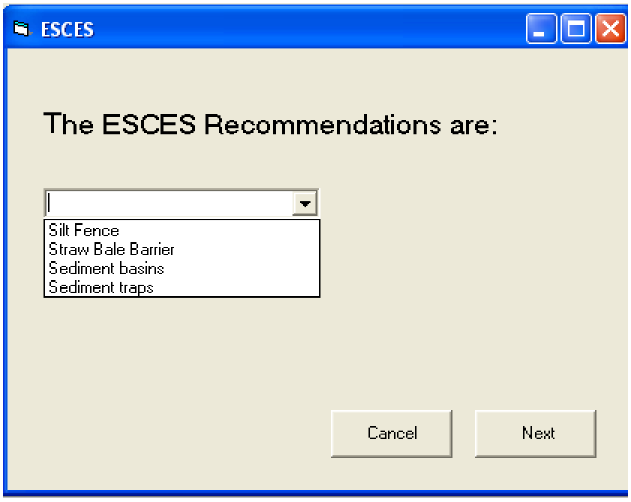

Fig. 9 Typical output of recommendations

IV. OVERALL EVALUATION OF THE SYSTEM

The consultation process of the ESCES was reasonably satisfactory and systematic to the knowledge engineers. The flow of consultation is flexible, allowing the user to go back for a new consultation, to review input values until he/she is satisfied with the results. The ESCES has the ability to run using Windows operating system. Moreover, the knowledge of the ESCES was based on the latest edition. In order for expert systems not to become obsolete, they must be nurtured and kept current. This involves a mechanism for making modifications as knowledge needs to change, and to include new knowledge. All expert systems, the ESCES included, cannot claim completeness in their knowledge bases; they are always subject to upgrading, modification and correction. The existing knowledge base for the ESCES can be improved by:

(i) Refining, expanding, and reinforcing its knowledge base using new findings as reported in literature or new experience from domain expertise;

(ii) Adding further functional capabilities; and

Adding photographs as bitmap images showing the preliminary design of the device for example the preliminary design of the silt fence that is used for sedimentation capturing.

Regarding the evaluation process or so called “validation”, it has been achieved by applying the data that have were collected from Cameron Highland project to the developed system. First, the Cameron Highland construction site area has been divided into a number of sub areas each has different slope pattern. The soil characteristics, slopes, contributing drainage area, and other site characteristics for each sub area have been collected from the Environmental Management Plan which has been prepared by the Department of Environment (DOE). Data collected from each sub area have been inserted into the rapid prototyping expert system so as to choose the Best Management Practices that suit the inserted characteristics. The same procedure has been repeated to each sub area. After developing the system and test it with the Cameron Highland construction site data, the prototype has been presented to some experts in erosion and sediment control. Afterwards, simple questionnaire has been distributed to them so as to capture their impression about the prototype developed which indicates their convenience.

V. CONCLUSIONS

Construction activities usually generate massive amount of erosion and consequently sedimentations that will be responsible for degrading the quality of the adjacent water bodies, thus, will affect the habitats of ecosystem, fish spawning areas, navigation by the sediments, and so on.

This study has presented a demonstration of rapid prototyping expert system knowledge based expert system (ESCES). In particular this rapid prototyping expert system is developed to give advices on how to minimise the erosion and sedimentation during construction to the adjacent water bodies. The ESCES observed to be able to provide recommendations which are suitable for specific site characteristics. It has been concluded that the development of this demonstration rapid prototyping (ESCES) is feasible to minimise the erosion and sedimentation from Malaysian construction sites and can be used by the construction engineers, construction managers, construction coordinators, contractors, decision makers and other water resources users. The ESCES can save time and money since the consultant is not always available, and in case if he/she available, it might takes some time for him/her to identify the most feasible stormwater erosion and sediment control measures that are suitable to a specific site characteristics and choose the optimum control measures based on the criteria mentioned in Figure 3. Furthermore, the consultation is a costly issue that will add further financial allocations to the project. The programming language is Visual Basic version 6 (VB6) which have been used for developing the ESCES. The use of VB6 provides greater flexibility and adaptability in developing this rapid prototype. This flexibility allows the knowledge engineer to present domain knowledge more freely. However, programming languages require more development time since the developer must be familiar with the computer languages and must develop program codes. Debugging the program is often more difficult.

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