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Knowledge based expert system to minimise environmental pollution in Malaysian construction sites

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Abstract

Construction activities generate enormous amount of erosion and sediments sediments that is 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) reommended have good suited the site characteristics. As a conclusion from this study, the ESCES can be considered as part of the "Green Technology Tool" since it helps in protecting the environment and preserve good quality of water adjacent to the construction sites in Malaysia.

Keywords: Best management practices, Construction sites, Environmental pollution, Expert systems, Multi criteria analysis.

1. 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 contaminations, 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 water. Construction site usually exposes large areas of bare soil to water erosive forces, 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 quantities, total economic and ecological impact. In Malaysia, Kuala Lumpur and in the neighboring urban centers 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 diminished 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 soil.

In addition to the environmental problems, there are significant direct economic impacts. Furthermore; sedimentation may clog storm sewer systems, reduce reservoir storage capacity and hence increase flood frequencies of receiving streams and rivers. All the above problems emphases on solutions to solve the problems of onsite erosion and offsite sedimentations to the adjacent water bodies, these solutions can be demonstrated by onsite and offsite best management practices (BMPs) for controlling the erosion and sedimentation associated with the construction activities. The aim of this study is to develop a prototype expert system which is entitled Erosion and Sediment Control Expert System (ESCES) for minimising the erosion and sedimentation associated with the construction activities to the adjacent water bodies in Malaysia and in other countries which have the same climate, environment, and topographic features.

Multi Criteria Analysis (MCA) technique is a structured framework for investigating, analyzing, and resolving decision problems constrained by multi 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. The MCA is emerging as a popular approach for supporting multi stakeholder environmental decisions [5, 6] describes a web-based multi criteria analysis which 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. [7] have utilized 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 involve reservoir operations [8]; planning or irrigation [9]; water quality and ecosystem impacts [10, 11] 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 stormwater runoff conveyance to the downstream Surma rive. This river is found to be encroached at many locations of the city and found to be very vulner vulnerable. The evaluation process has been conducted by the application of the Multi Criteria Analysis (MCA) by adopting nine criteria which have been categorised under four main criteria (Technical, Environmental, Economical, and Social).

As mentioned earlier, the aim of this study is to minimise erosion and sedimentation due to stormwater in Malaysian construction sites by adopting 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. Section 4 and 5 represent the overall evaluation of the ESCES and the conclusion respectively.

2. Methods

The methods adopted herein this research have been commenced from the data collection, interviewing with the relevant experts, identifying whether this kind of problem is suitable for an expert system type approach, knowledge acquisition, preparing the Graphical User Interface (GUI), and eventually validation of the prototype. Figure 1 illustrates the overall methodology adopted in this study.

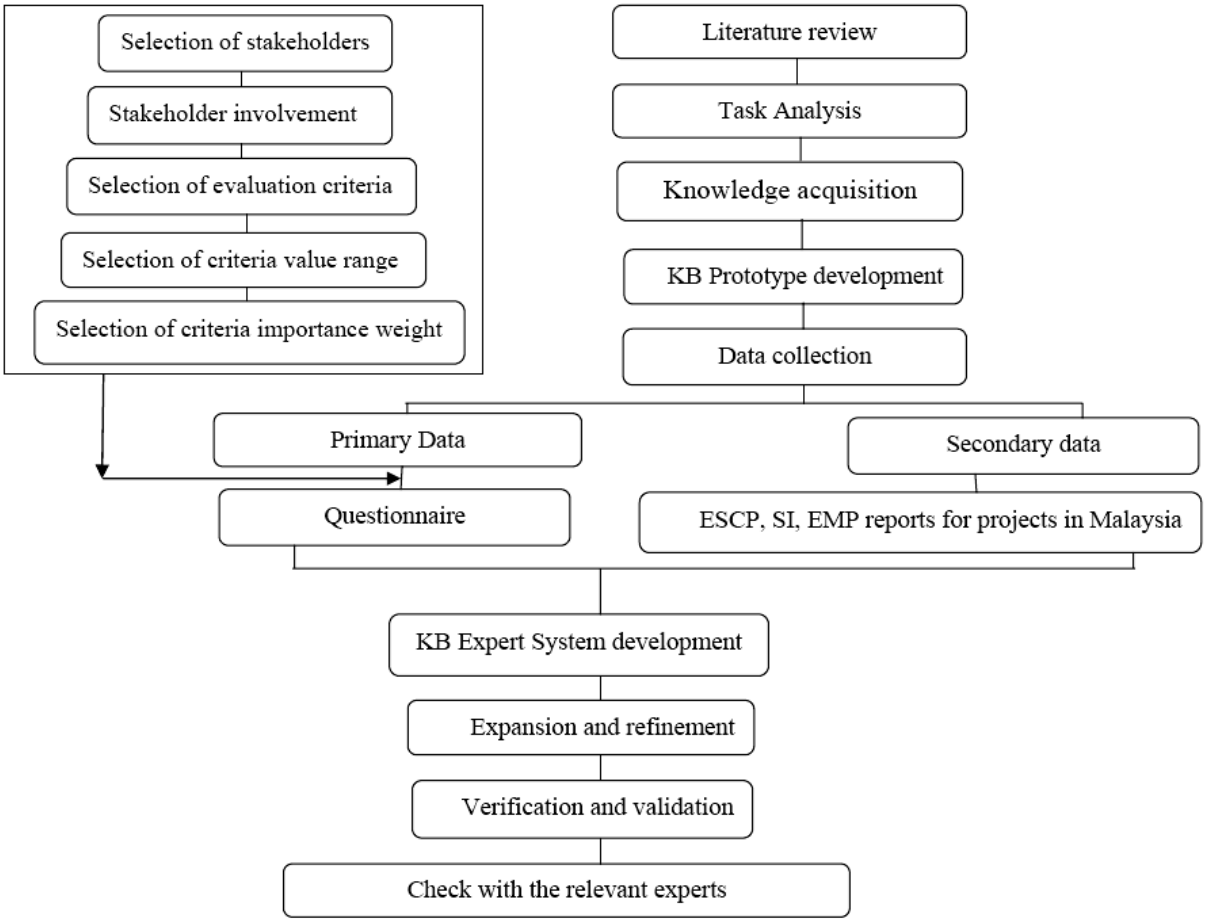

Figure 1. Overall study methodology

2.1 The knowledge base

A knowledge engineer acquires knowledge from various sources of expertise and codifies it into an expert system. The prerequisite for developing knowledge based system in the construction domain; the knowledge engineer has to be familiar with the essential components of expert system technology as wellas the domain of erosion and sediment control from construction sites in Malaysia, to develop a successful system, it is also necessary to understand the language being used. In this approach, engineers of the domain (the authors in this case) who have mastery of expert systems technology were to become the knowledge engineers, have the experience in using the Visual Basic 6.

2.2 Flow diagram of acquired knowledge

After acquiring the knowledge from multiple expertise sources, a flow diagram for this rapid prototyping, was developed as shown in Figure 2. This flow diagram was used to develop objects and rules for the knowledge based. This diagram shown that the user have to check that the water quality parameters before construction is hold, and then entitle these values as the base line water quality parameters. Duration of need of the erosion and sediment control have to be selected either 0-6 months or 6-12 months. The user has to select the erosion and sediment objective which will either be erosion control, sediment control, or erosion and sediment control. For each of these objectives, have its own sub categories. Site characteristics has to be inserted by the user so as to select the BMPs that are suitable to the inserted site characteristics (e.g. drainage area extent, type of land use, soil erodibility, flow condition, grade slope steepness and length, and so on). Now the system shall be able to give recommendations that match the inserted site characteristics. Bu using the multi criteria analysis (MCA) technique, the system shall be able to give the best alternative among many alternatives available to the user by depending on some criteria for the evaluation whichever is best functioning in the reduction of erosion and sediment generated from the construction sites. The MCA is both an approach and a set of techniques, aiming at providing an overall ordering of alternatives from the most preferred option to the least preferred one [11]. It is used to appraise a discrete number of alternatives (options) against a set of multiple criteria and conflicting objectives [12]. When the optimum solution been presented to the user, the ESCES shall be able to provide the user with some information regarding the selected BMP like a preliminary design, construction and maintenance, location by a simple guide, costing, and eventually some graphics for further illustration of the proposed BMP. New GUI shall ask the user regarding the water quality parameters during construction. Comparison between the measured water quality parameters after installing the BMP and the existing values shall be fulfilled.

2.3Data collection

Data collection involve two types of data, , the first set of data is the primary data which can be collected via questionnaire. The questionnaire has been collected from the relevant experts in whom the authors have met them. The first aim of the questionnaire survey is to gather past and current information from the relevant experts regarding experiences/problems related to stormwater erosion and sediment control measures during construction activities in Malaysia, while the second aim is to get ranking for various stormwater erosion and sediment control practices. The first meeting was conducted at the International Hydrology Seminar which have been organised in Kuala Lumpur, Malaysia. In the seminar, the authors have presented their project and the audience have ansked some questions for more clarification. The audience was from different departments and organisations such as the Drainage and Irrigation Department (DID), Department of Environment (DOE), and experts from other institutions (i.e. academics) from the Universiti Kebangsaan Malaysia (UKM), Universiti Sains Malaysia (USM) and other institutions and organisations. The second meeting have been conducted through a three days workshop which have been organised and held in Universiti Tenaga Nasional, Kajang, Malaysia. The questionnaire have been distributed to 50 participants and the authors have get the feed back from 10 participants only because some of the participants have not totally fill the questionnaire form and others have commented that they are not so specialise in that field. Analysis from the questionnaire data can be used as an input to the Multi Criteria Analysis (MCA) technique. The second set of data represents the site investigation report data, environmental management plan data, and other reports for a specific construction projects in Malaysia. The latter set of data can be used for validating the prototype expert system ESCES.

2.4Multi criteria analysis structure

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 clarified in Figure 3. The questionnaire involved ranking of stormwater best management practices according to the set criteria in Figure 3 below.

This paper have adopts and extended the basic structured classificatory methodology by Voogd (1983) 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 adopted in this study:

$$s_{ij} = \frac{x_{ij} - x_{j\min}}{x_{j\max} - x_{j\min}} \tag{1}$$

$$s_{ij} = \frac{x_{j\max} - x_{ij}}{x_{j\max} - x_{j\min}} \tag{2}$$

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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 ty, x_j *max* = the maximum performance score under the j^{th} criterion, x_i *min* = the minimum performance score under the j^{th} criter.
Equation (1) can be used where a higher criterion score indicates better performance while equation (2) can be used where a lower criterion score indicates better performance.
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:

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

where v_i is the value (or utility) of the i^{th} alternative relative to the other alternatives, S_{ij} is 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

2.5 Prototype development tool

For the development of the Erosion and Sediment Control Expert System (ESCES), object-oriented software called Visual Basic 6.0 (VB6) was used. Apart from its powerful object oriented capabilities, enable the interfacing with user, making human computer interaction more natural and easily, VB6 also allows representation of knowledge using production rules. VB6 (http://www.wcupa.edu/infoservices/vpis.sat/SATPDF/Visual%20Basic%206.0.pdf) is a very powerful and safe programming language tools, further it is especially well suited for dealing with complex knowledge. Moreover, VB6 was chosen because it's proven reliability and knowledge engineers' familiarity of working with this language.

2.6 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 (Construction Site Best Management Practices (BMPs) Manual 2003, Guidelines for Prevention and Control of Soil erosion and Siltation in Malaysia 2008, Urban Storm Water Management Manual for Malaysia 2000, Guidelines for Prevention and Control of Soil Erosion and Siltation in Malaysia 1996, Levi et al. 2004). 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).

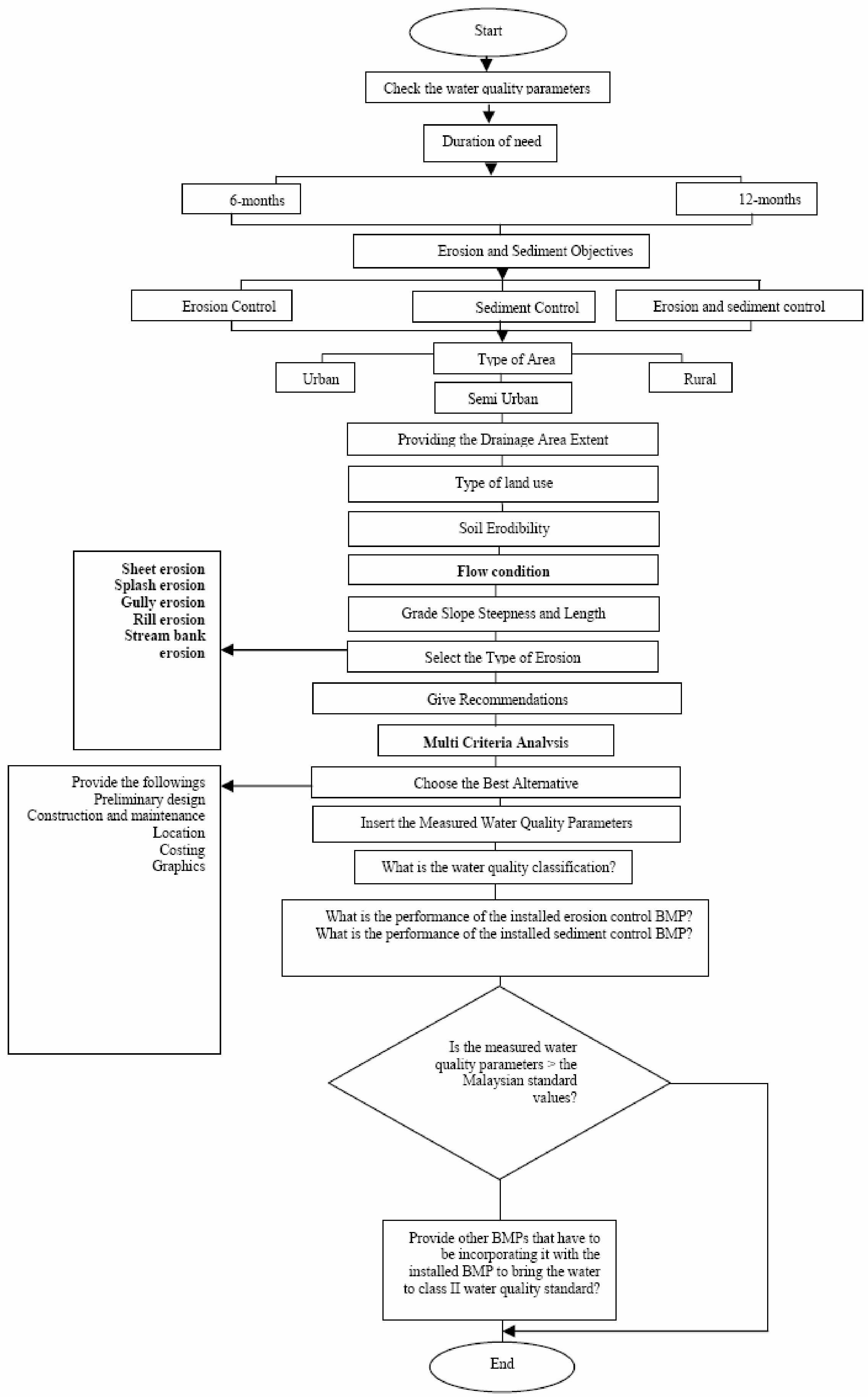

Figure 2. Flow diagram of knowledge for minimising erosion and sedimentation during construction activities in Malaysia

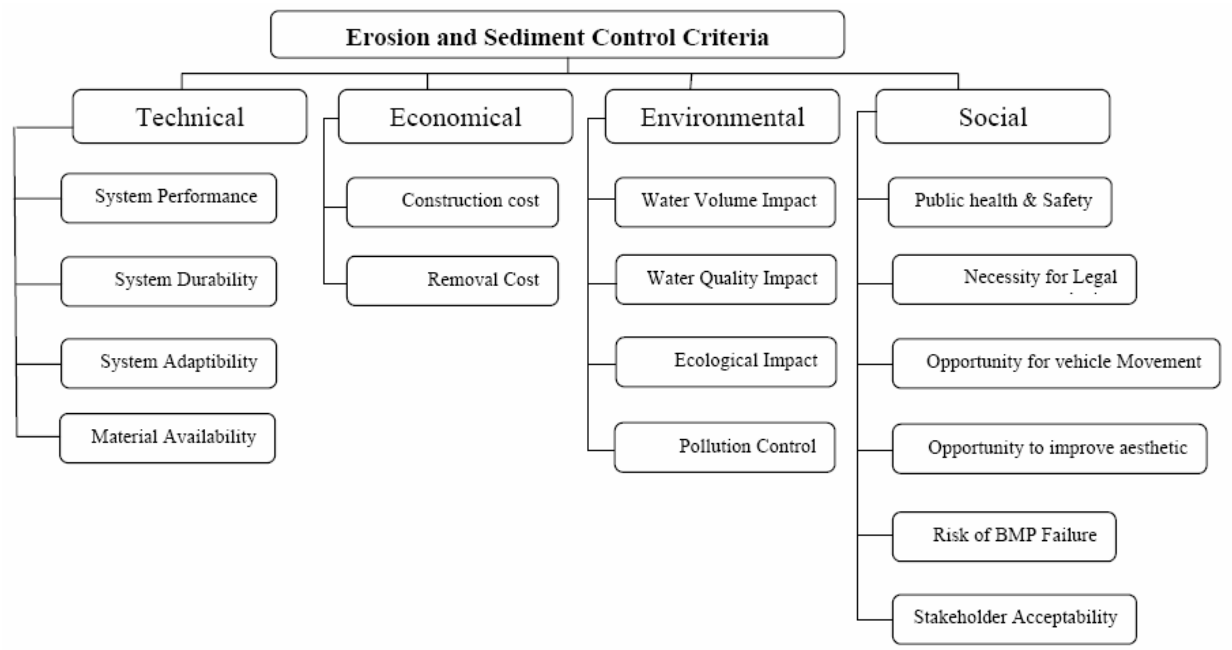

Figure 3. Criteria used for evaluation of each BMP

3. Results and discussion

Results that have been obtained during this study involved the prototype expert system ESCES out put results for recommending the stormwater best management practices which are suitable to a specific site characteristics. Figure 4 shows the first window of the ESCES. To start formal consultation, the user needs to press on the **OK** button (Figure 4). Initially, the basic water quality parameters (i.e. the water quality parameters before construction commenced) has to be inserted as shown in Figure 5. 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 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 all together). 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 (6, 7, 8) 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 9.

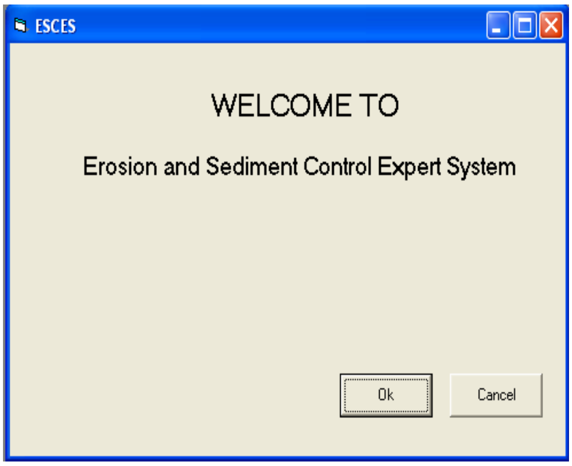

Figure 4. First window of ESCES

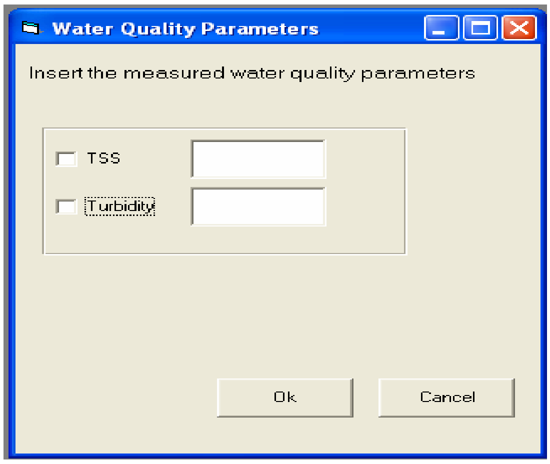

Figure 5. Inserted values of the existing water quality parameters

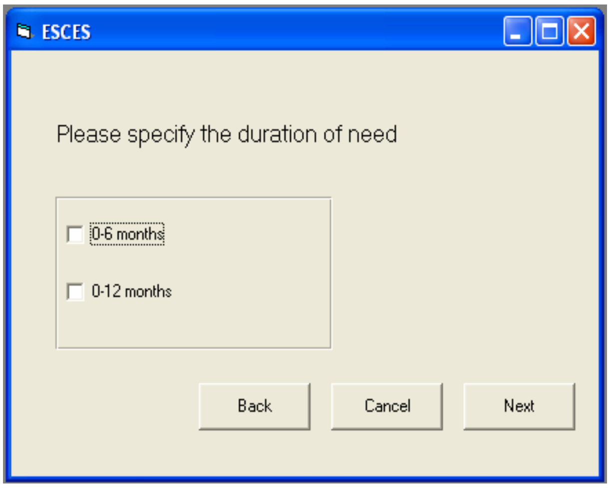

Figure 6. The duration of need

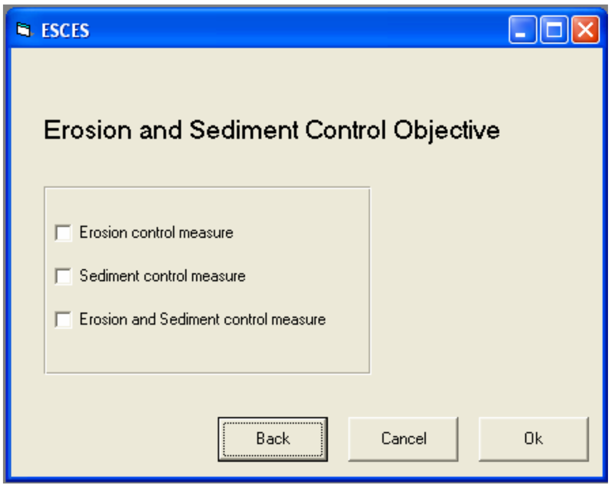

Figure 7. Erosion and sediment control objective

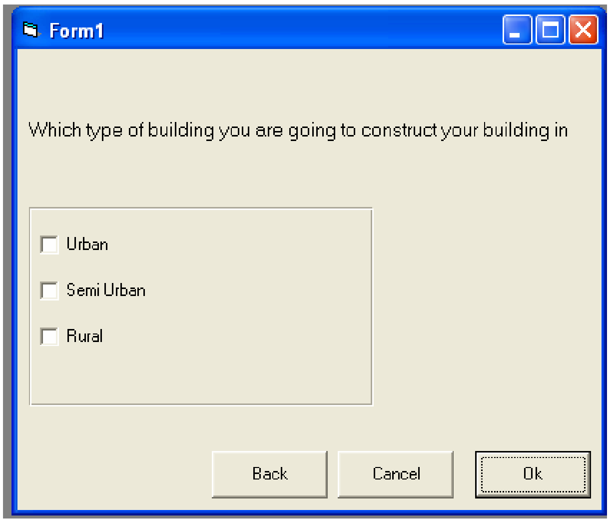

Figure 8. Type of area

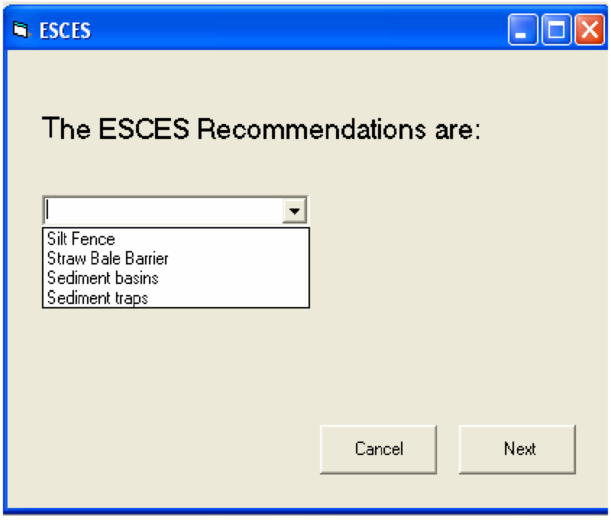

Figure 9. Typical output of recommendations for the inserted data

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
(iii) 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.

4. Conclusion

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 miminise 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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