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Rapid Prototyping Expert Systems for Minimising River Pollution During Highway Construction Activities

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Abstract: Highway construction activities will generate massive amount of different types of debris and pollutants that will degrade the adjacent water bodies and this in turn will affect the ecosystem environment, affect on navigation by the sediments that will be deposited in the river via., various construction activities. The development and main features of a knowledge-based rapid prototyping expert system for highway construction called Highway Construction Expert System (HCES) are described. This rapid prototyping has been developed for only one of the highway construction activities entitled vehicle maintenance, servicing, washing and fueling in which the rapid prototyping will give recommendations on how to minimize the effect of spillage and suspended solids associated with this activity to the adjacent water bodies. An object-oriented model was developed using Matlab, where the rule-based reasoning and other decision processes operate on or across objects. The knowledge and experience were acquired from various textural sources. Preliminary results of this study demonstrated a typical output transcript image of recommendations for the input data presented to the user via., PDF file format. Currently, the rapid prototype of HCES development based solely on texts and in the early stage. It can be used to give advice on how to mitigate the environmental effects due to highway construction activities. The conclusion of this study indicated this system will be beneficial in making decision to consulting engineers, construction engineers, construction managers, construction coordinators, decision makers and civil engineering students.

Key words: Expert system, highway construction activities, river pollution, best management practices, knowledge-based

INTRODUCTION

Typically during highway construction, associated grading activities are initiated with a clearing and grubbing phases in which vegetation and other naturally occurring soil stabilizing materials are removed from construction site. The surface areas and slopes created by excavation or embankments are exposed to the erosive forces of wind and rain until the earthwork is completed and the grassy vegetation is restored or the surface is artificially stabilized. There are so many kinds of mitigation measures used so as to reduce the impact of highway construction generated pollution such as, erosion and sediment control or source management methods. Slope covering techniques include temporary and permanent vegetation establishment, plastic sheeting, straw and wood fibre mulches, matting, netting, chemical stabilizers, or some combination of the above. Sediment control may be considered as the second line of defense which includes sedimentation ponds, post-sedimentation pond devices and silt or sediment barriers (Hittman Associates, Inc., 1976).

Highway construction engineers must make judgments based on experience acquired over many years for the purpose of elimination/reduction of the effect of highway construction on the adjacent water bodies. Gaining this experience can be difficult because of the time and wide range of knowledge involved. As a result, this type of problem is suitable for an expert system type approach (Zhu and Simpson, 1996). The development of an expert system that will be integrated with the geographic information system for minimising the effect of highway construction on the water quality is the most appropriate, beneficial and economical approach for such problems.

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Flanagan *et al*. (2002) evaluated the effects of polyacrylamide (PAM) and gypsum soil amendments treatments on runoff, sediment yield and vegetation establishment in field plot experiments on steep slopes under natural rainfall. They conducted two experiments in which one of them was conducted on a highway cut slope on clay loam subsoil placed on 35% slope. The second experiment was conducted in a surface sanitary landfill on a filled silt loam top soil placed at a 45% slope. Total runoff volume and sediment loss were measured by using a barrel collection system. Results from this study indicated that the two experiment silts treated with PAM was able to reduce the total soil loss in the range of 40 to 54%, compared to the control. On silt loam soil, the addition of gypsum had a significant effect on runoff volume, possibly due to higher rainfall at that site. Grass establishment and growth on treated plots was increased by the application of PAM and PAM with gypsum compared to the control. As a conclusion from this study is that the use of anionic polyacrylamide (PAM) (with or without gypsum) can provide substantial benefits in reducing runoff and soil loss and enhancing vegetation growth on very steep slopes.

Silt fence is one of the most widely used mitigation measures at highway construction sites. Many studies done for highway construction sites showed failure for using the silt fence due to flow around the end of the fence, besides the concentrated erosion along the toe of the fence. For solving such problems, erosion and sediment control manual often recommend installing a tie back at the down slope end of the fence.

Barrett *et al*. (1995) suggested tying silt fences back into the contour with a tieback (j-hook) pattern to originate a small sediment basin that can permit sediment deposition. However, these references neither give a quantitative guesstimate of the effectiveness of tieback designs, nor present a sane explanation for how and why they work. Moreover, none of the putting in procedures takes in to consideration the effect of highway grade in their design, which adds considerable uncertainty in the use of silt fence tie back installations.

The first prototype development is often the interesting subset of the task chosen to demonstrate the capability of the whole project. For an encouragement and as a focusing device, rapid prototype development may be based solely on texts. The time scale for the development of a typical prototype varies according to the nature of the problem. There are three conditions under which rapid prototyping can be successful in developing solutions to knowledge-intensive problems. They are: the problem should be sufficiently small that one person can understand and encode the problem directly; the system is experimental and will not require maintenance or modification and a tool should be available for developing the prototype.

The objective of this study is the development of a rapid prototyping Highway Construction Expert System acronym as HCES, that was developed to give recommendations on how to minimize the impact of vehicle maintenance, servicing, washing and fueling activity that are utilized in the highway construction sites to the storm water and consequently to the adjacent water bodies. This rapid prototyping has been developed in the early stages of the HCES development, in which after the completion of the whole system will be beneficial for civil engineering students, consultant engineers and so on.

MATERIALS AND METHODS

The knowledge-based: 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 highway construction domain; the knowledge engineer has to be familiar with the essential components of expert system technology as well as the domain of highway construction. 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.

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 Fig. 1. This flow diagram was used to develop objects and rules for the knowledge based. The diagram shows that the user have to select the main activity (in this study the researchers chosen the first activity that is entitled temporary occupation) and then, selecting the sub-activity (entitled vehicle maintenance, servicing, washing and fueling).

After selecting the main and sub-activity, the user have to select the impact that will be associated with this activity on adjacent water bodies (let say reduced water quality by hydraulic fluid spills or by suspended solids). Afterwards, the user have to adjust the water quality default values based on the standard levels and then selecting the water quality parameters that the user going to put his/her monitored values for the purpose of comparing these two kinds of values and give recommendations on how to mitigate the impact associated with this activity on the adjacent water bodies based on the contamination/pollution level.

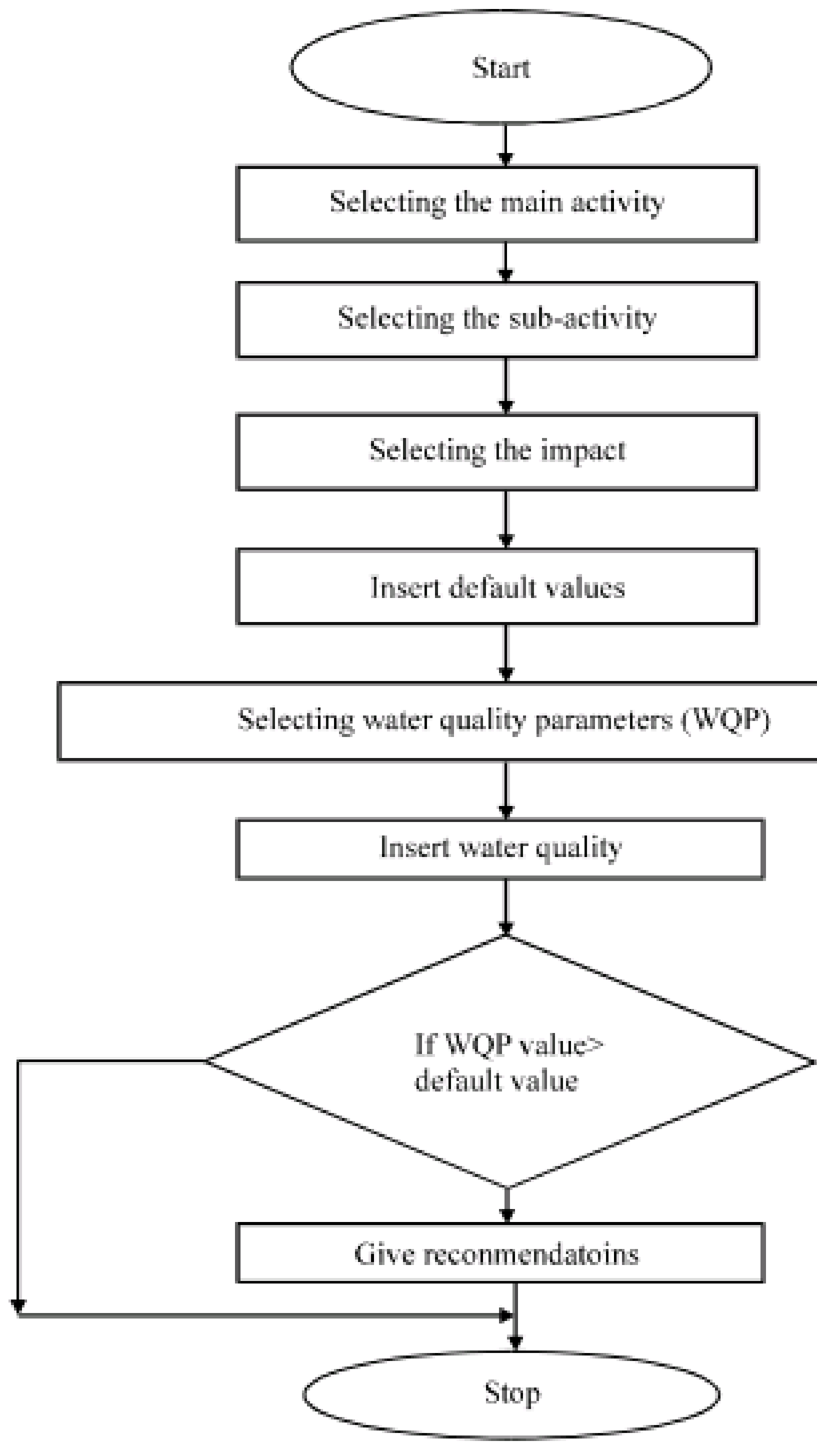

Fig. 1: Flow diagram of knowledge for minimising river pollution during highway construction activities

Prototype development tool: For the development of HCES, object-oriented commercial software called Matlab was used. Apart from its powerful object-oriented capabilities, enable the interfacing with user, making human computer interaction more natural and easily, Matlab also allows representation of knowledge using production rules. Matlab (Houcque, 2005) is very powerful and safe programming language tools, further it is especially well suited for dealing with complex knowledge. Moreover, Matlab was chosen because of its proven reliability and knowledge engineers' familiarity of working with this language.

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 HCES knowledge based are acquired from many sources that were written by experts and related professional institutions (Construction Site Best Management Practices (BMPs) Manual, 2003; Wright Water Engineers, Inc. and Denver Regional Council of Governments, 1999; Department of Environmental Services City and County of Honolulu, 1999). Acquiring knowledge from such sources was felt to be the most difficult and time consuming task in this rapid prototyping of HCES.

The knowledge acquisition was performed by classifying and summarizing information needed for the vehicle maintenance, servicing, washing and fueling in highway construction site and by incorporating the writer's experience in this field. Knowledge representation is a method of organizing and representing the knowledge. By far the most popular knowledge representation technique is ruled-based. A ruled-based system such as highway construction production rules, specify a set of conditions and use an if-then statement to represent a production rule.

The operation of HCES 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 Matlab (for windows XP and above) and at least 1.66 GHz CPU. The following sections give the general information about the system, input information required, typical output in the form of recommendation and overall evaluation of the system.

RESULTS AND DISCUSSION

The result of this study is the output of the rapid prototyping Highway Construction Expert System (HCES) which are presented via figures and associated with well illustration for each. Figure 2 shows the first window of the HCES. To start formal consultation the user needs to press on the Continue button (Fig. 2) that will open new window as shown in Fig. 3. This window (Fig. 3) comprises the main window of HCES. The system will be divided into two parts, one of them is for the highway construction activities that do not need to choose any site characteristics (i.e., topography, drainage, soil type, ground cover, critical areas and so on) and the other part is for the highway construction activities that have to use site characteristics so as to give recommendations based on these site characteristics. For the rapid prototyping it will be under the first part that does not need any site characteristic and the recommendation will be given based on the contamination level only (i.e., water quality parameters). For the other part of the expert system, it will be developed later on.

Fig. 2: First window of HCES

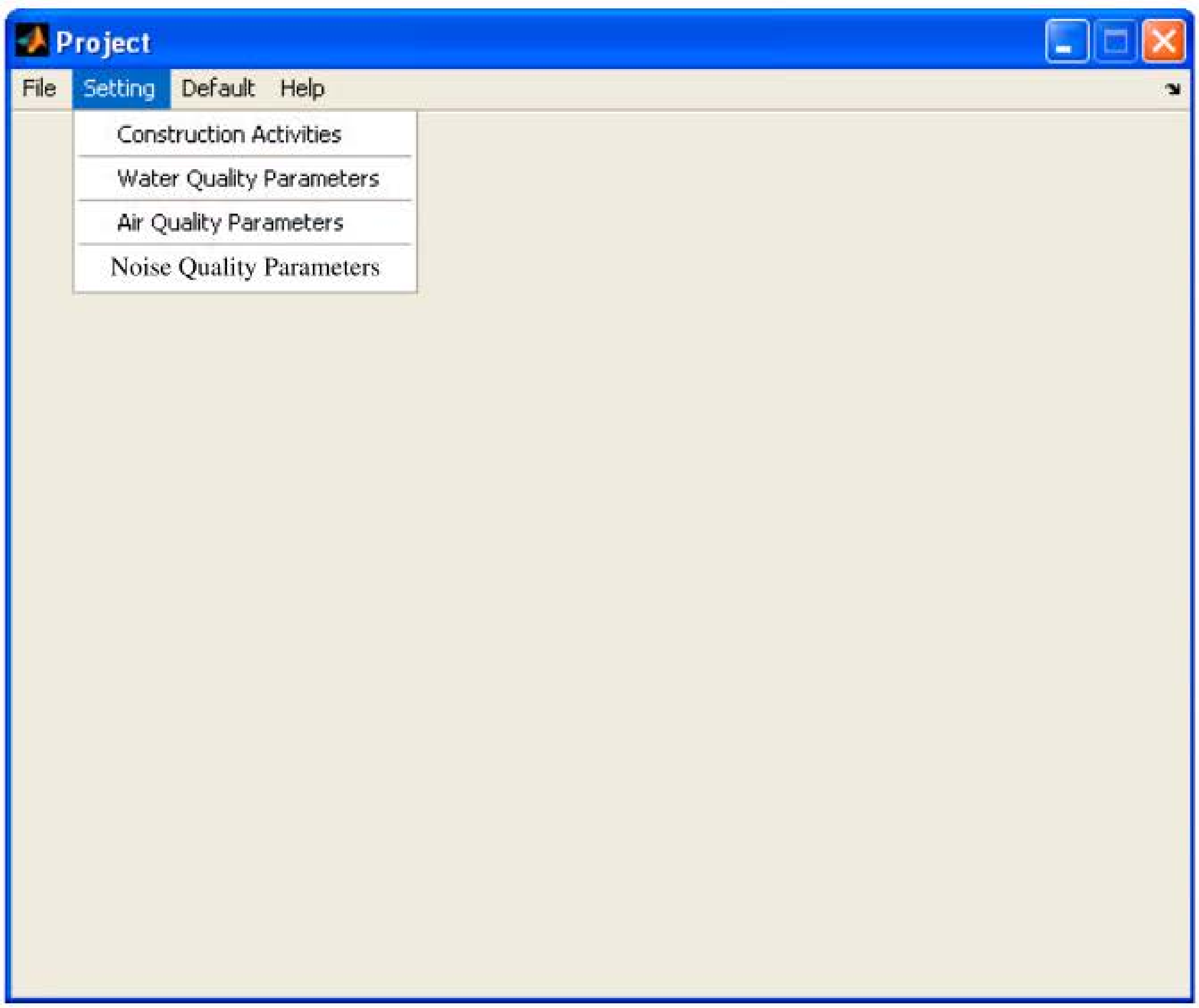

Fig. 3: The main window of HCES

Data input: The user has to press the default button that is located in Fig. 3 and the window that will appear as in Fig. 4. Figure 4 shows the default values adjustment by choosing the type of parameters such as chemical, physical, biological, or heavy metals and then input the standard data and press the save button for the purpose of saving the inserted values in the system. For the monitored water quality parameters data insert, it is well shown in Fig. 5. After inserting the data of monitored water quality parameters, the user have to press the advice button (Fig. 5) for making the system give recommendations on how to reduce the pollution that is associated with the selected activity on the water quality.

Recommendation and explanation: The system gives recommendation in a transcript image according to the data supplied by the user. The HCES produces recommendations by comparing the monitored water quality parameters that the user enters in the system with the default values. A typical output transcript image of recommendations for the input data is presented to the user via PDF file format as shown in Fig. 6.

Overall evaluation of the system: The consultation process of the HCES 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 HCES has the ability to run using Windows operating system. Moreover, the knowledge of the HCES 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 and

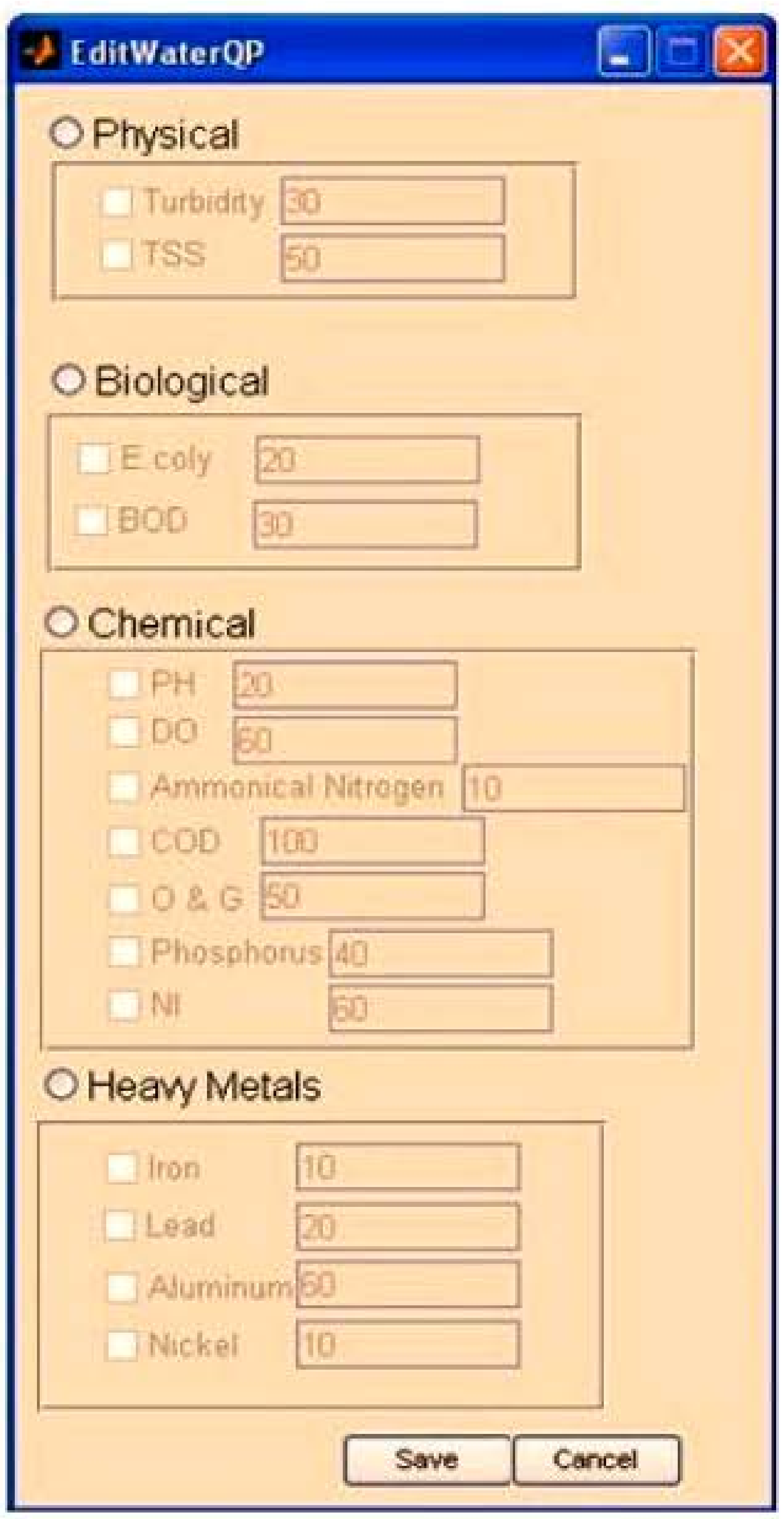

Fig. 4: Editing window for the default values

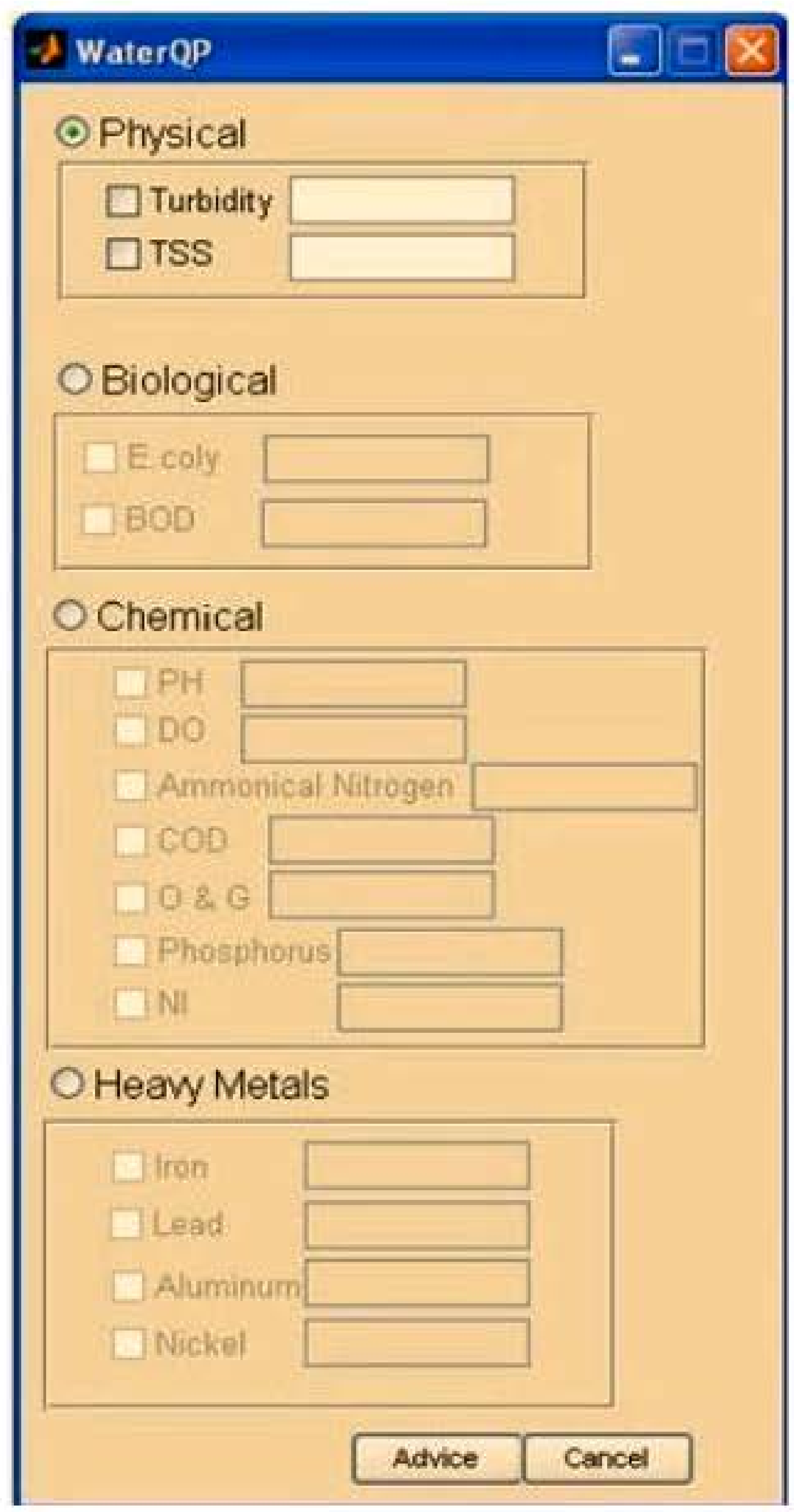

Fig. 5: Editing window for the monitored values

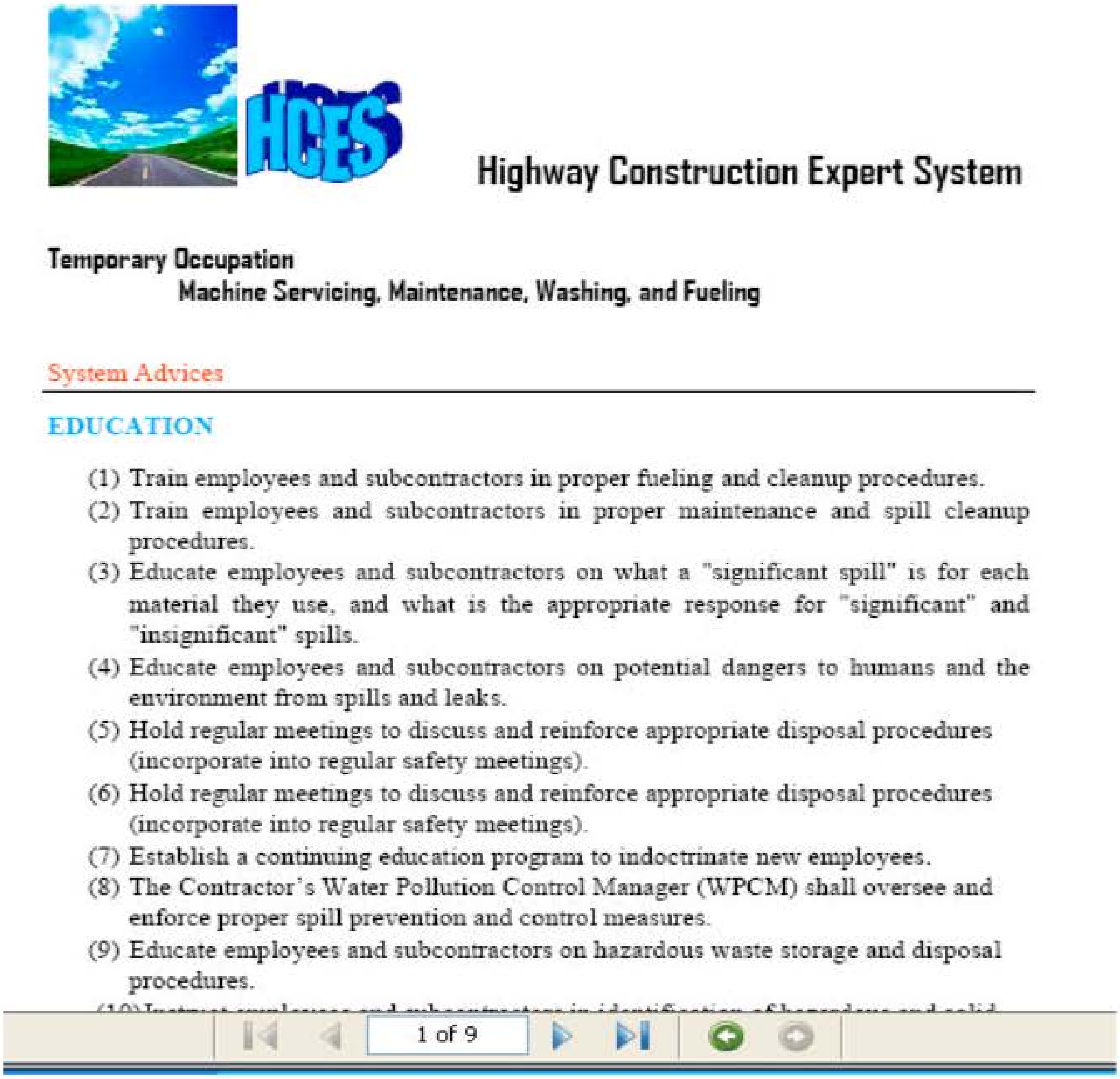

Fig. 6: Typical output of recommendations for the input data

needs to change and to include new knowledge. All expert systems including the HCES, cannot claim completeness in their knowledge bases; they are always subject to upgrading, modification and correction. The existing knowledge base for the HCES can be improved by:

- Refining, expanding and reinforcing its knowledge base using new findings as reported in literature or new experience from domain expertise
- Adding further functional capabilities
- Adding photographs as bitmap images showing the preliminary design of the advice for example the preliminary design of the silt fence that is used for sedimentation capturing

CONCLUSION

Highway construction activities will generate massive amount of different types of debris and pollutants that will degrade the quality of the adjacent water bodies, thus, will affect the habitats of ecosystem, fish spawning areas, navigation by the sediments that will be deposited into the river and so forth.

This study has presented a demonstration rapid prototyping expert system knowledge-based expert system (HCES). In particular this rapid prototyping expert system is developed to give advices on how to minimize the impact of vehicle maintenance, servicing, washing and fueling on the ambient environment. Development of this demonstration rapid prototyping is feasible. The programming language is Matlab version (R2008 a) for developing the system. The use of Matlab provides greater flexibility and adaptability in developing this rapid prototype. The 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 code. Debugging the program is often more difficult. It was indicated that this system will be beneficial in reducing the time for the consulting engineers, construction engineers, construction managers, construction coordinators, decision makers and civil engineering students.

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