# Artificial Intelligence Expert System for Minimizing Solid Waste during Highway Construction Activities

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*Abstract*— **The development and the main features of an Artificial Intelligence rapid prototyping expert system for highway construction, called Highway Construction Expert System (HCES), are described. This rapid prototyping has been developed for giving advices on how to minimise the impact of solid waste management in the construction site. Using Matlab, an object-oriented model was developed where the rule-based reasoning and other decision processes operate on or across objects. The knowledge and experience were acquired from various textural sources. Results from this study can be demonstrated as a typical output transcript image of recommendations for the input data that are presented to the user via PDF file format. For an encouragement and as a focusing device, this rapid prototype was based solely on texts and was developed in the early stages of the development of Highway Construction Expert System (HCES).**

***Index Terms*— Expert system, environmental impact assessment, highway construction, rapid prototyping.**

## I. Introduction

Highway construction and associated grading activities typically are initiated with a clearing and grubbing phases in which vegetation and other naturally occurring soil stabilizing materials are removed from the 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 control and sediment control or source management methods. Slope covering techniques include temporary and permanent vegetation establishment, plastic sheeting, straw and wood fiber 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 [1].

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 [2]. 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.

"Ref. [3]" indicated that sediments from construction sites typically consist of larger percentage of smaller particles (silt and clay) than the parent soil. This is because of the small (unconsolidated) particles in storm water runoff associated with highway construction that are displaced easily than the larger particles in compacted soil further more the smaller particles remain in suspension for longer periods of time (settle slowly) and are transported readily.

Many researchers [4]-[5]-[6] recommended the rapid prototyping approach where knowledge acquisition is integrated with the development of the prototype. 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 [5].

The objective of this paper is the development and the main features of a rapid prototyping highway construction expert system (HCES) that was developed to give recommendations on how to minimise the impact of solid waste management that will generated during the various steps in highway construction and demolition activities to the adjacent water bodies or to the construction site environment.

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## II. Development of the Highway Construction Expert System (HCES)

### A. The Knowledge Base

A knowledge engineer acquires knowledge from various sources of expertise and codifies it into an expert system [7]. As a 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.

### B. Sources of Expertise

Criteria for the selection of sources of expertise are domain specific [8]. Regarding the case of highway construction, there were a variety of expertise sources, e.g. manuals, guidelines, conference papers, journal papers, which were found in scattered locations. Such a situation necessitated the selection of multiple sources of expertise. Knowledge for the HCES was thus acquired from manuals [9, 10, 11] written by experts and related professional institutions, and research papers. Acquiring knowledge from these sources was felt to be the most difficult and time consuming task in the prototype development process.

### C. 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 1. This flow diagram was used to develop objects and rules for the knowledge base. The diagram shows that the user have to select the main activity (in this paper the authors chosen the first activity that is entitled temporary occupation) and then, selecting the sub activity (solid waste management), then the system will ask the user on the type of the solid waste that are associated with his activity as it is categorised into sex main categories they are (1) vegetation and demolition waste from land clearance, (2) excavated materials from embankments (cuttings, pile foundation), (3) general construction work, (4) bentonite slurries from pipe construction, (5) chemical wastes from general practices (vehicle and equipment maintenance), and (6) municipal wastes generated by site workers. After selecting the main and sub-activity, the user have to select the impact that will be associated with any of these sex kinds of wastes on water bodies (let say increase the suspended solids associated with demolition works). Afterwards, the user have to adjust the water quality default values based on the standard values and then input the monitored water quality parameters for the purpose of comparing these two types of values and give recommendations on how to mitigate the impact associated with this activity on the adjacent water bodies and the ambient environment based on the contamination level.

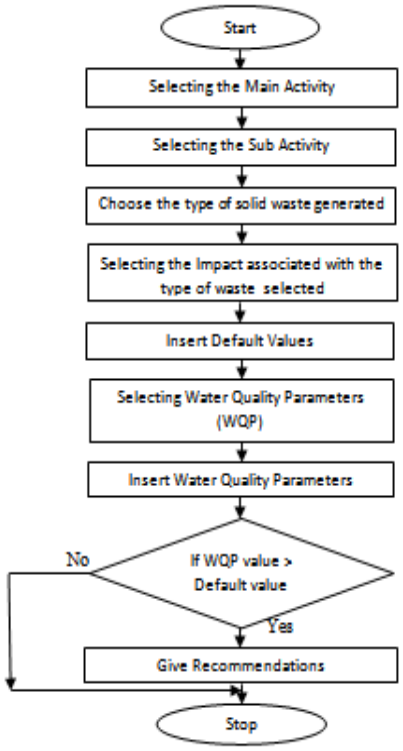


Figure 1: Flow Diagram of Knowledge for Minimising River Pollution during Highway Construction Activities.

### D. Prototype Development Tool

For the development of HCES, an object oriented, 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 is a 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.

### E. Production Rules of the Acquired Knowledge Prototype

After the construction of the object-oriented model of the domain, the knowledge presented in the flow diagram (Figure 1) was transformed into a rule-based structure called production rules. To be workable in Matlab, these production rules were translated into Matlab format.

## III. Main Features of the Highway Construction Expert System (HCES)

The operation of HCES consists of a series of selections linked by if-then logic. Its control system supports a forward-chaining procedure. The HCES (Highway Construction Expert System) 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.

### A. *General Information*

The Highway Construction Expert System rapid prototyping HCES was developed for giving advices on how to minimise the effect of solid waste that are generated in the construction site to the ambient environment, this can be accomplished by identifying the impact associated with this activity to the adjacent water bodies and identifying the parameters involved for each type of solid waste generated during highway construction. (Total suspended solids, turbidity, oil and grease, heavy metals and so forth). Figure 2 shows the first window of the HCES. To start formal consultation the user needs to press on the **Continue** button (Figure 2) that will open new window as shown in figure 3. This window (Figure 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 our rapid prototyping it will be under the first part that does not need any site characteristic and the recommendation will be given basing on the contamination level only (i.e. water quality parameters). For the other part of the expert system, it will be developed later on.

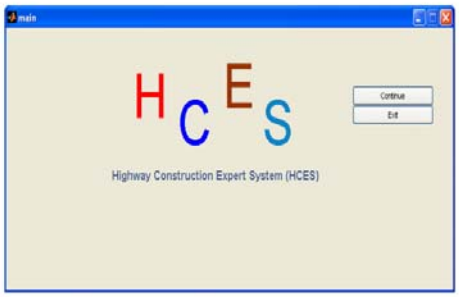


Figure 2: First Window in HCES

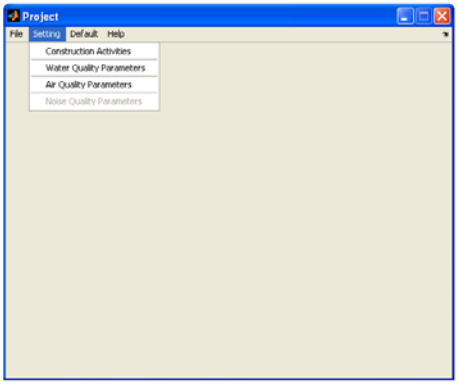


Figure 3: The main window of HCES

### B. *Data Input*

Data input session is well illustrated into Figures 3, 4, and 5. The user has to press the default button that is located in Figure 3 and the window that will appear is Figure 4. Figure 4 shows the default values, and then choose 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 inserting, it is well illustrated in Figure 5. After inserting the data of monitored water quality parameters, the user have to press the **Advice** button (Figure 5) for asking the system to give recommendations on how to reduce the pollution that is associated with the selected activity to the ambient environment.

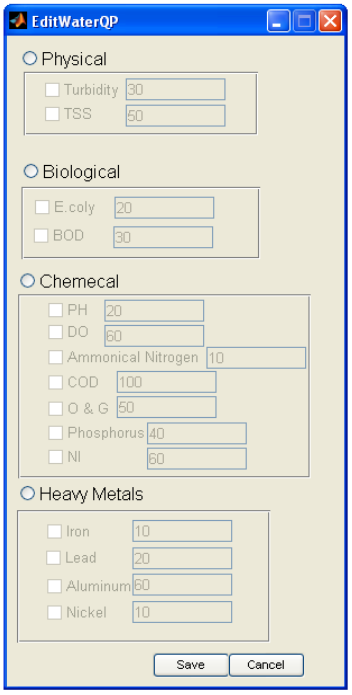


Figure 4: Editing window for the default values.

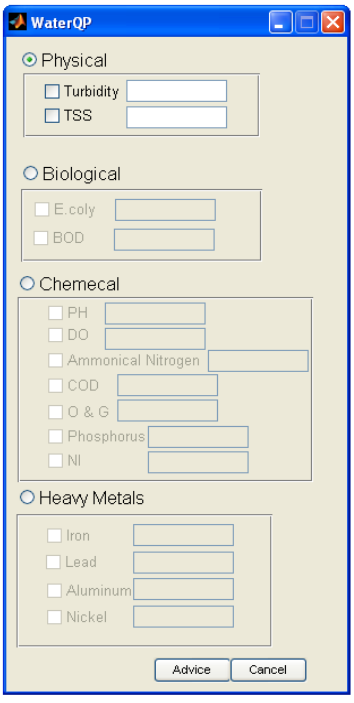


Figure 5: Editing window for the monitored values

### C. *Recommendation and Explanation*

The system gives recommendations 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 Figure 6.

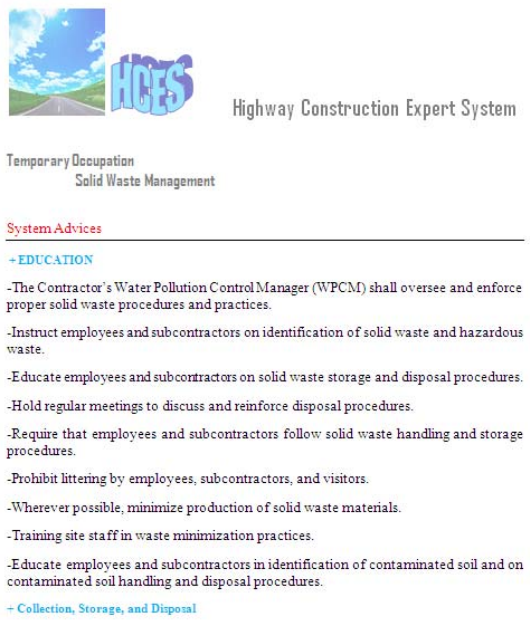


Figure (6): Typical output of recommendations for the input data.

### *D. 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 of the guide compared to those of the similar systems. 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 needs to change, and to include new knowledge. All expert systems, the HCES included, 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

(1) refining, expanding, and reinforcing its knowledge base using new findings as reported in literature or new experience from domain expertise;
(2) Adding further functional capabilities.
(3) 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.

## IV. CONCLUSION

Highway construction activities will generate massive amount of different types of 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. An extensive literature review on the solid waste management in the construction site revealed that most of the available guidelines and instruction manuals (regarding the solid waste generated during highway construction activities) implementation are in conventional format. We have found that the hardcopy and compact disk manuals are not readily available for efficient use and requiring a familiarity with solid waste management in order for selection. The situation led the authors to initiate a simplified expert system that incorporates knowledge and inference rules derived by specialists in the field.

The use of expert systems can minimize the effect of highway construction to the ambient environment especially for the case of solid waste management in the construction sites. The developed prototype expert system, the Highway Construction Expert System (HCES), is an attempt to achieve this objective. Knowledge was acquired from a variety of expertise sources, modeled using the object-oriented approach in combination with rule-inferencing techniques, and codified into software. It has reasonably achieved the objective of harnessing scarce expertise in an important domain, and exploiting the potential of the latest in software technology in order to create a user-friendly expert system.

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