A Review on Computer Based Expert System for Evaluation of Erosion Control on Highway Applications

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Abstract: *The paper described herein has led to a convenient; computer based expert system for identifying and evaluating potentially effective erosion and sedimentation control measures for use in roadway construction throughout Iowa and elsewhere in the Midwest. The expert system is intended to be an accessible and efficient practical resource to aid state, county, and municipal engineers in the selection of the best management practices for preventing unwanted erosion and sedimentation at roadway construction sites, during and after construction. The expert system is based on a comprehensive review of the literature on erosion and sedimentation control methods (ESCMs). The literature includes diverse in house manuals, information on state DOT websites, as well as an array of publications from various agencies and industry, design manuals, guidelines, and specialized computer programs. The literature review and the surveys led to the expert system, which comprises a structured of information on ESCMs. It provides information on the principal technical, implementation, economic, and operational efficiency considerations. A notable finding of the literature review and the state DOTs survey is the identification of numerous in house manuals developed by the various agencies directly involved with mitigating erosion and sedimentation concerns. The manuals are mainly in hardcopy format, though some are in an electronic format. The literature review and survey revealed that, although extensive ESCM literature exists, much of it is not organized to enable effective use by highway engineers. This finding motivated the paper investigators to initiate and develop a contemporary, computer based expert system.*

Keywords: ESCM, DOT, Sediment Control, EPA, Expert System.

Introduction:

Each year, large amounts of soil are eroded from highway sites, especially from highways under construction. It usually is rather difficult to control erosion at highway construction sites because of the extent of disturbed soil and the difficulty of controlling water runoff.

Though data on the overall rates of sediment transported to streams at these sites limited, erosion rates from them are typically 10 to 20 times the rates from agricultural land, some reports suggest erosion rates up to 100 times as high. The eroded soil incurs severe economic costs (e.g., excavation or dredging, soil replacement, highway consolidation) and environmental impacts (e.g., deterioration of water quality in the watershed and streamside vegetation, removal of important topsoil constituents). Consequently, erosion prevention and sedimentation control are major factors in the design, construction and maintenance of highways. Irrespective of paper size and erosion mitigation method, selection of the optimum erosion control measures for a specific situation needs to be facilitated using a comprehensive, yet straight forward plan. Besides being technically feasible, quick, and economic, the current approach in implementing an erosion control paper includes compliance requirements with federal, state, and local regulations. Protecting water quality is of paramount concern in this regard. The new Phase rules from the Environmental Protection Agency (EPA) concerning storm water erosion and sediment control practices. Moreover, state DOT's must be ready to demonstrate how current methods, as well as new and innovative methods, will meet the water quality standards mandated by the Phase rules. Efficient planning for erosion control requires a comprehensive consideration of site topography, drainage pattern, rainfall data, soil data, existing vegetation, off-site features (streams, lakes, buildings), as well as available types and operational characteristics of the erosion control methods. These varied and complex considerations, commonly limit the number of problems encountered in finding feasible and economic methods to minimize erosion. Several disciplines of science and engineering are required to address erosion problems. Highway designers, paper engineers, and maintenance personnel often need the advice of hydrologists, hydraulic engineers, soil engineers, soil scientists, agronomists, landscape architects, and other specialists to minimize erosion problems. The literature regarding erosion control methods are scattered in diverse published accounts such as guidelines or instructional manuals published by an array of agencies, such as Environmental Protection Agency. The lack of a centralized source of information has led to a variety of erosion-control designs and procedures now in use during highway construction. Therefore, engineers from state, counties, and municipalities are forced periodically to conduct extensive literature reviews of erosion and sediment control protection methods. The reviews can be labor intensive, requiring engineers to survey needs, and develop best management practices for erosion and sediment control, and to adapt methods to meet the climatic variations that prevail locally. The objectives of the present paper are identification and evaluation of erosion control methods utilized in highway applications in Iowa through a literature review

and assemblage of this information in a practical resource. This compilation provides assurance that the best appropriate methods for preventing erosion are being used at each site, during and after construction. The present paper entailed a comprehensive review of the literature on Erosion and Sediment Control Methods (ESCM). The literature was collected through conventional means, internet search, and a survey submitted to the Great Plains and Mississippi Valley DOTs. A cursory examination of the literature shows that there are numerous guidelines for erosion and sediment control methods used in highway applications. The literature survey conducted for this study revealed that all the surveyed DOTs rely on guidelines assembled in hardcopy manuals comprising hundreds of pages. Manual layout commonly follows conventional arrangement of content; i.e. temporary measures, permanent measures; or, alternatively, measures for protection of soil surface, runoff control, and sediment removal. Most of the newer manuals include the provisions related to the Storm Water Pollution Prevention Plans (SWPPP) that are presented separately. Important considerations involved in the selection process, such as overall efficiency and suitability of Erosion and Sediment Control Measures (ESCM) for particular conditions is not included. It is, therefore, often difficult to use the published literature to quickly identify, assess, and efficiently select site specific erosion control methods for temporary or permanent use.

Review of Literature:

The review of literature on highway erosion and sediment control methods, included publications from diverse sources: state DOTs websites, industry, and tribal, state, and federal government publications, design manuals, federal and national guidelines, and computer programs. Particularly useful information was obtained from a survey of DOTs. The questionnaire used in the survey, the list of contacted persons, and the summary of the survey responses, and specific comments are presented in paper. The common characteristic for all DOTs, in this regard, is that most they have developed their own in house compilations of manuals/guidelines, possibly to take into account specific issues related to local state conditions. The survey reveals another common feature, namely that almost every state DOT compiles its own customized set of manuals/guidelines adapting best management practices for erosion and sediment control to allow for the climatic variations that prevail in the respective state. An increasing number of these publications is available on the internet, some at no charge, some procurable at modicum prices. The availability of the literature in electronic format is advantageous because the software used for displaying the documents contains rudimentary search engines that provide increased flexibility in use. However, the search engines are general tools with limited functionality for efficient selection of an ESCM.

The literature review also searched the internet and software for information on ESCMs. Both electronic sources of information are being actively developed, and hold great promise for disseminating information on erosion and sediment control for roadway applications. However, currently these sources have not attracted independent use. In summary, the literature and internet surveys show that there exist numerous sources of information covering aspects of ESCM design, construction, permit compliance, inspection, and removal. The existing sources are useful for design engineers, or engineers with vast experience in the area. However, the sources often are difficult to be used by practitioners with limited experience on ESCMs, such as city and county engineers with limited access to colleagues with extensive ESCM expertise. The number of information sources available in electronic format is growing, but these sources do not yet significantly aid the decision making and design. Rather than compiling a new set of paper guidelines on ESCMs, the present study initiated the development of an expert system to aid ESCM selection. The bulk of the literature surveyed for this study now is enclosed in the expert system. The content structure and operation of the system are described next.

Expert System Concept:

The work described leads to an expert system that identifies and provides specifications on erosion and sediment control measures for highway applications in Iowa. The expert system assembles pertinent literature on erosion and sediment control in an efficient, practical source that can be accessible for highway engineers of various levels of technical background. An expert system is the best choice for accomplishing this task. The role of the expert system is to identify that the appropriate methods for erosion and sediment control are used at each site, during and after construction. An expert system (ES) is a type of computer application program that aids decision making or solving problems in a particular field by using knowledge and analytical rules defined by experts in the field. Expert systems are part of a general category of computer applications known as artificial intelligence, because these computer applications perform tasks that would otherwise be performed by a human expert. For example, there are expert systems that can diagnose human illnesses, make financial forecasts, and schedule routes for delivery vehicles. Some expert systems are designed to take the place of human experts, while others are designed to aid them. To design an expert system, one needs to study how human experts make decisions and translates the rules into terms that a computer can understand. Human experts solve problems by using a combination of factual knowledge and reasoning ability. In an expert system, these two essentials are contained in two separate but related components, a knowledge base and an inference engine.

The knowledge base provides specific facts and rules about the subject, and the inference engine provides the reasoning ability that enables the expert system to form conclusions. Expert systems also provide additional tools in the form of user interfaces and explanation facilities. User interfaces, as with any application, enable people to form queries, provide information, and otherwise interact with the system. Explanation facilities, an intriguing part of expert systems, enable the systems to explain or justify their conclusions, and they also enable developers to check on the operation of the systems themselves.

ES Design Principles:

The expert system (ES) designed during this study is a comprehensive guide aimed at assisting state, city, and county engineers to select, design, construct, inspect, and maintain erosion control measures. Special attention was given in the design of ES to ensure that the optimum solution for mitigation of soil erosion effects takes into account site conditions, the lifetime of the planned solution, and conditions in Iowa. The current version of the expert system is configured for PC platforms. Further development of the database, as a web-based engine, can be expanded to other user categories, i.e., associate general contractors, design engineer, consultant engineers, etc. The present ES was developed with its users in mind. Discussions with state DOT personnel during the initial stage of ES development emphasized that primary users will be field engineers. Suggestions collected from state and county engineers prompts to development of the ES for ESCMs. The design of the ES was guided by the principles described below:

- **Comprehensive simulation of the ESCM decision making process**. All technical elements involved in the selection of the control measures are incorporated in the ES (objectives, type, site evaluation, ESCM specifications). Permitting considerations relevant to selection of the ESCM are also included.
- **Multi layered information:** User interfaces for each requested input or output information are contained by two or more layers: the first layer addresses general information valid for classes of ESCM, while the subsequent layers address details pertaining to specific factors or selected ESCM. Given the fact that field engineers are only occasionally implementing ESCMs, the terms of the interfaces are explained in plain language to accommodate various technical backgrounds.
- **Self Contained:** The various levels of information make the ES a comprehensive source of information that does not need additional references to guide in the selection of the appropriate ESCM for a particular situation. When needed, the user is directed

to additional sources of information regarding data collection, and data interpretation and evaluation.

- **Portability:** The current design of the ES assumes user access to a personal computer (PC). Further development considers transitioning to web-based version of the ES that will allow user to access the information from any computer. Each of the steps involved in the decision making process can be printed as hardcopy containing exclusively the specifications related to the ESCM of interest.
- **Compact format and efficient navigation:** Use of the multi-layer structure allows minimization of the number of ES interfaces. Navigation rules are simple and straightforward, thereby enabling users to form queries, provide information, and efficiently interact with the ES. The ES prompts the user when input data are incomplete or the functions are not yet implemented in the engine.
- **Flexibility:** The design of the ES allows unlimited further development and upgrading of the database with minimum changes to the core ES elements.
- **Iowa Specific**: Though the information assembled in the ES is collected from various state DOTs and Iowa counties, priority was given to include ESCMs evidently best suited for Iowa and to rely in principal on the literature resources available in the state.

ES knowledge Base:

The content of the ES is based on relevant information regarding erosion and sedimentation control methods collected from the sources, with special emphasis on ESCMs utilized in Iowa, The review of the information was not a simple compilation of the erosion control measures used in highway applications. The review was conducted to develop a structured encompassing all the relevant elements involved in ESCM design, construction, inspection, maintenance, removal, economical considerations, and efficiency considerations. Once set in place, the ES can be updated and upgraded to include the best management practices (BMP) as they develop. Papers that expose areas of soil to erosion, such that sediment could adversely affect operations on the highway or associated rights of way could be introduced into receiving waters, or could affect adjacent properties, sensitive environmental resources need to provide ESCM. Efficient planning for ESCMs requires a comprehensive knowledge of the site to be protected, permitting requirements, as well as the available types and operational characteristics of potential ESCM. The database attempts to take into account all of the variables that impact the decision making process when one selects a BMP for ESCMs. Papers involving no clearing and grubbing, excavation, stockpiling of topsoil, borrow or construction of embankment normally will not require an ESCM. Therefore, they are not

included in the ES. Examples of such actions are: installation of lighting, signing, traffic signals, guardrails, weed spraying, and pavement marking, seal coating, and planting of landscaping materials.

ESCM Specifications:

The ES provides in one place all the elements needed for the user to select the best ESCM option. At this point in time, due to the limited resources available for the paper, the descriptive elements regarding each ESCM are provided as citations of reference, including the page where the specific information can be found. Despite of the extensive literature used for compiling the present ES, the references are limited to those used by the Iowa DOT (IDOT), as well as Iowa county and municipal engineers. This limit is used because of considerations of accessibility and technical acceptance by DOT, county, and municipal engineers. Future development of the ES will include detailed Plan Notes, Special Provisions, Supplemental and Standard Specifications for each ESCM. It is envisioned that the ES will use direct links to existing internet information or may duplicate the information in an electronic format.

CONCLUSION:

The objectives of this paper are to evaluate the literature on erosion and sediment control measures, to synthesize the best management practices relevant to Iowa conditions in an efficient format, and to formulate further research lines that significantly improve current practices in erosion and sediment control applied to roadway construction. The paper involved a comprehensive literature review on highway erosion and sediment control methods, including specialized publications, state DOTs websites, industry, various publications, design manuals, federal and national guidelines, and computer programs. Particularly useful in the review were two surveys. The state DOTs survey revealed that the current practice for documentation of erosion and sediment control methods (ESCMs) is the preparation of and periodical upgrading of in house manuals, disseminated in hardcopy or electronic format. The most cited references for direct use (or otherwise assimilated in the manuals) are EPA and IECA. The literature review also revealed that, though extensive ESCM literature exits, much of it is not configured for convenient use by highway engineers. This finding directed the paper to develop a contemporary, computer-based expert system for use by highway engineers seeking guidance on ESCMs. The expert system designed in the study is a comprehensive inference engine aimed at assisting state, county, and municipal engineers in the selection, planning and implementation of ESCMs. It is developed to ensure

that the selected ESCMs take into account site characteristics, the lifetime of the planned solution, and Iowa's Midwest environment. The expert system suggests potential ESCMs for a particular situation, and provides general and detailed information on the technical elements involved in ESCM design, construction, inspection, maintenance, removal, economical considerations, and efficiency. The expert system developed during this paper is the first of this kind for ESCM purposes. The system potentially can serve other state, county, and municipal engineers beyond Iowa. Given that this first version of the expert system is PC based and addresses limited user categories, it is anticipated that by further refining the level of detail of the knowledge database and by transitioning to a web based platform, the expert system can be considerably enhanced. In parallel with the literature synopsis and the development of the expert system, the study identified further research needs regarding methods and materials for erosion control, and methods for transitioning temporary methods to permanent ones.

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