Malaysian Journal of Computer Science, Vol. 12 No. 1, June 1999, pp. 19-27

DEVELOPMENT OF EXPERT DATABASE SYSTEM FOR ENVIRONMENTAL IMPACT ASSESSMENT (EDEIA)

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ABSTRACT

Expert Database System for Environmental Impact Assessment (EDEIA) was developed using FoxPro and CLIPS. It consists of a database and an expert system prototype. The EDEIA system developed a database system that allows an EIA expert to manage EIA report information and produced a set of rules that enable the ES to be aware of the existing environment component classes. The rules were developed according to the environmental component classification characteristics. The system is based on three assumptions: the environmental components and prescribed activities should be classified, the description of environmental component classes as well as the prescribed activities information must be collected; and finally, the potential impact, mitigation measures and residual impact have to be clearly specified. The main role for EDEIA is to assist EIA experts and companies in producing complete and efficient EIA reports. The system is very useful in supporting EIA expert prediction of expected potential environment impact and best method for mitigation measures. The EDEIA system has friendly graphical user interface, as well as satisfying EIA report requirement.

Keywords: ***Environmental Impact Assessment, Expert System, Database Management System, Expert Database System, CLIPS, FoxPro***

1.0 INTRODUCTION

Any choice with a significant impact on the environment should in principle be the outcome of a political process reflecting the social performances of all the people involved. However, this ideal procedure requires time and money at a level that do not justify its application for planning each specific intervention. A wide variety of factors such as disaster, media attention, green consumerism, and tougher environmental legislation, have contributed to this international environmental awareness. Along with this worldwide awareness, Environmental Impact Assessment (EIA) has been established to improve and protect the environment. EIA is a process designed to identify and predict the impact of man's health and well-being as a result of development projects, also to interpret and communicate information about that impact [1]. To complete an EIA efficiently and to realize its objectives the various phases should be taken into consideration [2]. Fig. 1 shows these phases. The first phase is a description of the project (considering its possible linkage with plans, programs and the alternative possible technical solutions), and also a description of the environment (i.e., the place where the project will be installed). The second phase is the identification of the environmental effects (with consideration of potential and important effects), and evaluation of the environmental effects (with discussion of the information needed and the methods to be used). Next, the management and control of the environmental effects (i.e., the mitigation, compensation and monitoring measures that could modify, minimize, etc., the effects). The fourth phase is a presentation of the study (considering how to communicate the result of an EIA). The fifth phase is participation of the public (discussing an EIA study with the public). The last phase involves judgement by the authorities (the comparison of the result with criteria and values i.e. the proper "assessment" and the final political decision).

EIA usually deals with rather complex problems that touch upon many disciplines, and rarely will an individual or small group of individuals have all the necessary expertise at their disposal. The Expert Systems (ES) component of an EIA system helps to fill this gap and at the same time take over the role of tutor [3]. A forecast of likely consequences and impacts has to be based on some kind of model, whether that is a mental model, a set of rules of thumb or heuristics an expert might use, or a formal mathematical model, or the necessary information to be inserted in the procedure. If no specific data is available, one has to look for similar problems where an experience exists and extrapolates and draws upon analogies. This role is usually filled by the expert's knowledge, or by handbooks and similar sources of information.

A reliable and adequate database system needs to be established, to support the subsequent phases of an EIA study, that is, on prediction of impacts to the environment as a result of the proposed development. This can affect relationships between various project activities and the physiochemical, biological and human elements in the project environment and it's surrounding. Hence data gathering is not necessarily limited to the project site but may need to be extended to the surrounding areas [1].

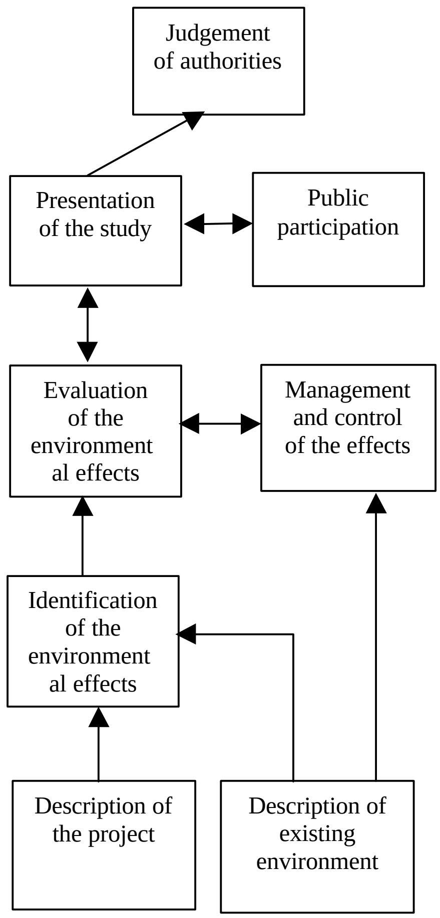


Fig. 1: Main Phases of an EIA study

An expert database system is a development tool for application requiring a DBMS and one or more ES's [4]. In this paper an integration of ES and Data Base Management System (DBMS) technologies is suggested. This Expert Database System (EDS) prototype is designed to produce timely and adequate EIA reports.

2.0 RELATED WORKS

The environment has a very important role in public health (i.e.: cardiovascular pathology, discomfort). Doing an appropriate Environmental Impact Evaluation of man's action will help to preserve public health from possible harmful effects of these actions. Environmental Impact Evaluation using Leopold and Battelle methods have been implemented in the EEIE expert system [5]. SCREENER is a software tool for the initial screening of projects for environmental impacts and selection of mitigation options. Nathan discussed how SCREENER mimics the steps in an initial environmental screening. Details of the main components of the program as well as the expert system (knowledge base) representation were provided [6]. Vrtacnik designed an initial model of an expert system which provide quick responses for Slovenian river water pollution emergency situations [7].

An integrated knowledge-based system RAISON was developed for environmental applications using expert system and neural network technologies [8]. On the other hand Booty presented the RAISON system for carrying out environmental impact assessment for point source discharges, with an example of assessment of acid mine drainage in Ontario, Canada [9]. The management of environmental data requires a database system, which maintains the topology of time and space. Due to the complexity and variety of environmental data such a system should be flexible with respect to the database schema. A database system with a special data model was designed for the management of environmental data in the field of environmental impact assessment [10].

Masera discussed the features of an information system to be used as a tool in EIA studies. A knowledge base system approach has been adopted, as it allows us to store and integrate the abilities necessary in EIA, such as very scientific knowledge and technical skill, and also making them operational to non-experts [2]. The package named SILVIA has been implemented. It includes three parts, concerning, respectively, the preliminary phase, the analysis phase and the decision phase of an EIA procedure [11].

3.0 SYSTEM ASSUMPTIONS

The Expert Database System for Environmental Impact Assessment (EDEIA) is based on three assumptions. The first is that environmental component and prescribed activities were classified. Department of Environment (DOE) specified several environmental components including physiochemical, biological and human environmental categories. The system assumes these environmental components to be classified into classes according to the component characteristics. Furthermore, prescribed activities maybe divided into different types and sizes.

The second assumption is the descriptions of environmental component classes and prescribed activities were expected to collect from sources of EIA study information. The last assumption is the specification of expected potential impact, mitigation measures and residual impact for applied project activities on environment component classes. All these description were prepared from EIA expert knowledge, study of previous EIA reports and literature review. Fig. 2 shows all these assumptions and the system predevelopment preparations. Information is collected from environment data resources, besides the information about project description. Also, potential impact, mitigation measures and residual impact will be collected from EIA experts, historical EIA reports and literature reviews.

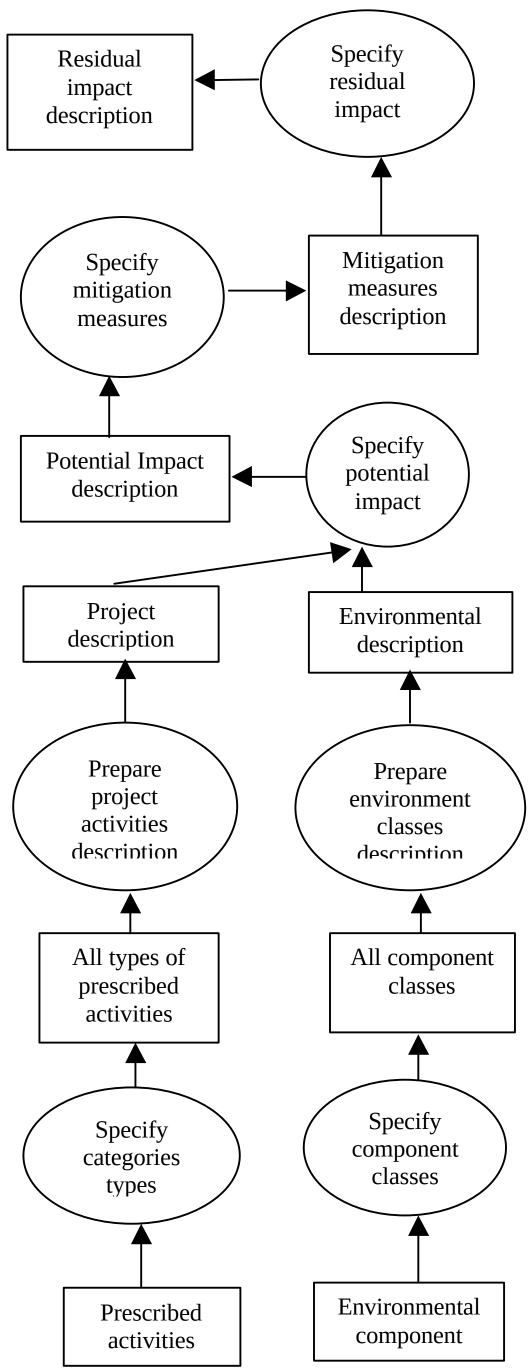


Fig. 2: System Predevelopment Preparation

4.0 SYSTEM OBJECTIVES

The objectives of this study are: first, to develop a database system that allows an EIA expert to manage EIA information related to EIA study, such as an existing environment and project description, besides potential impact, mitigation measures and residual impact. Second, to produce a set of rules which enables the expert system to be aware of the existing environment component classes and project types. Last, to provide one way to integrate database management system and expert system whereby each system is developed individually; then the database system imports the expert system recommendation to manage its queries.

The proposed system provides a prototype to handling any type of sharing information. It also assists an EIA expert to prepare EIA report, supports EIA expert prediction of expected potential environmental impact and assists EIA companies to prepare complete and efficient EIA report in a short time.

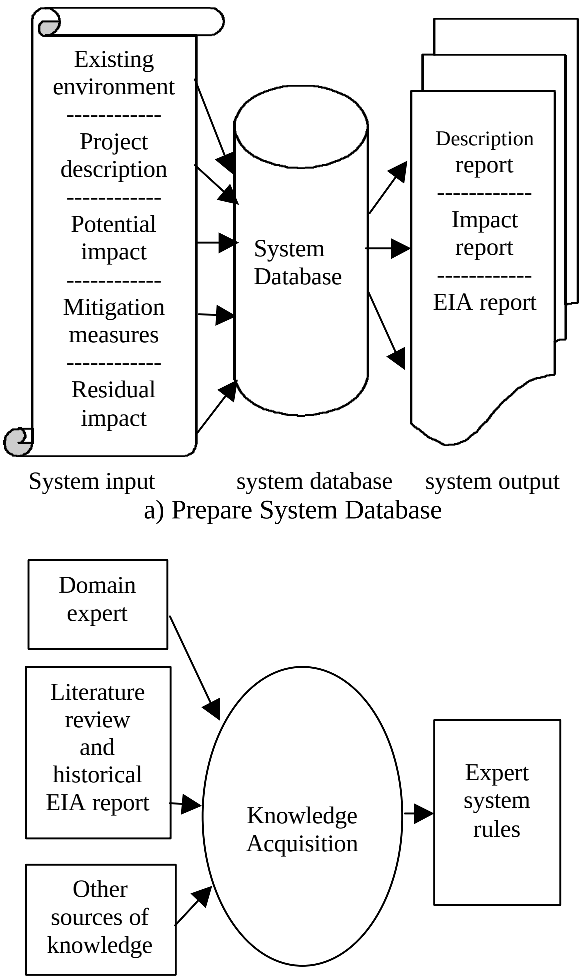
5.0 EXPERT DATABASE SYSTEM COMPONENTS

The system mainly consists of a database management system and an expert system. The function of DBMS is to manage information about EIA study components. The functions of an expert system are to provide recommendation and specify the user environment component classes and prescribed activity type.

The system assumes that all information about EIA components are prepared which includes existing environment, project description, potential impact, mitigation measures and residual impact. The system is divided into two stages, the development stage where it functions to store and manage information about EIA study components, and the operation stage, which provides different functions to the users by using database information and expert system rules.

In the development stage the system permits storage of information about EIA components, in the text and figure form. This is done through data entry screens, using direct manipulation interface and control panels. These data entry screens provide facilities to add, edit, delete and retrieve data items. The system has capabilities to prepare reports for description and impact information. In addition, it prepares the set of rules that enable the ES to be aware of the existing environment component classes. A knowledge acquisition is defined as the transfer and transformation of potential problem-solving expertise from expert and other sources of knowledge to program. Fig. 3 shows the system development stage structure.

The system in the operation stage provides different functions to the system users. The main function is to prepare EIA report through several steps. First step, the user interacts with the expert system interface by answering its questions, which leads to specify the classes of environmental component and prescribed activity. According to that all related information of EIA components should be filtered from the database. In the next step, special information about the project and environment is added to the filter database through data entry screen for text and figure information. Besides that, information about project proponent and project area, location and co-ordinate is inserted by the user. If the user wants to edit, delete or add information to EIA report data, the system provides facilities to do so. The last step is to send the EIA report to the report destination that is selected by the user (printer, file, and screen). Fig. 4 shows structure of the system operation stage.



a) Prepare System Database

b) Prepare Expert System Rules

Fig. 3: System Development Stage

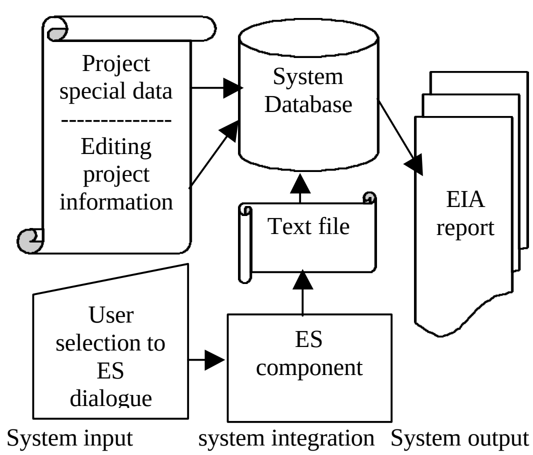


Fig. 4: Structure of System Operation Stage

5.1 EIA Database Management System

The system is based on a database, consisting of all information about the description of existing environment in the specified domain. This includes the condition in qualitative and quantitative terms of physicochemical, biological and human of environment characteristic, the description of potential impact, mitigation measures and residual impact. This describe how both beneficial and adverse significant impact is expected to occur, measures to reduce or to eliminate the significant impact and which may remain after mitigation measures.

Functional requirements are these statements of services that the system should provide, which includes, first, the system shall provide data entry screens and permit an EIA expert (development user) to store complete information about existing environment in the system domain, projects description, environment potential impact, mitigation measures and residual impact. This information is composed of text, tables, graphs, map or any type of figures. Next, the system provides data entry screens and permits the project (operation user) proponent to store special information about his/her project or its location. This information consists of text, maps, photograph or any type of figures. Furthermore, it prepares reports about the description of existing environment and project for text information and figures. It includes all environment component classes in system domain and all project activities for prescribed activities specified by the DOE. These reports review on the screen or printer. Moreover, it prepares reports about the project impact on environment. It covers environment potential impact, mitigation measures, and residual impact for text or figure information.

A data model is an abstract representation of the data about entities, events, activities and their association within a system data. A relational model is an appropriate data model for large shared data. The techniques selected for developing the EIA database system relational database is normalization. The design proceeds as follows: first, a poor relational schema is designed directly from the requirements. A poor tabular design for a database may cause problems of redundancy, potential inconsistency and update anomalies. The schema at every step satisfies certain mathematically defined criteria of non-redundancy corresponding to this step. These criteria are called normal forms corresponding to this step: first, the initial schema is called in the first normal form; second, the product of the first step satisfying certain broad criteria is in the second normal form. Third, the product of the next step satisfying certain stricter criteria is in the third normal form; finally, the normalization process can continue further until the arsenal of normal form definitions is exhausted. The normalization approach takes dependencies among data items as input.

FoxPro is selected as a tool for developing EDEIA. FoxPro database management system is a powerful object-oriented environment for database construction and application development. It provides the tools for system management and including organisation of large tables of information, running queries, and programming a fully data-management system. The system main menu is displayed at starting EIADB with a friendly user interface. The menu displays a list of options which are classified into five popup menus namely, text data, figure, coding, report, help, and quit. Fill in the blanks data entry forms are one of the most useful features of EIADB. Like their paper equivalent, they tell the user exactly what information is needed. The data entry screens distributed on three groups these are, text data, figure, and coding. System data entry screens have a control panel technique that supports a user interaction. An example to one of these screens shown in Fig. 5.

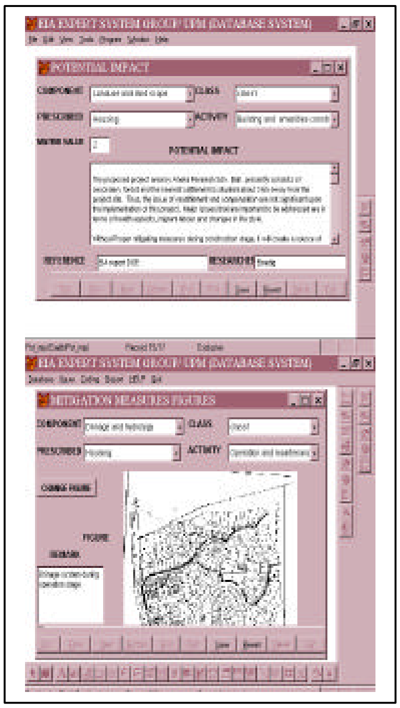


Fig. 5: Example of Data-Entry Screens

EIADBS provides four categories of reports. These are EIA report chapters, description reports, impact description reports, and coding reports. Each one of them split to more reports, these reports created by means of a "what you see is what you get" (WYSIWYG) interface. Some are column reports that are organised into rows and column much like tables. The others are form report, which controls over data created with one record or several records per page and places data anywhere on a page and creates all types of new totals and summaries. The reports include lines, boxes and figures with colour facilities to make the reports more readable. Fig. 6 shows an example of these reports.

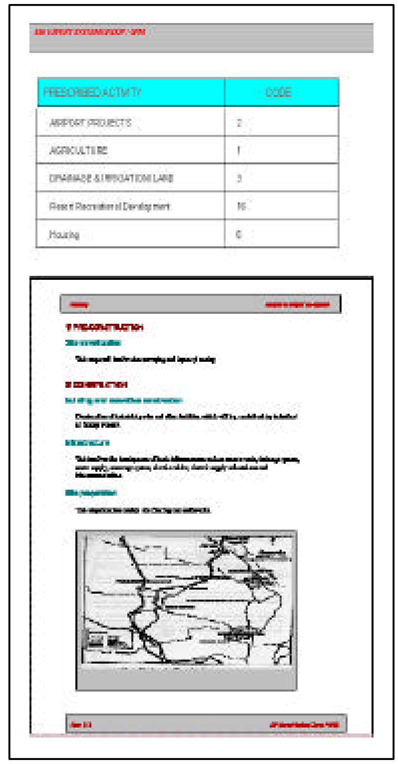


Fig. 6: Example of System Reports

5.2 Expert System Prototype

Prototyping is the act of building a small-scale, representative or working model of the user's requirements for the purpose of discovering or verifying those requirements. This is the "They'll know what they need when they see it" approach. It is used to discover the user system requirements. The intention is to simulate the users' thinking. The concept is simple. The users will recognise their requirement when they see them. The important benefits of prototype are as follows: End-users become more active participants in the system development as they tend to be more excited by working on a prototype than paper design specifications. When requirements definition are specified through realisation, many end users will not be able to understand or picture the detailed requirements until they see a prototype. Expert system prototype provides an opportunity to test assumptions about its knowledge, inference strategies of the expert and other characteristics of the system.

A knowledge acquisition is defined as the transfer and transformation of potential problem-solving expertise from the experts and others sources of knowledge to program. It includes the stages specified in the following subsections.

5.2.1 Identification

In this stage, the problem domain, objectives and goals are specified. The main purpose of ES rules is to manage and control the system database by specifying which information is related to the user. After extensive analysis on the characteristics of environmental component and in-depth study of the previous EIA reports, the results are translated into three sets of rules. First, location of the project, next, the type of existing uses for some environmental component and finally, the status of the facilities and residential area.

5.2.2 Conceptualisation

This stage uncovers the key concepts and the relationships between them. Most of the environmental component types are related to the location of the project as the nature of most components is related to the global latitude and longitude and covers a wide domain of area. The system prototype domain was specified to cover west Malaysia. The system's interest is to know more information about the area that surrounds the project location within a circle of three Kilometres radius. These components are the availability of infrastructure and services besides the residential area around the project area.

5.2.3 Formalisation

This stage understands the nature of the underlying search space, and the character of the searches that are being conducted. Most of the environmental components are related to the location of the project. The system used questions that have selected answers from a list to determine the project's location. It divides the system domain into small areas that approximately contain similar types of most environmental components. The system first divides the domain to states. Next, each state is divided into districts. Finally, each district is split into mukim (local Government administration unit). The expert system requires answers to three sets of questions which include the state, district and mukim. The answer from the first question directs the system to specify the next question, while the answer from the second one directs it to a third question. The answer from the third question leads to the system partial recommendation. When the system determines the location, it is able to specify most of the environmental component classes such as some components about land, surface water, groundwater, atmosphere and noise from a physicochemical environmental category. All this is controlled by the set of rules.

There are some environmental components where their existing use changes from one place to another within the same mukim. Thus, the system provides some questions (select from list form) to know the existing use of these components such as surface water, ground water and land-use. Each answer leads to an understanding of the systems partial recommendation concerning with the related environmental components. Moreover, there are some environmental components whose classes depend on the availability of some services and other factors around the project location. Thus, the system provides some questions (select from list form) to know the availability of these components such as services effected factors and residential type. The answer of each one leads to an understanding of the system partial recommendation concerning the related environmental components.

C language Integrated Production System (CLIPS) was selected as an expert system tool. It is a productive development and delivery expert system tool which provides a complete environment for the construction of rule-based, object-based expert system and supports only forward chaining rules which are more convenient for a diagnosis system.

The sequence of system searching techniques starts by asking about the state where the project is located followed by the district, and the project mukim. This is to determine the system's location. After that, the system wants to test the area around the project location within a radius of three kilometres in order to specify the current utilisation of land, surface water and ground water. On the other hand, the system wants to test the availability of services and residential in that area. It starts by asking about the electricity facilities, water supply facilities, tele-communication and transportation services. Next, the system is also interested to know special information about some factors which will affect the status of some environmental components, especially airflow, noise and air quality, and also, other factors which specify the types of mitigation measures which are more convenient to these environmental components. It starts by asking questions about the availability of highways around, tall buildings and earth works. Lastly, the system asks about the types of residential areas around the project location, whether these types are quarter areas, house areas and village areas. Fig. 7 shows some of ES question.

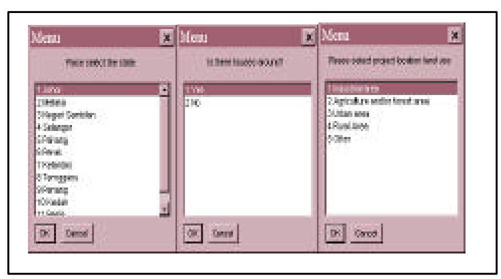


Fig. 7: Example of ES question s

The rules in this ES are represented as the form of a production rules, which consist of condition and action pairs of the form

IF condition-1
    AND condition-2
  :::: :::::
    AND condition-n
THEN action-1
    :::::
   Action-n

Which reads, if conditions 1 to n hold, then perform actions through n conditions are also refereed as premises, situations or the left-hand side of rules. Actions are refereed to as conclusion, recommendation or the right-hand side of rules. There are many sets of production rules include in the ES knowledge. Fig. 8 shows examples of these rules. When the IF portion of the rule matches the information contained in the working memory, the system performs the action specified in the THEN part of the rule which called conclusion or recommendation. The recommendation includes system output command to write the code of existing environmental component classes into a text file. Fig. 9 shows part of ES recommendations.

IF s_question= Kedah
And d_question=Bandar Baharu
Aand m_question=kuala Batu
THEN recommndation1= loc_rec

IF ls_question= Industrial area
And sw_question=Irrigation
And gw_question=Engineering domestic
THEN recommndation4=gw_dom

Fig. 8: Part of ES Rules

Project code environmental Component component class

"housing" "landform" "class1"
"housing" "shoreline" "class3"
"housing" "water quality" "class2"
"housing" "landuse" "class2"
"housing" "terrestrial vegetation" "class1"
…. ….. ….

Fig. 9: Part of ES Recommendation (Text File)

5.3 DBMS and ES Integration

The term EDB has no precise meaning either for the academic computing world or the computing industry [12]. The term used in this system to describe the enhancement of DBMS with 'intelligent' software (ES). There are a variety of ways in which an ES might interact with a database. The type of EDB used in this system is an enhanced database system. In this type an ES components are joined with DBMS, thus producing an enhanced database system. The user and queries program module are directed through an ES component before being processed by the DBMS. In this sense, the ES acts as an interface between DBMS and the user. Fig. 10 shows the enhanced database system.

The EDEIA starts by the interaction of the ES and user to produced ES recommendation, which contain the user class selections. The recommendation stored by the ES as a text file. The text file is imported by the import-module to produce a database file, which will be used by the query module in next step. According to the user's selection, all related information will be transferred to the user files after execution of the system query module. The system report generator lastly is ready to print EIA report for that user. Fig. 11 shows the logic of expert system data handling.

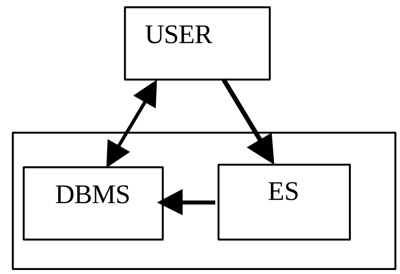


Fig. 10: Enhanced Database System

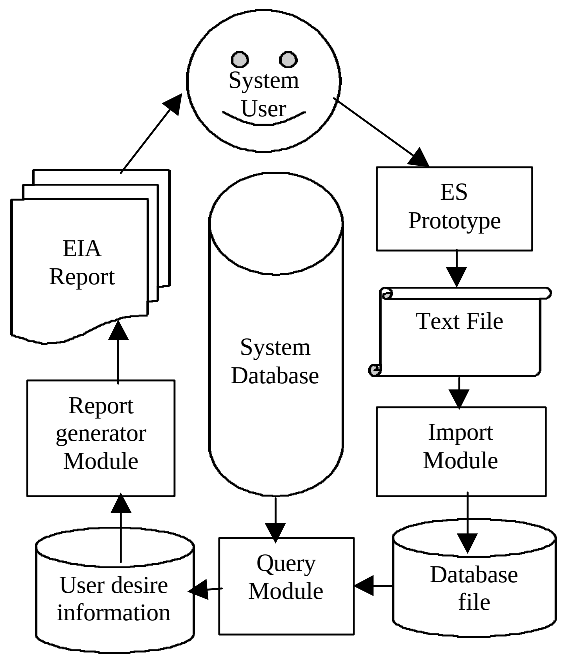


Fig. 11: System Data Handling

6.0 SYSTEM USER INTERFACE AND SECURITY

The system user interface designs are based on important GUI components which include menu, window, direct manipulation, and control panel. In a system menu interface, a popup menu is selected to use in system menu, which permits users to select one of a number of possibilities and issues a command to the machine. It has the advantage that the users always know that they are there and they can predict the result of clicking on them. The system menu uses the popup menu design technique. A direct manipulation is selected as user interface design for data entry form. It has advantages that the users feel in control of the computer. Also the control panel is selected to use with user interface design which can be a simple icon where each icon is equivalent to selecting the command from a menu or type its name.

System security is a major issue, which is built into the system. There are three areas of the system security, namely, the security of the data from error or destruction, the security of data program and security of system using. Protecting data against error and destruction during data entry is implemented by using data editing routines in the programs, also the system minimises inserting of data by using a selection list to avoid user errors. Making a backup routine for database and system programs protect data and program against accidental destruction. To protect the system from illegal use, a password facility is added to the system to allow only authorised users.

7.0 SYSTEM VALIDATION

The system will need to be periodically tested and evaluate to assure that its performance is converging toward established goals. The task of evaluation EDS is unlike that found for conventional program where the verification of the software is of primary concern. Because of the lack of gold standard in intelligent software the evaluation process is more concerned with system validation. Validation efforts determine if the system satisfactorily perform the intended task. EDEIA system models the EIA human expert. If correctly design, the system will derive the EIA report the same as that produced by EIA human experts. Formal testing has been done to the system and it involves the use of a test case. The test case represents some previous EIA reports, which include all EIA study information. After did of all system predevelopment and development procedures, the system during the operation stage gives a good result which satisfy EIA report requirements. Fig. 12 shows part of these reports.

8.0 CONCLUSION

Integration of ES and DBMS technologies (EDS) are developed for EIA study to produce timely and complete EIA reports. The system assumed that environment component and prescribed activity are classified according to their characteristics, and the information about EIA study components were collected and prepared to store into the system database. The system uses two stages, the development stage, to store all information about EIA study and the operation stage to provide services to prepare EIA report. The system is based on a wide database, consisting of all information about the description of existing environment in the specified domain, including conditions in qualitative and quantitative terms of physicochemical, biological and human of environment characteristic component classification. The ES recommendation represents the user classes of his/her selections, which is stored by the ES as text file. That text file is imported by the database system, and according to the user selections, where all related information (existing environment, project description, potential environment impact, mitigation measures, residual impact) is transferred to the user files. Then the system is ready to print EIA reports.

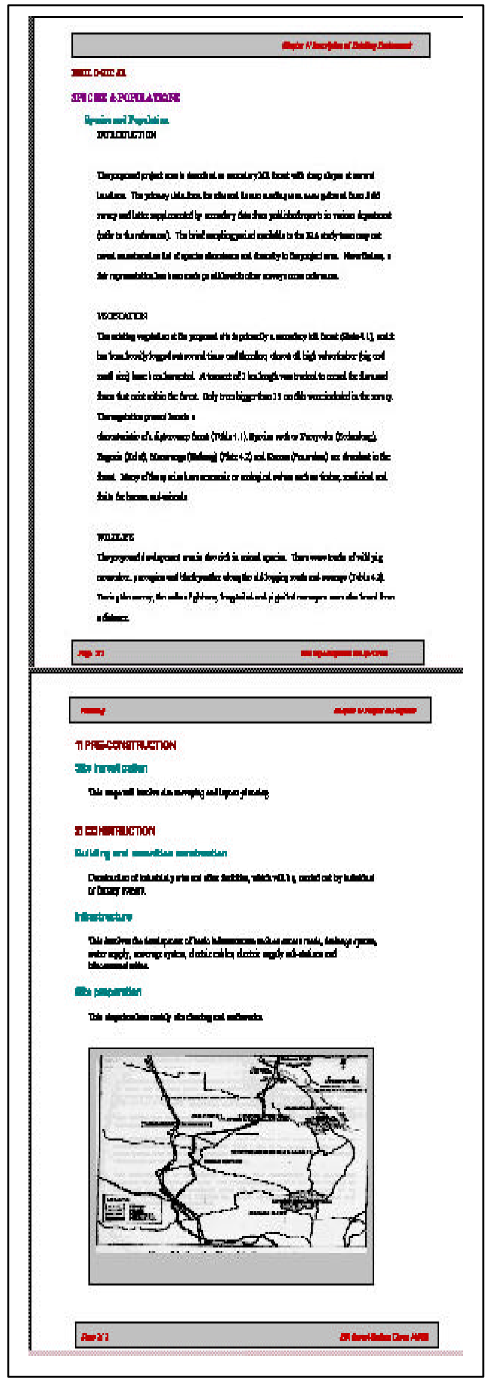


Fig. 12: Part of the Validation Results

The system provide key environment data forms as many possible organisations use environment data. It may be used to handle a database system for any type of sharing information system. It also assists EIA experts to prepare EIA reports and supports his potential environment impact prediction. The system is developed using FoxPro as a database system tool and CLIPS as an ES development tool. It has a friendly Graphical User Interface (GUI) as well as satisfying EIA report requirements.

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