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# the Environmental Impact Assessment
# Method

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## Abstract

*In this paper an expert system for environmental impact assessment, known as the EIA-system, is presented. This system provides advice for hydropower development and river regulation projects. It is based on a method used for assessing the impact that hydropower development and river regulation will have on the environment, called the Environmental Impact Assessment (EIA) Method (Strömquist & Tatham, 1992). Knowledge relating to the entire project is required with this method to enable a stepwise approach to be adopted for the assessment. Since people in developing countries lack knowledge about the impact a project will have on the environment, as well as expertise and resources, an expert system should be invaluable to assist the end users in their decision-making regarding the impact hydropower development and river regulation projects will have.*

*The EIA-system was developed to provide advisory and educational support for end users using the EIA method within developing countries. The system has to be appealing to use and, moreover, it must motivate the users to utilise it and thereby the EIA method within political settings disinterested in environmental concerns. Furthermore, the system needs to be useable and comprehensible to the end users. To realise these requirements, a logic programming language was utilised together with hypermedia technology. Briefly, the logic programming language formalises the domain knowledge and the inference mechanism. The hypermedia technology used a multimedia system to constitute the user interface and to convey domain specific information and explanation facilities.*

# 1. Introduction

Expert systems are developed to support end users in accessing a domain expert's domain knowledge whenever an expert is not available in person. These systems focus on simulating the domain experts' problem solving abilities, i.e., they simulate human reasoning in performing some portion of the relevant tasks. Furthermore, they perform reasoning about the representations of human knowledge and solve problems by heuristics or approximate methods (Jackson, 1999).

The benefit of these systems is their performance of many different functions (Awad, 1996). The use of expert systems can, e.g., improve productivity, retain scarce expertise and upgrade the performance of skilled and experienced personnel. Furthermore, these systems can improve production operations, increase output and help to standardise approaches to problems that require expertise and utilise incomplete and uncertain information (Awad, 1996).

The expert system described in this paper makes use of an existing method that it is designed to be incorporate when assessing the impact hydropower development and river regulation will have on the surrounding environment. The method adopts a stepwise approach to the Environmental Impact Assessment (EIA).

The expert system, the EIA-system, has to be advisory and educational according to the stepwise assessment (Håkansson & Öijer, 1993). Since it is presumed that there will be no expertise available to the end user or other kind of help on the spot when using the system to execute a project, the system needs to be highly supportive and rather easy to use. With the specific intention of being as supportive as possible, the EIA-system uses declarative programming as its inference mechanism and hypermedia techniques for the user interface (Håkansson & Öijer, 1993).

## 2. Related work

It has been shown that the representations used in hypermedia systems are compatible with frame-based representations (Woodhead, 1991). The field of artificial intelligence offers automated reasoning strategies and heuristics, enabling the user to follow the reasoning in large or complex domains. The incorporation of hypermedia offers different styles of dialog and decision-making, selected to suit different users.

In recent research, using knowledge systems together with hypermedia systems has proved to be a powerful means of supporting end users (Edman, 2001). The combination of these systems can support learning by facilitating co-operation between the end users and the computer systems (*ibid.*). The knowledge system is intended for solving problems, whilst, hypermedia systems are designed to present information in a user friendly manner. The purpose of combining the two is to improve the user interaction and to facilitate the users' learning of the domain knowledge. Furthermore, the purpose is to provide transparency, modularity, clarity, maintainability and reusability (Edman, 2001).

## 3. The Environmental Impact Assessment Method

The Environmental Impact Assessment (EIA) method is utilised to assess the impact that hydropower development and river regulation will have on the environment in different climates (Strömquist & Tatham, 1992). The benefit of EIA method is the growing awareness of and concern with environmental issues at all levels of society. Society increasingly recognises the need to incorporate environmental considerations into economic development.

The method facilitates the integration of environmental factors into the development process and generates alternatives that minimise the wasteful use of natural resources and reduce the impact on the environment. Furthermore, EIA is an anthropocentric concept since it is centred on the effects of human activities and involves society making value judgements concerning the significance and importance of these effects. These judgements, often based on social and economic criteria, reflect the political reality of impact assessment in which "significance" is translated into public acceptance and desirability. Thus, EIA method is a sequential set of activities designed to identify and predict the consequences an action has on the biogeophysical environment and on man's health and well-being. It is also designed to interpret and communicate the information about the consequences (Strömquist & Tatham, 1992).

## 4. The consequences of hydropower development and river regulation

Hydropower development and river regulation have consequences that affect human, biological and physical components of the environment. Some land will be flooded, the hydrological regimes disrupted, the water quality altered and the downstream riparian[1] environment changed. In assessing the river development, the analysis and presentation of the findings are organised to correspond with the project's geography, i.e., the upstream catchment area, the reservoir and reservoir area, the site of the dam and the downstream reaches. The upstream

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[1] Riparian: relating to or living in and located on the bank of a natural watercourse, such as a river, or sometimes a lake.

catchment area is analysed for the purpose of locating any condition that would have a specific impact on the project. The size and shape of the reservoir are important elements in evaluating the future environmental conditions. An inventory takes place downstream to identify potential problem areas, which should be monitored during and after the implementation.

## 5. A stepwise assessment

Environmental Impact Assessment (EIA) is carried out by conducting a sequence of steps (Strömquist & Tatham, 1992):

• The pre-field investigation phase is the initial period of learning about the project and the project area. Existing geographical background data is collected from sources such as maps, aerial photographs and satellite images, and evaluated to reveal as much as possible about the geographical settings and to identify the possible impact zones of a project. From this assessment, the field programme is designed and defined in terms of the areas to be studied in the field.

• The field investigation phase is undertaken to check the field to confirm or modify the assessment made prior to the visit. Detailed field studies of problem areas, like soil profiles and vegetation inventories, illustrate the nature of the problem. If some important components, like nature protection or site-specific negative impacts, are discovered, realistic alternatives will be sought.

• The compilation and presentation phase (including the impact assessment) is conducted to compile the field data with the data collected in the first pre-field stage. This leads to an evaluation of the probable environmental impacts of the project. The results from the compilation and evaluation are presented to the decision-makers to facilitate the interpretation of the EIA and to help in the process of decision making.

## 6. Approaching the development of a system

The practice of EIA method in developing countries is difficult. There is also some concern about the effectiveness of the assessment model and procedures, particularly, where these are constrained by limited resources or by a limited environmental mandate. The constraints limiting the implementation of environmental impact assessment in developing countries are ineffectual institutional collaboration, insufficient political awareness and a shortage of expertise and experience. Furthermore, it is difficult to assess existing background data and, more often than not, there is a lack of relevant quantitative background data and up-to-date technical information on EIA (Strömquist &

Tatham, 1992). These factors, the inadvertent lack of knowledge and expertise, ignorance of the cost of environmental damage and only considering the technical feasibility and economic acceptability of a project all contribute towards costly and untimely production and delivery of information of environmental concern.

To support the use of EIA method in hydropower developments and river regulation projects in developing countries and to supply the decision-makers with the expertise and experience required to make an informed decision, a domain expert, geological professor Lennart Strömqvist, initiated the development of an expert system, the EIA-system. His aim was to develop a software system that could replace him, at least in some phases of the stepwise EIA method. The system was to function as an intermediate link between the domain expert and the end user. The domain expert follows up the advice offered by the system and comes to a conclusion about the viability of the project. Furthermore, if the existing background data is insufficient, the expert supports the end user by supplying the relevant data and providing the latest technique.

## 7. Requirements imposed on the EIA-system

The domain expert specified some specific requirements that the EIA-system must fulfil: The system must be able to draw conclusions that correspond according to the domain expert's opinions. The conclusions are the consequences a hydropower development and river regulation will have on the environment and the consequences the environment will have on the project under consideration. These conclusions are based on background data collected by the end user. The system must also prevent a random choice of answers being made. To prevent a random choice of answers, the end users should be requested to gather this background data before consulting the system.

The domain expert imposed certain significant conditions on the EIA-system. The expert system is supposed to be able to handle all kinds of climates, not only the climates of developing countries, but also of industrial countries and polar areas; thus it should work for every climate found on the globe, ranging from the tropical humid climate (A) to polar and highland climates (E)[2]. The system has to infer the correct conclusions about carrying out the steps in the stepwise approach to environmental impact assessment since these are significant for the work with the entire assessment method. Furthermore, the interface of the logic programming language needed to be improved by integrating the system with other programs such as a calculating program and a

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[2] Climates are commonly referred to by letters, and are given in brackets.

map-digitising program. The intention had been to generate questions concerning a specific area from the end user's selected area, i.e., upstream area, reservoir or downstream area. Moreover, the system must make it possible to expand the knowledge base during execution to contain data gained by experience.

## 8. The EIA-system

The EIA-system is a rule-based expert system with backward chaining, depth-first interpretation. The purpose of the system is advising the end user whether the hydropower development and river regulation project is viable. It supports developing countries by being able to consider the tropical humid climate (A) with three different sub-climates.

When considering and utilising the EIA stepwise filtering assessment (which involves the three different phases for EIA discussed in 5), the system uses two separate question sessions in a consultation with the end user. The questions posed are relevant to the pre-field and the field investigations, whilst the conclusions are dealt with through the compilation and evaluation of the impact assessment.

## 9. The architecture of the EIA-system

One intention in using the EIA-system was to develop an extendable and maintainable system that would neither be time-consuming to learn nor to modify. To support this requirement, the logic programming language code is allocated in separate module, see figure 1.

Another requirement on the EIA-system was that the interface needed to be intuitive since the EIA-system is used without any support from domain experts or knowledge engineers. The interface needed to be supported by a system that had proved itself to be useful, i.e., that was known to be easy to use for non-skilled end users. Furthermore, the domain expert was to maintain the expert system, providing upgrades on a continuous basis. A kind of hypermedia technology was selected — multimedia technology — since the domain expert was familiar with hypermedia and could develop his own applications using this programming language. Moreover, multimedia is an interactive media and can, therefore, generate questions on the basis of the users' choice of area in the interface. The system can ask questions from three different categories with the specific area being chosen by the end user. This user interface is separated from the logic programming language.
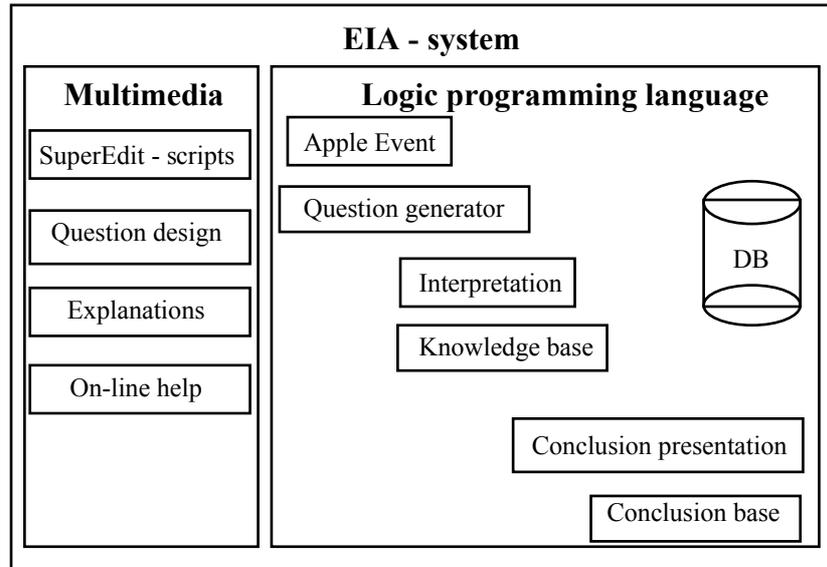
*Figure 1. The architecture of the EIA-system.*

The modules in the multimedia system are *SuperEdit*, *question design*, *explanations* and *on-line help.* This application has been developed in an application development language, "SuperEdit". By using scripts, the application in the multimedia system communicates with other programs. The "question design" involves the static presentation of questions on pre-decided cards in the multimedia system. The "explanations" are pre-defined and are presented in a dynamic manner because they differ for each question. The "on-line help" presents the button functionality in a static sense since it is identical whenever asked for.

The logic programming language consists of *apple event*, *question generator*, *interpretation*, *knowledge base*, *conclusion presentation* and *conclusion base.* The "Apple event" is necessary for the handling of the communication between the multimedia system and the logic programming language. The "question generator" module contains two lists with object names where each object corresponds to multimedia system cards[3] together with the conditions for asking the questions.

The "interpretation" interprets the knowledge in the database and the knowledge base. The database (DB) exists during consultation and is expanded with the end user's answers. The "knowledge base" contains the rules. Besides being used for inference, these rules are applied in another way: All of them are involved in calculating risk factors, i.e., every rule increases or decreases the risk factor associated with the viability of the project.

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[3] Each question in the expert system has a corresponding card in the multimedia system; the correspondence is stated as an object in the expert system and the card name in the multimedia system.

The module "presentation of conclusions" uses the conclusions drawn from the interpreter to fetch the appropriate texts from the "conclusion base". Both the explanation of why a question is asked and how a conclusion is reached are moved into the multimedia system and presented with textual commentary. Some explanations are static and directly written in the multimedia system, one example being why a question is asked.

Extending and maintaining the system should be simplified by using modules. Alterations will be limited to a few modules in one of the systems and will involve adding or modifying data in the question generator, the knowledge base and the presentation of the conclusions presentation and the conclusion base. This can be performed without being familiar with the functionality of the system.

## 10. Coupling the different systems

The two different systems can be coupled by using the process strategies Subsystem, Client-Server or Peer processes strategies (Barklund *et al*., 1992).
In the subsystem strategy, the inference system is a subsystem of the multimedia system. This strategy gives a tight coupling between the systems, both of which can access the internal structures, but it requires extension modifications of both systems to get them to work.

In the client-server strategy, one of the systems constitutes the client and accesses the other system constituting the server. Both systems run concurrently, but several separate clients can access the server system simultaneously. Unfortunately, the server cannot access or control the actions of the client system, but it can ask whether the server system has an action to be carried out or not.

In the peer processes strategy the systems cooperate, allowing each system to provide services to and request services of the other. It is appropriate to base the peer process on a standard communication mechanism such as the client-server or a subsystem with additional services ensuring greater flexibility. A commonly encountered problem is implementing the server capabilities (Barklund *et al*., 1992).

In the EIA-system, the logic programming system and the multimedia system are, for the moment, running on the same computer, and the multimedia system usually invokes system. Thus, a kind of subsystem technique is being used, but one could use a peer process technique instead.

The multimedia authoring system commands the logic programming language by sending calls then waits for a reply. Such calls could be, e.g., start up the logic language, fetch question object, retract object, assert object, evaluate and present conclusion. The logic programming language returns the calls, which causes the multimedia system to perform an action.

The decision to let the multimedia be the commanding language arises from the characteristics of the logic programming language, which is being executed constantly in the background until a pre-implemented time limit is reached. Since, the distinctive feature of the EIA-system is to let the end user answer questions over a period of hours or, even days, the time limit will easily be exceeded. However, this can be dealt with by allowing only the peer process technique.

## 11. The result

The EIA-system is both advisory and educational. It is helpful in accomplishing a correct pre-investigation and then increasing the probability of the project being successful project. To handle the end users' — often too large — confidence in computer systems, emphasis is put on providing advice about the possibility of implementing a hydropower scheme and the reliability of the advice will depend on the quality of the background data.

Dividing the question session into two separate parts instructing the end user to obtain external information in accordance with the questions asked by the system relating in the first instance to knowledge accumulated prior to venturing out into the field and subsequently to data obtained from the field, has proved to be a successful strategy. The quality of the advice given depends on the quality of the end user's answers and thus, it is vital that the end user has fully understood how to obtain qualitative answers and that these are correct. The essentiality of the quality of the information is emphasised by the system.

Between these sessions, the system draws conclusions and provides advice about useful means of accumulating data and the tools available and their scope and limitations. During the second question session, the end user can ask for the conclusions drawn from the first session or ask for advice from the system. This is an important feature since the second session depends on all the advice obtained in the first session and, therefore, the end user must be able to consider any available advice whenever needed. After the second session, the system draws a conclusion and provides information about the consequences the project will have on the environment.

In the EIA-system, each question that the system can ask is posed directly on a specific card, as shown in figure 2. This card uses both text and pictures to support the end user when answering a question.
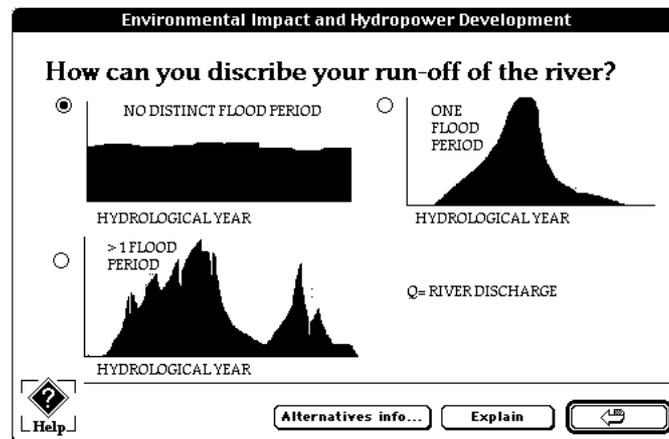


*Figure 2. An example of a card in the EIA-system.*

It is important to create a self-consistent interface. This is accomplished by retaining fonts, the locations of the buttons and formulating the questions consistently. Icons are used on some buttons supporting a metaphor. For instance, the arrow symbol is used because of its resemblance to the keyboard's return-key. The question mark gives on-line help and explains the functionality of the card and its buttons. Furthermore, the end user can get information about the alternative answers for each question, thereby getting very thorough information.

To avoid confusing the end user, who could easily "get lost in hyperspace", the multimedia system is restricted to three levels. The card-type consultation is placed on the main level. Beneath this level, different advice placed on two different levels is accessed in accordance with the users' navigation to obtain on-line help or definitions of the alternative answers. Furthermore, the information on the cards has been limited. Functions are found in the form of buttons on the card, if they concern information on the specific card, or they are available as options in the menu bar. Moreover, as mentioned, the card design is coherent because of the consistent appearance. This feature facilitates recognition and should support the end user while using the system.

## 12. Conclusions

The EIA-system discussed relies on the acquisition of domain knowledge from the expert and its successful insertion into the system. It is important to utilise the domain expert's comments and requirements when evaluating the system, an evaluation that should be made with the domain expert.

Some substantial requirements were imposed on the EIA-system. The use of modular architecture for the system, the quality of the domain knowledge and the interface chosen for the system were the most significant aspects. Extensibility and the ability to make modifications with ease were two important aspects of the design, however the system also needed to be appealing to users, encouraging them to use the system, and thereby the EIA method, in their hydropower project. Furthermore, as the domain expert is not available to the users in person, the system needs to be understandable to all users regardless of their experience. This included making the system easy to use and ensuring that the domain knowledge provided to the users is comprehensible.

To meet these requirements, a logic programming language was coupled with a multimedia system and the programming code was divided into modules. Roughly, one can say that the logic programming language formalises the domain knowledge, the inference mechanism and the knowledge provided by the end user during execution. The user interface is comprised of the multimedia system, which conveys domain specific information and explanation facilities. The interface handles the end user's inputs, the outputs of the system and the domain-specific explanations provided to the end user whenever the user asks for these.

Furthermore, some ordinary facilities, such as the provision of explanations to the tasks to be performed, for example, why a question is asked and how the system reached a conclusion and on-line help supporting the user with additional information, were implemented. Moreover, the system was to enable communication to be made in the end users' native language in the interface.

## 13. Discussion

The system is command-driven and it supervises the end user during the consultation to counteract any negative effect that the end user might have on the interpretation. The questions are asked in a predetermined order and an unanswered question is repeated directly.

The system communicates with the end user exclusively by means of questions and conclusions given in the form of cards. This is only a small part of the content of the system, implying low transparency. One benefit of this is that it becomes unnecessary to initiate the users into the content of the system, but the drawback is that it hides the reasoning from the user. Even though the system structure is educational, given the sequence of steps taken in the EIA, it is difficult to provide in-depth information to the end user about the consequences of an answer on the interpretation, and, consequently, to provide them with sufficient advice. Furthermore, it is impossible to instruct the end user about the

answers leading to an optimal result for the project. If this facility were accessible, the end user could use the flexibility to assess the general site to find the ideal place in the river to develop the hydropower facility instead of having to test several sites until a suitable one is found, which will probably not be the most preferable one.

The domain expert was unable to cope with the uncertainty. Because of this, the domain expert insisted on composing the certainty factors, through his own effort. The EIA-prototype utilises domain distinctive certainty factors as a measurement for the feasibility of the EIA project. These are utilised to calculate the main conclusion. The calculation of the certainty factor adds a stipulated value if the impact is assessed to be positive, and subtracts a stipulated value for the negative impacts. The result of this is that there are only two main conclusions in the system and each of these is based on a giant rule making a large number of premises. This is a clumsy solution, but, presumably, it has resulted in a greater degree of accuracy in the answers. The calculation of certainty factors and the probability of using the resultant factors incorrectly would increase the plausibility that the system developed would be erroneous.

The domain expert disliked the reasoning strategy fundamental to the EIA-system, deductive reasoning, and wished to switch to another strategy. It is difficult to investigate another human being's reasoning strategy and the domain expert's reasoning was not followed. Moreover, deductive reasoning is one of the common and successful techniques; therefore the deductive reasoning strategy was kept. Nevertheless, the system should provide the possibility to select a strategy that may be more in keeping with the expert's own strategy.

The domain expert critically examined the system and found the functionality satisfactory, but the interface unacceptable. He explained that he had expected an acceptable, attractive and tidy interface enticing the end user to use the system. The system has been designed to execute on different platforms and, furthermore, the interface of the system has been improved. The system has to be easy to use to avoid the need of a training program because the end users cannot be trained owing to the large geographical distance and the poor means of communication. The domain expert was familiar with hypermedia and was very pleased with the interface this offered.

A vernacular, containing technical terms and explanations for these terms in Swedish, was implemented. Unfortunately, this vernacular was unused in the system, but it can be implemented as a lexicon to explain the terminology to those end users who understand Swedish.

## 14. Extension to EIA-system

The EIA-system is capable of functioning and therefore of achieving its purpose, but the EIA method is incompletely implemented. The system covers all areas causing an impact on the project, with the exception of the socio-economic aspects. Thus, it can take into account the population surrounding the reservoir, but not the need to replace land and livelihoods that would be lost or endangered by the project etc. Additionally, the attitude of the local population must be considered. These socio-economic aspects can be extensive and would be difficult for the EIA-system to handle since, e.g., attitudes reflect subjective opinion and because the certainty factors have been omitted. One particular problem concerning uncertainty in hypermedia is that of finding an acceptable solution without having to search all the available material. The deficiencies of the system and the uncertainty just mentioned remain to be solved.

Integrating a system for the digitisation of maps would greatly enhance the use of the facilities provided by the multimedia system because such a system could support links to different questions relating to a specific area.

## 15. References

Awad, E.M. (1996) *Building expert systems*. West Publishing Company.

Barklund J., Hamfelt A. & Wünsche J. (1992) Building Modular Legal Knowledge Systems. *Expert Systems with Applications* 4: 343-353, Pergamon Press Ltd, USA.

Edman A. (2001) *Combining Knowledge Systems and Hypermedia for User Co-operation and Learning*. PhD Thesis, Division of Computer Science, Department of Information Science, Uppsala University, Sweden.

Håkansson, A. and Öijer, C. (1993) *Utveckling av expertsystem för miljökonsekvensanalys (The Development of an Expert System for Applied Environmental Impact Assessment)*. Bachelor's/BSc Thesis, Computing Science Department, Uppsala University, Sweden.

Jackson, P. (1999) *Introduction to Expert Systems*, Addison Wesley England.

Strömquist, L. & Tatham, S. (1992) in Strömquist (Ed.) *Environmental, Development, and Environmental Impact Assessment: Notes on Applied Research*. Department of Physical Geography, Uppsala University, UNGI Nr 82.

Woodhead N. (1991) *Hypertext & Hypermedia. Theory and Applications*. Addison-Wesley Publishing Company, Wilmslow, England.