In order to check how far we could achieve our objective of building an expert system let us refer to the standard methodology used to build an expert system as presented in fig No.3.3. After defining the problem, acquiring the knowledge and analysing it so as to bring out its main characteristics, we searched for adequate or possible technical solutions and finally have come to the end of the feasibility study wherein the results must be synthesised. Conclusions must enable to define new representative problems for which a prototype can be developed, validated and finally used to obtain the output.

7.1. FEASIBILITY

7.1.1. General achievements

Section 5.3.4. gives a summary of the conclusions on knowledge characteristics obtained during the knowledge acquisition phase.

The diagnostic process requires various kinds of actions. In turn these actions resort to different nature of knowledge (and logics) which all are not equally amenable to transcription to expert system. These different actions contribute to four phases, the goals of which are:

(i) Understand the objectives and their transcription in the present context
(ii) Choose adequate performance indicators and select or elaborate on an adequate package of political rules that will serve the objectives as understood and according to the site and to the diagnostic framework
(iii) Proceed to the analysis of what exists, of the state in which it is and of why it is so through systematic actions, data collection within the fields of interest as defined by the political decisions
(iv) Based on the objectives, the performance criteria and the analysis of the system achieve full logical and political reasoning process of diagnosis with identification of bottlenecks and recommendations.

Generally rules are not permanent and ever valid, they change according to the chosen objectives; contradictory rules may have to be used. Fig No.7.1. shows two rules which answer to the objectives of labour intensification and production in the command area; still both rules will be triggered when the engine is backtracking from the search of preferable solutions. These two rules lead to contradictory statements and therefore should not be present in the same knowledge base.
Objectives
Production in the command area
Labour intensification on the command area

Rules
if a proposal provides more labour then this proposal is preferable
if a proposal provides a more important value of production in the command area then this proposal is preferable

Object
"change rice for casuarina" is a proposal

Conclusions
casuarina provides less labour in the command area than rice therefore "change rice for casuarina" is not preferable
casuarina provides a more important value of production in the command area therefore "change rice for casuarina" is preferable

Fig No. 7.1: Contradictory rules for two different objectives.

Of course some rules are unchangeable whatever be the conditions; but mostly these are technical rules and fixed procedures which do not require any experts. (hydrologic values, economic balance etc...) They are standardised procedures that could be performed quite often by a traditional programme; a solution obtained under these conditions is much preferable to any expert system. Therefore immutable expertise must be parted from the necessary adaptation to each "real case" (objectives/site/framework) and from the consequent rules for which expert's knowledge is vital. These are two types of knowledge. The second one is more characteristic of expert's skill and requires both logical reasoning based on technical knowledge and political choices. Logical/technical reasoning as well as political reasoning are two expressions of decision making which are supported by more or less explicit information for the preparation of decision. This decision making is a part of a management process and the decisions are management results which should be recognised as independent products of well defined management concerns. (Kamfraat characterises a management process by its concerns, the room of decision, the preparation of decisions, the translation of decisions into message communicated to others and the monitoring of impact for corrective action). Yet, the problem of diagnosis is that it ends up with the preparation of decisions and the proposals for their translation into operational messages. This, the lack of clarity of the management concerns and the discrepancies between them is responsible for the problem of expert's knowledge: their decision making is often weak not only on the preparation phase but also on the feedback to validate their diagnosis.

Expert system transcription is helpful to research and turn the implicit non formalised elements into explicit formalised ones. But quite often the expert's decision making
### KODUR DIAGNOSIS

<table>
<thead>
<tr>
<th>Client:</th>
<th>Sugar factory</th>
<th>PWD/EEC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Terms of reference:</td>
<td>increase sugarcane in the area</td>
<td>living system to standards ensure a better management</td>
</tr>
<tr>
<td>Overall procedure:</td>
<td>what are the technical requirements of sugarcane in the area?</td>
<td>what is the present state of system?</td>
</tr>
<tr>
<td></td>
<td>what is required to provide good agronomical conditions for sugarcane?</td>
<td>what can be done to ensure better efficiency of the irrigation system?</td>
</tr>
<tr>
<td></td>
<td>what is required to make farmers produce sugarcane?</td>
<td>how can the design be altered to make the management easier?</td>
</tr>
<tr>
<td></td>
<td>how to implement it?</td>
<td>will it contribute to the increase of the productivity of the system?</td>
</tr>
<tr>
<td></td>
<td>at which costs?</td>
<td>how to implement proposed modifications?</td>
</tr>
<tr>
<td></td>
<td></td>
<td>at which costs?</td>
</tr>
</tbody>
</table>

**Fig No.7.3: general change in the diagnosis process**
Feasibility, Validation and Generalisation

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blatemeril A source of problem is water pricing

A source of problem is the lack of farmers organisation

<table>
<thead>
<tr>
<th>Rule</th>
<th>If a source of problem depends of an institution then elude this problem analyse next problem</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>If the present project has no possible action on this institution then elude this problem analyse next problem</td>
</tr>
<tr>
<td></td>
<td>If acting on this parameter would take too much time for the present project then elude this problem analyse next problem</td>
</tr>
</tbody>
</table>

Application Pricing depends of the government in the present framework of this diagnosis there is no possible action on government taxes then elude problem

Creating farmers organisation is a long process the framework of this diagnosis specifies that results must be obtained within two years then elude problem

fig No.7.4 : Political rules according to the room of decision

The knowledge as analysed shows that the acquired knowledge is not complete there are holes regarding the political decision process that should be set precisely to enable the development of a complete expert system. The questions as to what are the missing steps, the rules or heuristics which could not be identified with experts, the shape and nature of these holes define further research aspects to investigate in order to make out explicit knowledge for these holes. The concept of hole is not adequate since it is rather a matter of double logic process with conflicts bearing on each inference rather then a logical process and gaps or jumps as initially identified.

As specified in § 6.6 the output of the transcription phase is that:
- a fully formalised reasoning process can be translated and then performed by an expert tool;
- such expert systems can be chained in a systematic process in which decisions can be introduced from outside. Therefore a tool is available that may be used to develop expert systems if adequate knowledge is available.

7.1.2. Feasibility and new representative problem identification

The field of knowledge required to build a complete multidisciplinary expert systems includes both technical consistent rules and political rules which are interwoven in the general reasoning process. There is no major problem to translate to the available tool the rules based on logical decisions and political concerns provided these latter have been clearly identified. Since the two types of rules are interwoven the only subproblems for which it is interesting to develop an expert system are those for which the set of political decisions which are taken are based on identical choices or at least determined according to a systematised and based on permanent patterns. The type of new representative problem that can be proposed for a
transcription into an expert system are diagnosis for particular objective and situation on which all the political choices can be fully explicated or explained.

Usually this is not the case. All the diagnosis studied resorted to different kinds of political resolution. These decisions were not evolved from preexisting formalised rules but they were the output of an initial learning process led by the experts at the beginning of each diagnosis. The methodology followed by D. Potten for the diagnosis of small holder irrigation schemes in Zimbabwe clearly illustrates the existence of this initial learning phase followed by a phase in which the selected decision rules are applied. (In this cases the two phases were distinct whereas quite often the two phases are overlapping). On this particular job, the experts first carried out a study of the irrigation sector followed by the study of a limited number of schemes presenting obvious differences (learning phase). Based on this knowledge, they had set up five decision rules which were used for the assessment of all the other schemes. Unfortunately the mechanisms of this learning process are not clear. Considering that the diagnostic process is a learning phase (to work out the decision rules) followed by the application of these rules in the diagnosis reasoning; then expert system is only for the application phase.

Therefore an expert system can only be developed for the diagnosis of tank irrigated systems if the political decisions required for the general diagnosis are constant on many similar applications. In such a case, the judgments evolved from the experts' traditional learning process could be elicited from several sample diagnosis, be formalised in fixed political rules and then translated into an expert system. Then such an expert system could be applied to the other cases. As suggested by Dr. S. Johnson III such an expert system could be developed for the diagnosis of small river diversion systems in Indonesia. The general context of this idea is the existence of many (over 100 000) small river diversion systems which are presently managed by government agencies and the will of the Indonesian government to hand over these systems to the farmers population. This process will require special measures to arrange for the state disengagement. These measures must be adapted to each case. It seems obvious that the Indonesian government does not have the means to provide a diagnosis of each system; for all of them, the management concerns and therefore the political decisions are clear and the room of decision is defined by the nature of the hand-over project. It seems also quite obvious that after some 200 (or maybe even less cases) diagnosis, the diagnosis business will appear to be quite repetitive. On these first diagnosis, experts will elaborate the set of decision rules which cover the different cases and any further work will consist in applying this knowledge to the new cases; for all these cases expert systems could be successfully used.
7.2. VALIDATION

7.2.1. Validation of initial rules against expert

Experts resent your attempts to formalise their political reasoning in a set of fixed rules that either appears simplistic to them or reveals (de facto) political choices that they had no intentions to make explicit or that they were not fully aware of the political choices (fig. No.7.4. example of implicit political rule inbedded). The validation of the rules against experts is usually evident for technical rules but much more problematical for the so called political rules. Quite often experts deny that the decision rules that they use are the ones you have identified but do not try to or cannot give the ones they have used.

The rules need not be the exact transcription of what experts think provided they lead to the same conclusions as to those experts would get. In such cases the validation of the rules must be made against the results considering the experts reasoning as a black box. This can be done if you can compare the conclusions given by an expert system to the experts'ones on different cases. This is not adapted to our sample diagnosis in which most of the studied teams only performed one diagnosis. The validation of a hypothetical representative problem (§ 6.1.2.) based on assumed political rules is not very significant since there is no reference knowledge and cases to confront the expert system with. The fact that the conclusions for a particular case look relevant and coherent is all the validation that can be obtained. That is what has been done with the chunks of knowledge base IRRSYS.KB and SOCSYS.KB on the control cases.

7.2.2. Validation of initial rules against control tanks

The validation of elementary expert systems has been done on the two control tanks. The conclusions of the limited chunks are quite satisfactory, but the process of asking questions and reasoning is quite slow. Nexpert on PC AT is limited by windows environment which is restrained on PCs because of the DOS operating system. Since the programmes must be written in C and must run under windows environment to be compatible with Nexpert, their programming has to be done according to the Windows programming conventions. These conventions are quite distinct from standard C conventions and reduce the portability of the software on a different material.

An interesting aspect of this problem of knowledge validation can be highlighted by the above mentionned Zimbabwee case. The diagnosis of majority of the systems was evolved from the five identified rules. A subsequent job in the same area gave the experts an opportunity to perform a more thorough diagnosis on some systems; it gave them some elements to check the quality of their earlier diagnosis. In fact their conclusion was that the diagnosis based on
such rules did not lead to foolproof conclusions and that the conclusions could be profitably perfected by further studies.

7.3. GENERALISATION

7.3.1. Knowledge analysis

The first part of this chapter showed that expert systems can be developed only for one set of explicit political rules. Therefore applications will depend on a package of rules bounded to the current management concerns. The interest of bounded rules (as well as that of expert systems having a limited scope) is that it enables to reach the conclusions through a shorter reasoning since the rules are more adapted to the area to the type of system, or to the country settings (political administrative and general organisation). Implicit knowledge is inbedded in the rules. But this limits the possible generalisation of the expert systems.

7.3.2. Applications to different type of system

A few-diagnosis that were performed either on big systems (Periyar Vaigai) or in a different context show that some specific knowledge base would have to be added to give a wider application field to an expert system.

In the case of big systems the administration of the scheme is quite important compared to tank irrigated systems and requires a specific assessment. It is a complex institution, the functioning of which has a bearing on the management of the system. Similarly, the assessment of the irrigation system has to take into account the functioning of the main system that performs specific tasks in the irrigation system (water transport and delivery) which cannot be tackled on the same scale as the functioning of a rainfed tank.

Similarly river pump schemes will require a specific knowledge base to diagnose river supplies, pumping station installation, and pumped water deliveries.

7.3.3. Applications to different location

Generalising to different countries is likely to require a lot of modifications in the political rules selected; quite often these rules are elaborated taking into account the particularities of each country context and the translation of objectives will vary according to the country settings. The sector study (part of the initial learning process of any diagnosis) will necessarily be different and so will be many of the implicit assumptions lying behind the political choices.
If the system has to perform the diagnosis in an African country, different set of crops have to be added as well as a module to select the adequate crops for any location. The labour conditions in India, Sri Lanka, Guinea and Sudan are different: India and Sri Lanka make intensive use of animal power; in Guinea the level of mechanisation is quite low (hand labour) and in Sudan most of the work is highly mechanised. In the three cases the assessment of labour will require a different set of questions and steps. These questions are necessary if the expert system scope has to be more general but they make the general reasoning process much longer. The more specialised an expert system is the faster it can achieve diagnosis since background knowledge is directly imbedded in the rules and is used in an implicit form.

7.4. COMMENTS

The method followed to gather knowledge has created hindrances for the transcription; the consistency and completeness cannot be ensured with different expert teams, acting under different objectives and generally in a different framework. Therefore, a new methodology could be devised in order to carry on this idea of developing an expert system for the diagnosis of tank irrigated system. Any new attempt should limit the knowledge acquisition to one team of expert (or one expert) and catch their diagnostic method and reasoning process on different systems under the same objectives. This assumes a close collaboration and cooperation of one expert team and those attempting the transcription to the expert system. On such cases the transcription will be more profitable.

With this chapter the feasibility study of the expert system comes to an end. The knowledge acquired is not (as such) sufficient to develop a full expert system to answer the problem initially posed. But its analysis and the transcription trials have led to the identification of the type of problems for which expert systems will bring a new and interesting solution.

The other important (and more interesting) outcome of this analysis is the identification of the problems which in the present stage of knowledge, are not amenable to transcription to an expert system. These problems and the missing reasoning rules and learning mechanisms open new areas of research. When these new areas are investigated the underlying knowledge and reasoning processes might become mature enough to contemplate a successful transcription to an expert system.