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THE DEVELOPMENT OF A DECISION SUPPORT SYSTEM GENERATOR VIA ACTION RESEARCH

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Submitted in accordance with the regulations concerning admission to the degree of Doctor of Philosophy

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March 1982

To my sons

Tiago and Pedro

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ACKOWLEDGMENTS

I am grateful to the Instituto Nacional de Investigacao Cientifica (Lisbon, Portugal) and to the Systems Science Pannel of NATO (Brussels, Belgium) for their financial support, and to the Imperial Chemical Industries PLC for having given me the opportunity of doing applied research in such an interesting field.

My special ackowledgemts are due to my colleagues in the technical team Messr. K.W. Boulton, D.E. Connaughton, P.J. Tosney and R. Vass for their competent work without which this project could not have been possible, to the planning team at Huddersfield Works and in particular to Mr. D. Cracknell for his devotion in helping pushing the prototype off the ground, and to Mr. D. Wright of the Computer Unit of the University of Warwick for his programming effort. My gratitude is also due to the project manager Mr. W.H. Swann for his continuous support and encouragement during the project, and for his most appreciated comments on the first draft of this thesis.

I am also very grateful to Mr. G. Stevens for his comments on an early draft of this thesis and to Mr. H. Boothroyd for the very stimulating discussions we had and for his critical comments and suggestions.

To my friends Bernardo Vasconcelos, Rui Guimaraes and Rui

Oliveira I also owe my deepest gratitude for the time and energy they spent in long discussions which have somehow influenced my way of thinking. I am also grateful to Walter Gregory for his most helpful correction of my english.

To my supervisor Bob Hurrion goes my undying thanks for his initial guidance and the continuous encouragement and support thereafter.

Finally I also must express my gratitude to Mrs. A. Stickley for her skilful typing of this thesis.

DECLARATION

Because of my active involvement in the action research project reported in this thesis, I have contributed to all its phases, from the initial systems study to the implementation of the prototype. This included a close involvement with the end users, the diagnostic of their deliberative process and the study of the evolution of the latter with the system. However, it is difficult to pin point my personal contribution without the danger of being unfair to all the other members of the team with whom I worked.

On the research front my contribution is more easy to isolate. It was substantial in the development of the concepts incorporated in the design of the overall DSS generator architecture, and of both the dialogue and display management systems.

In what concerns the material presented in Chapter 7 (Models and Searching Processes) I was responsible for the design, development and implementation of the whole structure but I must ackowledge that the formal process in which they are described was influenced by several discussions with Mr. H. Boothroyd.

All the computer programmes that form the DSS generator were written by myself, and the same happened with the experimental micro system described in Chapter 4. The writing of the programmes specific to the system installed in Huddersfield Works were shared with other members of the team, although it was my responsability to specify and flowchart all the basic models.

Some of the material presented in this thesis has already been described in four articles (Moreira da Silva et al, 1981b and 1982, and Moreira da Silva, 1982a and 1982b).

SUMMARY

The research reported in this thesis has the dual objectives of investigating:

1) the possibility of extending the field of application of visual modelling to decision areas where discrete event simulation is not the appropriate modelling technique;

2) the potential for designing a generalised framework that could form the basis for the development of decision making aids for different problems.

The work consisted of the design, development and implementation of a Decision Support System (DSS) for the production planning function of the sponsoring organisation, from which basis it was possible to generalise and isolate the components that form the generator with which other specific applications can be built more effectively.

This thesis reflects the action research methodology followed in the project. Some of the chapters are dedicated to the problems associated with the specific application, i.e. the description of the problem and its environment, the issues of managing a multi-disciplinary team with action and research objectives, and the problems of design, implementation and evaluation of a decision making aid in an organisation.

The remaining chapters discuss the design principles that were followed in the development of the DSS generator, which is independent of the data base and allows for the possibility of personalised interfaces and a modular structure of models that can grow to match the evolving requirements of different decision makers.

From this action research programme I have shown that:

1) It is possible to develop personalized interfaces that can be tuned to the cognitive requirements of different users.

2) The concept of semi-structured decisions can become operational with the proposed new definition of models and searching processes, and this enables a DSS to evolve with the modelling needs of decision makers.

This research programme has established design principles associated with those two topics, which should be considered by an analyst who wishes to develop a specific DSS.

1. INTRODUCTION

This thesis reports the results of an on-going action research project carried out in conjunction with Imperial Chemical Industries PLC.

The motivation for the research had two separate origins: In one hand the interest in extending the basic principles of visual modelling to decision areas where discrete event simulation is not the appropriate modelling technique; in the other hand the existence of a complex planning problem in the sponsoring organisation for which more conventional techniques had failed to provide the adequate decision making support.

The research strategy of the project consisted of two parallel and interacting streams of work that are characteristic of the action research methodology: the analysis of the real situation followed by the generalization and conceptualization of its requirements that could then be materialized and tested; the overall research objective of the project was to investigate whether that process would produce a generalized framework that could form a generator of aids for different areas of decision making.

The action project, which has been in progress for 27 months, consisted of the design of a specific Decision

Support System (DSS) to support the decision making process of some of the members of the planning team of Huddersfield Works (Organics Division). The result of the project is materialized in a set of computer programmes with more than 50,000 Fortran statements, of which about 7,000 constitute the DSS generator, which has been used to learn more about the planning activity and to stimulate the discussion and experiments of different approaches to support it.

Because the research was carried out in parallel with the design and implementation of a specific DSS, which was the result of a team effort, and since this thesis is meant to describe my personal contribution, the first person has been used to differentiate the latter from the initiatives and decisions which were taken either collectively by the team or without my involvement.

To protect the security of confidential information and at the request of Imperial Chemical Industries PLC some data has been disguised. However, this should not significantly affect the understanding of the project or the research findings. Examples of this are the organisation diagrams of Chapter 3, the photographs of Chapters 4 and 6, and the contents of the dialogue structure described in Chapter 6.

1.1 Plan of the thesis

This thesis reflects the research strategy mentioned above.

Three of the chapters (3,4 and 8) report different aspects of the specific DSS developed for Huddersfield Works and the other four (Chapters 2,5,6 and 7) are concerned with the conceptual and design principles used for the construction of the DSS generator. Finally in Chapter 9 I summarise the conclusions for both the action and the research results of the project.

Chapter 2 (Conceptual Problems In Aiding Decision Making) starts with a discussion of some conceptual views of decision making that lead to the question: 'How to aid decision making ?'. The traditional OR contribution is then critically examined and the role played in this domain by the University of Warwick research programme in visual interactive simulation is appraised. Finally the methodological foundations of a new discipline - Decision Support Systems - are described and their potential value to answer the former question is assessed.

Chapter 3 (Production Planning at Huddersfield Works) reports the systems study carried out in the initial phase of this project. The main objective of the chapter is the discussion of the findings of that study in terms of the scale and nature of the decision making process and the organisational environment where it takes place. In the last section I describe the long-term proposals that emerged from that study and the project objectives agreed, both in development and research terms.

Chapter 4 (Project Development) addresses the methodological problems characteristic of an action research programme and the evidence provided by the current project is reported. The problems faced by the multi disciplinary team, whose members experienced some difficulties in defining their terms of reference are also discussed, and the influence that the experimental micro system had on the problem is analysed. Finally the decision to aim for a prototype rather than a fully specified system is also explained.

Chapter 5 (DSS Design Philosophy) is the first of three chapters about technical developments which contain most of my research contribution. In it I discuss extensively the design principles used on the dual perspective of building a specific DSS in parallel with a DSS generator. The overall architecture of the system is then presented and some of its constituents, which for one reason or another were not worth a full chapter, are also described.

Chapter 6 (Interface Design) is composed of three sections. The first addresses the conceptual problems involved in the design of a DSS interface and the following two describe and discuss its two main components: the dialogue management system and the display management system. These two systems provide the ability to tune the interface to the requirements of each individual user. Although this is a characteristic often encouraged in the DSS and Ergonomics literature there has not been any previous report of its realization. Some of the problems that emerged from its use in decision processes involving negotiation are also discussed.

In Chapter 7 (Models and Searching Processes) I start by proposing a new definition of model that matches the modelling requirements of non-structured decision situations. Then I elaborate on how a conceptual structure was developed to hold models as modules that can be extended and assembled in parallel with the evolution of the decision making process. In the final section I also propose a conjecture about a searching framework that enables users to develop on-line models of their own particular problems.

I make no apologies for the formalism of the language used in this chapter. Because the concepts presented are different from those of OR and challenge the ones accepted by the DSS community, I had to make sure that they were discussed in a formal and consistent manner.

Chapter 8 (Implementation, Training and Evaluation) reports the experience of implementing the specific DSS at Huddersfield Works and describes the problems of training and evaluating met in spite of the prior programmes designed. I end this chapter proposing five guidelines for the implementation of DSS's that I believe can be of value in future applications.

Chapter 9 (Conclusions and Proposals) has two main sections: one dedicated to conclusions and the other to further research proposals. Since most of the chapters include a section on conclusions, I decided to divide the conclusions under three headings (methodological, technical and specific application issues) to enhance the overall perspective achieved with the action research. The last section is devoted to the proposal of the two mainstreams of research that were suggested by the project: the study of the influence of negotiation on the design of personalized interfaces; and the investigation of the appropriateness of the structure of models and searching processes proposed in Chapter7 to intrinsic semi-structured problems.

2. CONCEPTUAL PROBLEMS IN AIDING DECISION MAKING

"At a conference of like-minded peers, the analytic strategy is self evidently right; in the maelstrom of organizational activity, it may be equally self evidently wrong."
(Keen and Scott Morton, 1978 p.72)

2.1. Conceptual views of decision making

There does not seem to exist a generally accepted definition for the word 'decision'.

Simon (1960,p.1) identifies decision making with a three phase process: "finding occasions for making a decision; finding possible courses of action; and choosing among courses of action".

Harrison (1975,p.5) gives emphasis to the commitment involved in decisions and proposes the following definition: "a moment, in an ongoing process of evaluating alternatives related to a goal, at which the expectations of the decision maker with regard to a particular course of action impel him to make a selection or commitment towards which he will direct his intellect and energies for the purpose of attaining his objective".

Radford (1977) goes further and suggests that the process of resolution of a decision problem is concerned with the interaction between participants and also with the interaction of each of the participants with the environment, which gives a power perspective to the decision making process.

Many other attempts to define decision can be found in the literature and most of them refer to decision making process rather than decision, probably because the latter has often been associated in common language with the act of choice.

In this thesis I will adopt the identity drawn by Simon (1960) between decision making and managing. It is within the context of an organization that I am most concerned with the process of decision making.

Glimell (1975) stated that the "atoms of problem solving are known while the combined processing properties are poorly explored". This state of understanding of decision making had already prompted Simon (1960,p.23) to justify the adoption of words like 'intuition', 'insight', and 'judgement' and to use them to explain the mystery of the "almost random processes that we observe in the problem solver at work".

To understand better the combined processing properties of decision making many authors have attempted to define taxonomies to classify decisions according to different criteria such as their main components, their objectives, the managerial level at which they are taken, and whether normative rules can be defined to decide. A substantial majority of the literature bases its approach to decision making on the work of Simon (1960) in which he suggests a two-dimensional classification of the decision making process. In one dimension he defines the three activities involved in decision making:

1) Intelligence - searching the environment for conditions calling for decisions.
2) Design - inventing, developing, and analysing possible courses of action.
3) Choice - selecting a particular course of action from those available.

Simon (1960) argues that the cycle of phases is "far more complex than this sequence suggests. Each phase in making a particular decision is itself a complex decision making process". He also suggests that this pattern for decision making should be taken as "a paradigm for most executive activity".

The other dimension proposed to classify decisions establishes two extreme types: programmed and nonprogrammed. Simon expounds "decisions are programmed to the extent that they are repetitive and routine, to the extent that a definite procedure has been worked out for handling them... Decisions are nonprogrammed to the extent that they are novel, unstructured and consequential. There is no cut-and-dried method for handling the problem".

About this latter dimension Harrison (1975,p.11-15) makes a review of a few of the proposed classifications and concludes that one can distinguish a continuum between two extreme types that correspond roughly to those suggested by Simon.

More recently Keen and Scott Morton (1978) took a different look at Simon's two dimensional classification. They first suggest a change of names, from programmed to structured, and nonprogrammed to unstructured to avoid computer connotations. They then designate the decisions that lie in the middle of that continuum 'semi-structured' and define them as those where at least one of the activities is unstructured or semi-structured. This new view is more than just semantics. Indeed it opens up the possibility of detecting the activities that in a particular decision process are ill understood or have unstructured processing properties.

Radford (1977) argues that complex decision problems are seldom a matter for a single participant and that any model of decision making should include the stages where interaction between participants takes place. This interaction often results in some type of conflict that may arise due to the participants having different perceptions of the problem, different objectives, different value systems, or a combination of all of these. He proposes a three phase model that caters for multi-participants and incorporates the first two activities of Simon's model as phase 1:

"1) A first phase in which a participant : (a) reviews the information relevant to the problem in his possession; (b) sets about gathering such additional information as he considers is necessary and feasible to obtain; (c) formulates a perception of the problem; (d) specifies courses of action that he believes he and others might implement to bring about what they may consider to be a more desirable future; and (e) generates estimates of his own and other's preferences for possible future scenarios.

2) A second phase in which each participant evaluates (intuitively or by formal analysis) the strategic structure of the problem, determines which outcomes he considers might be stable, and assesses his preferences between outcomes.

3) A third phase in which information is exchanged between participants regarding their perceptions and preferences and from which agreement on a jointly acceptable outcome may emerge." (p.148,9)

The recognition of negotiation and (or) bargaining in the decision process is the most interesting characteristic of this model. Radford uses this simple model as a basis to develop a more complex one that includes time as one of the variables and treats decision making as a continuous process.

Another important characteristic of decision making models is whether they assume optimizing or satisficing behaviour of the decision makers.

The assumption of optimizing (or maximizing as some authors prefer to call it) behaviour in decision making is associated with the closed decision model conceived by the classic economic theory. Harrison (1975, p.63-4) suggests that this model contains the following assumptions:

1) A fixed or relatively unchanging objective.
2) A known set of relevant alternatives with corresponding outcomes.
3) An established rule or set of relations that produces a preference ordering of alternatives.
4) The maximization of some sought end or some form of utility.
5) General disregard of environmental constraints.

The same author concludes that this model is only appropriate for structured decisions and even these may be subject to environmental constraints at the time of implementation. He summarizes the case against this model of decision making in the following way (p.69):

> "The case against maximizing behaviour in the closed decision model seems fairly straightforward.

For one thing, objectives are dynamic rather than static, and it is doubtful if many organizations' decision makers attempt to maximize results. Moreover, information is seldom perfect and therefore alternatives, along with human cognition, are limited. There are also obvious time and cost constraints on the amount of effort that can be spent in the search. And alternatives of any complexity seldom lend themselves to a neatly quantified preference ordering. Finally, it is difficult to disregard the effect of environmental forces on the decision making process, especially at the time of implementation".

This model is still more difficult to justify if one considers that decision making is often a process that involves more than one participant who needs to negotiate, if not bargain, on the basis of different perceptions and cognitive limitations and styles.

The model that assumes satisficing behaviour of a decision maker differs from that of maximizing behaviour because it considers the existence of both internal and external constraints which limit the global rationality of the process of choice. According to Harrison (1975), the open decision model that is often associated with the satisficing behaviour can be characterized in the following way.

"1) Objectives and aspiration levels are dynamic.

2) Alternatives and outcomes are not predetermined; neither are the relations between specific alternatives and outcomes assumed to be always defined.

3) The ordering of all alternatives assumed in the closed model is replaced by a search that considers fewer than all alternatives because of imperfect information, time and cost constraints, and cognitive limitations of the decision maker.

4) Maximizing behaviour is replaced by the quest to find an alternative or combination of alternatives whose choice will satisfice an aspiration level or the original objective.

5) It is open in relation to the environment, i.e. does not assume that environmental forces are controlled and constant."

This model is intuitively more appealing because of its resemblance to real decision processes. It did inspire Simon (1957,p.198) to suggest the concept of bounded rationality which implies that the capacity of the human mind is limited and cannot comprehend the totality of alternatives of most complex problems. This concept was extended by Harrison who argues that, apart from the constraints imposed on the decision maker by his own intellectual capacity, cost and time constraints and imperfect information also limit the extent to which a decision maker can be rational. In figure 2.1 Harrison's model of bounded rationality is depicted.

He argues that this model is the "portrait of a rational decision maker operating in the open decision model bounded by constraints that are always discernible and which,in varying degrees, are always applicable to the process of choice". This model is still sketchy in its description of decision makers but it provides neverthless a much richer picture of the kind of limitations that affect humans in their decision process.

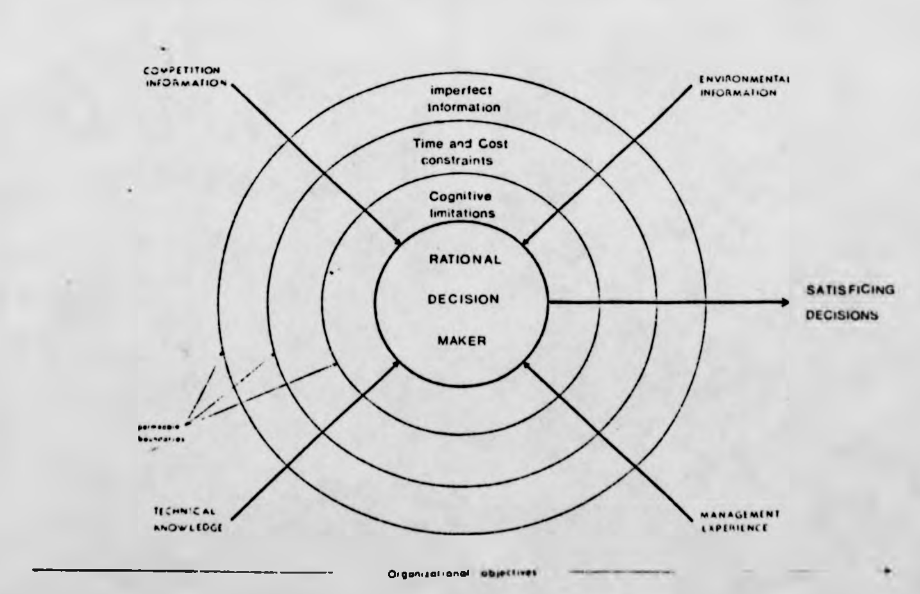

FIGURE 2.1 - The concept of bounded rationality (source: Harrison (1975), p.76)

Keen and Scott Morton (1978,p.7) set up two additional attributes by which decision making should be assessed: by its efficiency and its effectiveness. They argue that the former can only be achieved in closed decision models and is concerned with "performing a given task as well as possible in relation to some predefined performance criterion". The latter is particularly relevant when the environment is unstable and is concerned with "identifying what should be done and ensuring that the chosen criterion is the relevant one".

2.2 How to aid decision making ?

All the models of decision making referred to in the previous section make a contribution to the understanding of the essence and variety of decision making. The difficulty is selecting, from the smorgasbord of proposed methods, the appropriate mix of models to serve as the set of hypotheses that needs to exist when a particular decision system is under study.

The closed decision model and the maximizing behaviour which is associated with it has been successfully used in many structured decision problems. However complex and non structured problems are not infrequently treated under the same umbrella. It is true that the assumptions made about the environment are sometimes laid down precisely, and therefore one could accept the approach as a tool for improving the effectiveness of decision making in the context of bounded rationality referred to in the previous section. This could possibly work if the person that develops the model is simultaneously the decision maker, which is seldom the case. When this does not happen the usefulness of the model may be questioned on the grounds that the environment of the decision maker as perceived by the model maker is likely to be different from that which the decision maker himself perceives.

This situation may lead to the misinterpretation of the assumptions by the decision maker and hence lead him either to assume that the model includes some 'magic' insight to the problem and its environment, and that it expands in some way the boundaries of his cognitive and information limitations, or to discard the model because he does not believe in the representation of his own decision process provided by the model maker.

The concept of an open model of decision making is more appealing and indeed more appropriate when the problems are in some way unstructured. Keen and Scott Morton (1978,p.7) argue that in unstable economic conditions, which have been the rule since the oil crisis of 1973, managers devote most of their attention to unstructured and semi-structured problems. It seems then desirable, at least at the conceptual level and as a working hypothesis, that whatever the type of models used, they should encourage the decision maker(s) to use their 'insight', 'judgement', and 'intuition', rather than try to close the decision system with the limitations of hard information and describable decision rules. (The term 'hard' is used to qualify the information transmitted through formal communication channels in a specified format. Later I will use 'soft' to describe all the other information).

2.2.1 The traditional OR approach

It is difficult to agree what OR is, let alone what its traditional approach has been. If one judges by the definition presented by the UK Operational Research Society

> "OR is the application of the methods of science to complex problems arising in the direction and management of large systems of men, machines, materials and money in industry, business, government and defense. The distinctive approach is to develop a scientific model of the system, incorporating measurements of factors such as chance and risk, with which to predict and compare outcomes of alternative decisions, strategies or controls. The purpose is to help management determine its policy and actions scientifically".

It is questionable whether this statement should be considered at its face value, accepted as an intention of what the members of the OR community would like to see themselves doing, or a long defined statement which only those concerned with methodology are interested to debate.

What one can say is that OR, as seen by the non-OR world is synonymous with the quantitative modelling of structured problems. The reason for this may be the low proportion of articles published and catalogued as case studies or the high proportion of publications where the human part of the system is forgotten altogether. The latter point is surprising if one accepts the concept of bounded rationality in which the most stringent boundary is provided by the cognitive limitation of decision makers.

Some will argue that successful OR studies will only seldom be published because sponsor companies are reluctant to disclose the information, or practitioners have no incentive to publish their work; or simply because it is easier to write 'distilled' papers that only describe the mathematical model. But these reasons cannot provide the full explanation for that outsiders' view. How can one justify the birth and growth of, for instance, the Systems Engineering approach developed at Lancaster University? Curiously the Lancaster community started by accepting a definition which is very similar to the one accepted by the

OR Society. Jenkins (1969,p.8) writes:

> "Systems Engineering is concerned with the optimal use of resources of all kinds. The major resources are the four M's, namely Men, Money, Machines and Materials,... In addition to providing a method by which complex problems, activities and organizations can be analysed, Systems Engineering also provides the framework within which to tie together many separate and possibly divergent disciplines, which otherwise might fail to make an effective contribution to the overall optimization of the problem".

Boothroyd (1978,p.110-1) after justifying on historical grounds the reason why 'science' and 'optimization' have been considered as two 'self concepts' of OR criticizes the generalization of the optimizing quantitative modelling that has been the bulk of OR activity in the following way:

> "The free use of words 'science' and 'optimization' has had an unfortunate history in the OR world. Because most of its generally available writings have been about the internal challenges of precise problems, the free use of the two key words in the literature has largely associated them with the internals of precise problems. Since there is a

> resemblance between the precise-problem literature of natural sciences, and since most of the precise-problem theory of natural science is known to fit nature closely, there has also been an uncritical tendency to regard the models of the literature of precise choice as sound models of real decision situations, as being ready for easy use in deliberative argument, and as forming the main intellectual challenge of OR.
> The evidence is different. Many of the precise problems of the literature are defective in that they correspond to no possible point in the sequence of deliberation in an action programme ! The issues they embody are often a sharply delimited set, and the quantities symbolized are treated as though they are known precisely and as though that knowledge were not subject to revision. Precise models need to be separately checked in every situation they are used in, and they can be used quite misleadingly. But if their properties and shortcomings are understood they do have a powerful contribution to make to deliberative argument, if the problem of embedding their use in the programme can be solved."

So, apart from the need for separate checking of models of every situation, this author argues that there is an important role to be played by quantitative modelling, if one manages to get the model to become an integral part of the decision making process.

When the problem is structured (and this does not mean that only its internals are understood but also that there is time to work through the thought or computerized searching process that will produce a solution, and that there is no conflict) and it has frequently occured in the past an optimizing quantitative model is more likely to be accepted by managers. Because they can relate the results of the model to their experience, and because the number of assumptions is likely to be small, they can keep the model under close scrutiny.

When the decisions are less structured the cognitive limitations of managers and model builders will have a deeper influence on the perceived environment of the decision situation and therefore the assumptions made may well be incomprehensible to the managers, which in many cases has resulted in the non-implementation or misuse of the results.

In addition to this argument one has to put under debate the appropriateness of quantitative modelling as an aid to decision making in semi-structured problems. Quantitative models rely on known (or assumed) definable internal structures of decision problems and on information about the past that is believed to be near to the truth in the future. Not only might the latter assumption be inappropriate in an unstable economy but also the dynamism of the environment is likely to induce changes in the internal structure of the decision problem. Such models assume that those quantified relationships are universal and will remain so in future and they seldom contain the property of being able to adjust to changes in a short period of time.

Futhermore to base decision making on purely quantitative modelling seems a rather wasteful way of using the intellectual capacities of managers who have been subject to a constant flow of novel situations and have gained the experience of dealing with them.

2.2.2 Visual Interactive Simulation

The use of visual interactive simulation as an aid to decision making was first reported by Hurrion (1976) who applied it to production scheduling problems. The essence of this approach is a discrete event simulation model that generates a dynamic pictorial representation on a visual display in the form of a 'silent film' and enables the decision maker to interact with it to modify rules and experiment with different alternatives.

After Hurrion's initial work this approach was extended to a variety of production control situations in a series of joint research projects between Warwick University and several companies (Secker (1977), Brown (1978), Bowen (1978 and 1979), Rubens (1979)) and is now widely used not only for that purpose but also for aiding the design and selection of production facilities (e.g. Fiddy et al (1981)).

In his early work Hurrion (1976,p.141-2) concluded that this approach improved the confidence of the decision maker in the model and this led in the scheduling problems to better results that neither decision maker nor the computer (via a batch simulation model) could achieve alone. These conclusions were based on the modelling of quantifiable problems and that author showed that via his approach it was possible to get optimum or at least better results than could be obtained via any of the known good heuristic rules.

The application of this same approach to less structured problems of production planning and control was the subject of more recent work carried out at Warwick and Hurrion's conclusions have yet to be contradicted. One of the problems that has been encountered in these more recent projects is the development of good interfaces that enable the decision maker to use his creative thinking and pattern recognition capacities to their maximum potential. About this matter Rubens (1979,p.8) observed that "although this approach (visual interactive simulation) does offer a number of novel advantages over traditional batch mode modelling, such benefits can easily be lost if insufficient attention is given to the ergonomic and psychological issues surrounding man-machine synergism".

One, if not the main, reason for the success of this approach is the limited intervention of the analyst in modelling the problem. Indeed the role of the analyst is to provide the facilities to build a model and, after an initial systems study that is carried out with the decision maker's participation, design a first approximation of the system under study. Quite often the sketches that the decision maker draws himself to explain the production problems are used as a basis for display design. From this point onwards the manager is able to contribute to the building up of the model with positive suggestions as opposed to conceptual preferences for which it is difficult to find a common language.

The research carried out at Warwick by Fisher in structuring the visual simulation software in such a way that the design of displays and interactions is independent of the discrete event simulation model is quite relevant to this participative approach of system development.

More recently Withers (1981) has proposed the interactive development of visual simulation models. This new concept, that has yet to be tried out in a 'live' project, consists of providing the facilities for the interactive design of displays that can be used directly by the manager in the very early stages of the project. Futhermore the one-to-one relationship between display elements and simulation entities leads to the development 'behind the scene' of the simulation model by the system with very little involvement from the analyst.

It is difficult to establish a balance between analyst intervention and decision maker self support. The latter has the advantage of limiting the number of assumptions that the analyst builds into the model, but I believe that the analyst's intervention may bring about important contributions by exposing the manager to different and sometimes challenging views. In the opposite direction the exposure of the analyst to new problems is the only way of challenging the established technology and is therefore a relevant stimulus for creative applied research.

Neverthless I believe that Withers' work points into the right direction for research and only its application to real problems will correct any exageration.

The weakness of visual interactive simulation is that it relies on the problem being suitable for treatment using discrete event simulation, which is a limiting constraint.

One of the objectives of this thesis is the investigation of whether the visual interactive simulation philosophy could be used in more general areas of management with the possible incorporation of other types of models.

2.2.3 The Decision Support System approach

Recently a new methodology for aiding decision making has emerged. Although several articles mentioning the words 'Decision Support System' were published before, Keen and Scott Morton (1978) were the first to present it as a new methodology. According to these authors, DSS is

> "A point of view on the role of the computer in the management decision making process... (that) ... focuses attention on building systems in relation to key decisions and tasks, with the specific aim of improving the effectiveness of the managers problem solving process".

Although the phraseology is different from that of OR one can detect a clear overlapping of intentions. Once again a new emerging discipline identifies itself with what OR claims to be and relegates the latter to quantitative modelling of structured problems. As with the OR and Systems Engineering communities the DSS promoters also see themselves providing the framework for the comprehensive use of several other points of view provided by computer science, management science, behavioural science, data processing and management.

Vazsonyi (1978) considering the value of the DSS approach to managerial decision making proposes a pragmatic position for the OR worker, suggesting that OR (or OR/MS) "can get out of the straight-jacket of canned programs and predetermined data bases and become more flexible and quickly reactive to meet changing requirements". He also concludes that the OR analyst who ignores DSS is like "(1) the traveller who ignores the automobile; (2) the communicator who ignores the telephone; (3) the analyst who ignores the pocket calculator, etc.".

The DSS school bases its approach on an extention of Simon's taxonomy of programmed and non-programmed decisions. As already mentioned these two words were replaced by structured and unstructured and the middle ground between the two extremes is labelled 'semi-structured'. Keen (1980,p.27) argues that only the semi-structured decisions are likely to benefit from the "synthesis of human judgement and computer's capabilities" because "structured tasks can be automated or routinized, thus replacing judgement, while unstructured ones involve judgement entirely and defy computerization".

This taxonomy is not completely sound. The two extreme points (structured and unstructured) do not exist in the real world and are artificially used to give context to the middle ground of the spectrum. However this is not enough to operationalise the concept of semi-structuredness and as Keen (1980) argues, it is not clear whether structure is perceptual or intrinsic to the task. I suggest that in any managerial activity there are a mix of perceptual and intrinsic semi-structured tasks and the role of a DSS is to help managers structure the former and to enable symbiotic resolutions for the latter.

Keen (1980) also argues that despite the looseness of this taxonomy the notion of semi-structured tasks is intuitively convincing and useful to explain the concept of support, rather than replacement, of managerial activity.

Keen and Scott Morton (1978,p.61-77) argue that the DSS approach uses five different, and sometimes contradictory, models of decision making. In addition to the closed/optimising and the open/satisficing schools of thought discussed above there are three other perspectives of decision making that can contribute to a richer picture of a decision process, namely

1) The organizational procedure view, which seeks to understand decisions as the output of standard operating procedures invoked by organizational sub-units. In particular this viewpoint stresses the

importance of identifying organizational roles, channels of communication, and the relationships between them.

2) The political view which sees decision making as a "personalized bargaining process between organizational units". The emphasis of this perspective is on understanding the realities of power and on the compromises and strategies necessary to mesh the interests and constraints of the actors in the decision process".

3) The individual differences perspective. "This perspective concentrates on the individual manager and her or his problem solving and information processing behaviour".

The same authors conclude that it is not easy for the DSS designer to choose one of these models because all of them make positive contributions, but simultaneously provide a restrictive view of decision making. They suggest that the best way "to synthetyze these very divergent viewpoints is by adopting a diagnostic perspective". It is also stressed that this diagnosis should be concerned with "how managers do in fact make decisions rather than focus on the logic of how they should do so".

This last point may well be considered heterodoxical from the traditional OR point of view but it describes well the philosophy of the promoters of the DSS approach to decision making. It is neverthless exagerated and, in my opinion, is a reaction to the pedantic approach of OR which, for too long, has been believed to be the receptacle of the 'absolute truth'. This is probably more evident in the United States than in Europe but even here a quick look into the British and European OR journals confirm that optimization of precise problems is given much more attention than methods for helping in real decision making situations.

One other area in which I disagree with the DSS promoters is in the limited role they leave to the analyst. I believe that the analyst's challenging views about the organization internal diagnostic processes are important factors in improving the effectiveness of decision making. His function cannot be constrained to technical developments without the danger of maintaining a restrictive status quo for the decision making process.

In spite of these two comments about the DSS philosophy I still believe that its approach is useful in improving the effectiveness of decision making. Moreover I endorse the point of view that a right way of so doing, as far as semi-structured problems are concerned, is to give the decision maker the computer facilities that can process the structured parts of the problem and let him use his 'judgement' on the not-so-structured phases, rather than leave to the analyst the task of devising the 'best' way of solving the problem. By doing so the manager can concentrate on the parts of the problem that require his intelligence and this can lead to a progressive structuring of the problems. The technical challenge for the DSS designer then is to provide a system that is capable of adapting to the changes that the DSS itself is likely to induce in the decision process.

From the decision making models analysed earlier in this chapter the one concerned with the multi actors bargaining/ negotiation decision process seems to have been forgotten in all the bibliography of DSS. Although Keen and Scott Morton (1978) do mention the power perspective of decision making they do not illustrate how one can use that type of model in DSS design. This problem seems to be of paramount importance because not only many of the real life decision problems involve some kind of bargaining and/or negotiation but also the technical problems of developing a DSS for that type of environment are not trivial. This point will be discussed later, in Chapter 6.

3. PRODUCTION PLANNING AT HUDDERSFIELD WORKS

Huddersfield Works is the largest of five Works in the Organics Division of ICI and its main responsibility is the manufacture of dyes and some of the relevant intermediate products that are used in the production process.

At the beginning of the project a systems study was carried out. It is its findings, in terms of the scale and nature of the decision making process associated with the production planning function and the organizational environment where it takes place, that are the object of this chapter. In the last section I also describe the long term proposals that emerged from that study and the project objectives that were agreed later, both in development and research terms.

3.1 - Scale of the planning problem

Among the reasons for choosing Huddersfield Works for the purpose of this project were the scale and the complexity of the operations that take place in that factory. It was believed that they were representative of the general Divisional problem, and hence the results of the project would contribute to the learning necessary to develop a Divisional system.

A team composed of a planning manager, one co-ordinator, and five senior planners is responsible for the planning task which involves the monthly preparation of plans for the production of over 500 sales products. The plans cover a period of six months ahead, the first three in detail and the last three in outline only. These products are manufactured in 300 production units using over 600 materials which are also produced in those units plus some 400 basic raw materials and intermediate products that are imported from other Works in the Division or purchased from outside suppliers.

The number of manufacturing stages involved in the production of a sales product ranges from six to twelve and the product chain is very intricate. A raw material or intermediate product may be consumed by up to twenty five downstream products. Looking at the product chain from the other side, the typical recipe for a product contains six materials of which four are planned and manufactured in the Works under study and the other two are either raw materials or intermediate products imported from other Works.

A sketch of the manufacturing process and its scale is depicted in figure 3.1.

The use of the 300 manufacturing units varies from the mass production of a single product, which happens in the early stages of the manufacturing process, to units through which several hundred products and variants are processed, a characteristic of the later stages.

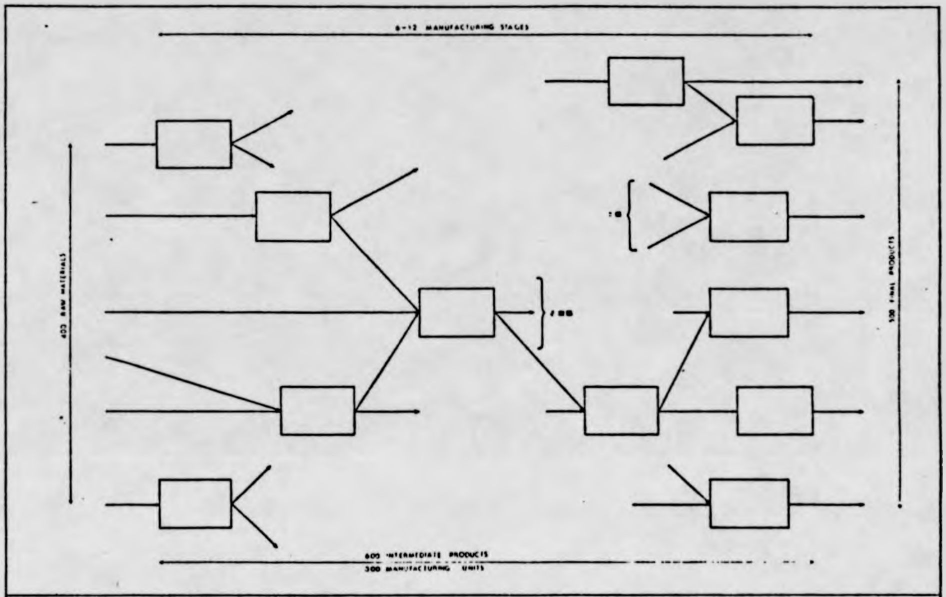

FIGURE 3.1 - The scale of the manufacturing process

3.2 The decision making process and its organizational environment

I have already mentioned that Huddersfield Works is one of five Works that form the manufacturing base of Organics Division. Each of the Works is divided into Cost Centres which are formed by several manufacturing units.

The interdependency of the Works in terms of their mutual supply function and the interaction between them and the Central Warehouse, which happens due to several sales products being manufactured in more than one Works, provide the wider organisational setting in which the subject of this project takes place. In figure 3.2 the sources and flows of 'hard' information that relate the different organisational units are depicted.

The left hand side of the figure represents the two computerised systems ("LONG TERM PLANNING" and "NORMAL COSTS") that are used annually by the Division management to define the product mix and the quotas for the different Works, and the standard costs to be used during the year. The data provided by these systems and the recipes which originate in the Division's Research and Development Department form the more stable part of the information held in the on-line production data system ("PRODUCTION RECORDS").

At the top of figure 3.2 is shown the computerised system ("DEMAND FORECAST") that generates the production requirements on the basis of demand history, firm orders from customers and current stocks held in the Central Warehouse and in the Works. This system is used monthly and its output forms the information needed to start the planning cycle for the final products in each of the Works.

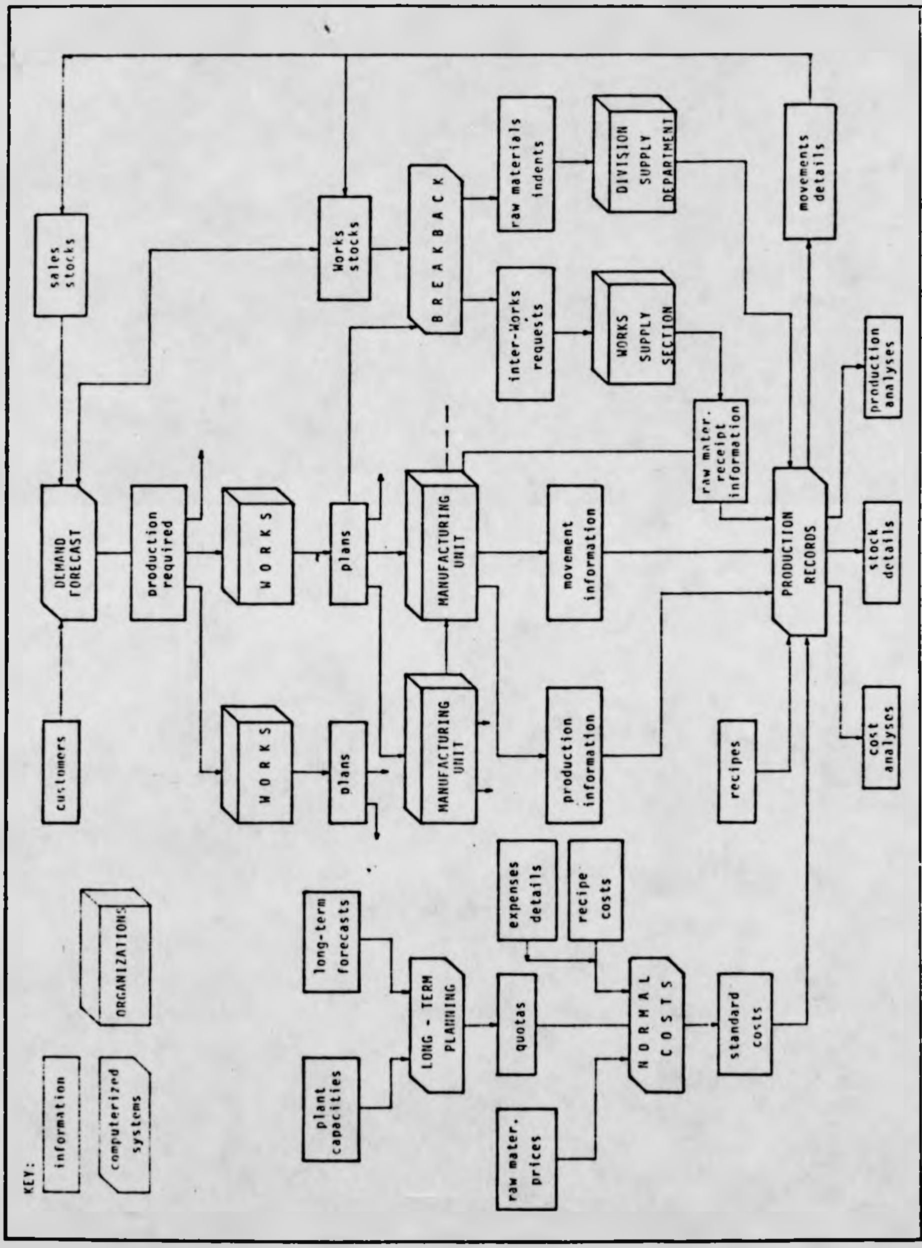

Figure 3.2 - Flows of 'hard' information in the Division

The plans that are prepared at the Works level are then passed to the manufacturing units and to another computerised system ("BREAKBACK") which generates the production requirements of intermediate products and raw materials needed for the manufacture of the final products. The requirements of intermediates are sent either to the planning team of the same Works, if the products are to be manufactured there, in which case they are used to start the planning cycle of a further stage of production; or to the supply section of other Works if they are to be imported from them. The requirements of raw materials are sent to the Division Supply Department which is responsible for arranging the relevant supplies.

Because of its complexity at each stage, the planning activity introduces some significant time lags in the manufacturing process.

Finally the manufacturing units feed the on-line system "PRODUCTION RECORDS" with production and movement of materials information that is used to produce the reports on production and cost analyses and actual stock movements and levels.

Figure 3.3 represents a more detailed picture of the flows of 'hard' information that affect the planning function in the Huddersfield Works.

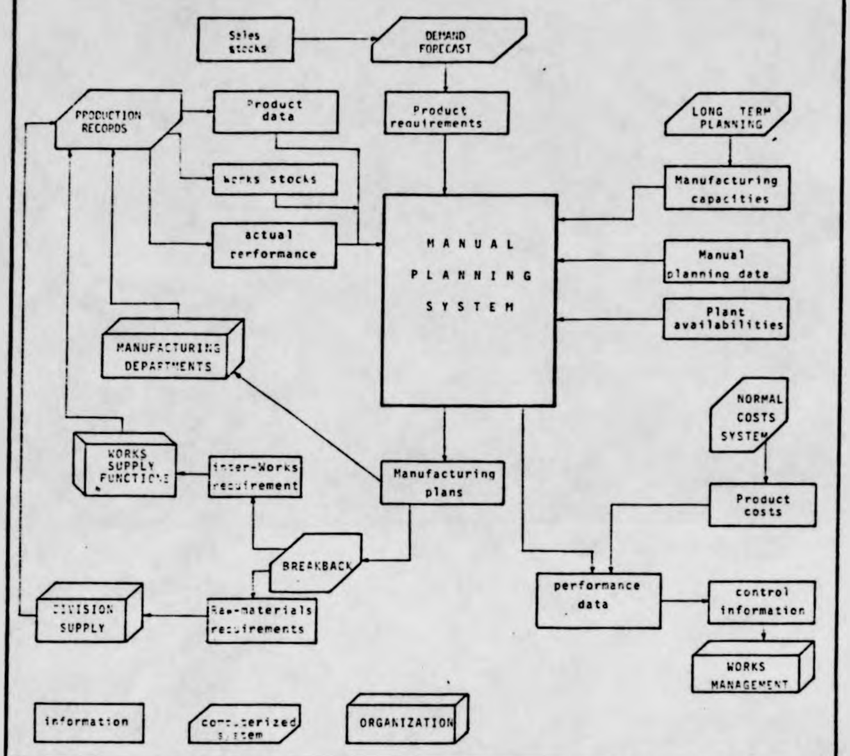

Figure 3.3 - 'hard' information affecting the planning function

In addition to the 'hard' information that is transmitted through the formal channels depicted in figures 3.2 and 3.3, the planners are also under the influence of a network of more informal contacts which generate the 'soft' information that keep them abreast of what is happening in adjacent areas. There are two main areas where events relevant to the planning function happen:

- One is formed by the Production, Marketing and Distribution Departments of the Division. This group interfaces between the market and the planning team and apart from other longer-term functions decides upon broad allocations and priorities whenever the planners are unable to resolve a conflict between demand levels and manufacturing capacity.

- The other group is formed by the Plant and Engineering Management who, in the plants, are responsible for the use of equipment under their control to meet the plans.

Hereafter these two groups will be designated Sales Group and Production Group respectively. The abundant and constant flow of soft information generated by these two groups is transmitted during a number of meetings and via the telephone. It is worth noting the central position occupied by the planning team in this network of contacts and hence the gatekeeper position that they have in the whole decision-making process. Figure 3.4 represents the informal communication links between the Planning Team and the two groups mentioned above. It also represents the three major causes of disturbance (breakdowns, technical problems and changes in demand) that are induced in the planning function via those informal links.

It is within the framework of organisational units and flows of 'hard' and 'soft' information described so far that the planning team works. It is now relevant to analyse how the planners perform their functions. These may be divided into two main categories:

1) The monthly planning exercise triggered by the demand forecast and/or the output of the Breakback system.
2) The constant updating and control of the plans necessary because of the disturbances generated both at the market and production ends.

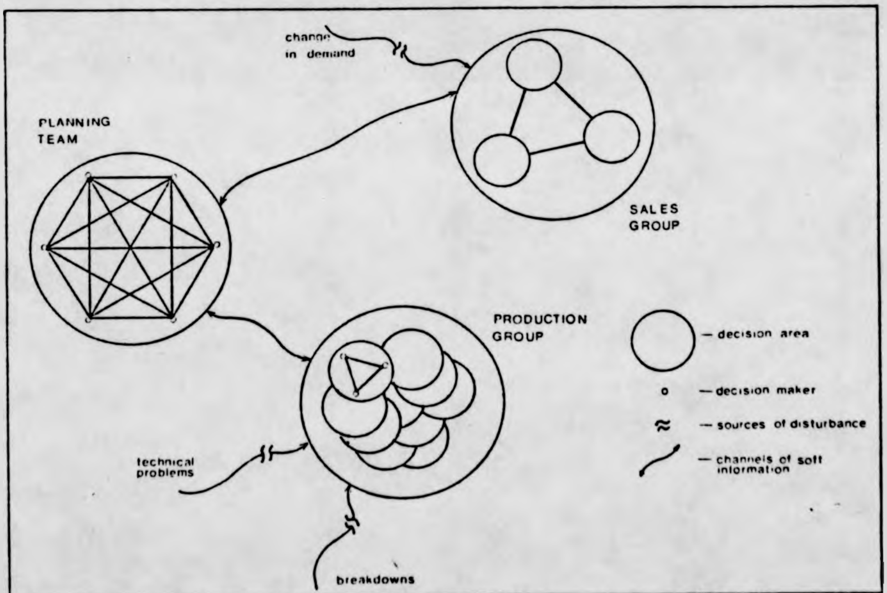

FIGURE 3.4 - Sources of disturbance and the informal communication links

The monthly planning activity of each planner is formed by two components: a vertical one which for any one stage interacts with the next stages up and down and is concerned with the provision and usage respectively of materials; a horizontal one that comprises the allocation and scheduling of the manufacturing units that he controls with the products that need to be manufactured. Figure 3.5 depicts this chain process which interfaces vertically with demand for sales products and supply of raw materials and externally supplied intermediates, and horizontally with Plant Management.

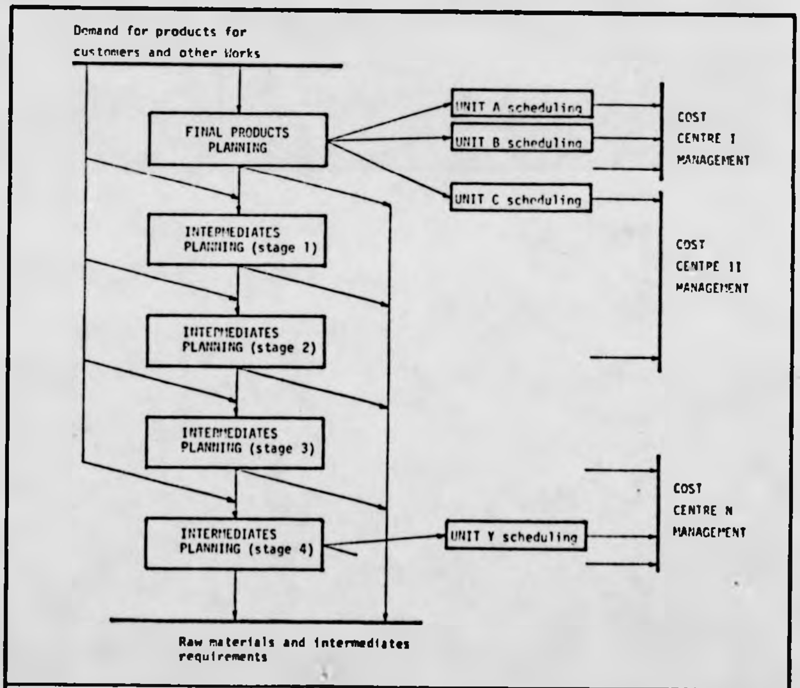

Figure 3.5 - The vertical and horizontal components of planning

It is the interrelationship between these two components and the scale of the problem that transform the planning task into a complex puzzle. It is not difficult to believe that planners with 50 to 300 products to plan and 20 to 80 units to schedule have difficulties in finding a feasible plan which is mutually acceptable to the Sales and Production Groups and to their colleagues in the Planning Teams at Huddersfield and other Works who are planning different products and units.It is worth noting that at the time of the initial systems study the planners often mentioned their difficulties in understanding the medium and long term implications of their decisions because of the time-consuming task of producing a plan.

The relatively junior position of the planners in the hierarchy also reduces their authority in the negotiations with the Sales and Production groups, and limits their institutional awareness of business priorities.

At that time two planners, one in charge of final products and the other responsible for the first stage intermediates, were asked to draw a diagram of their planning sequence. Their answers are depicted in figures 3.6 and 3.7

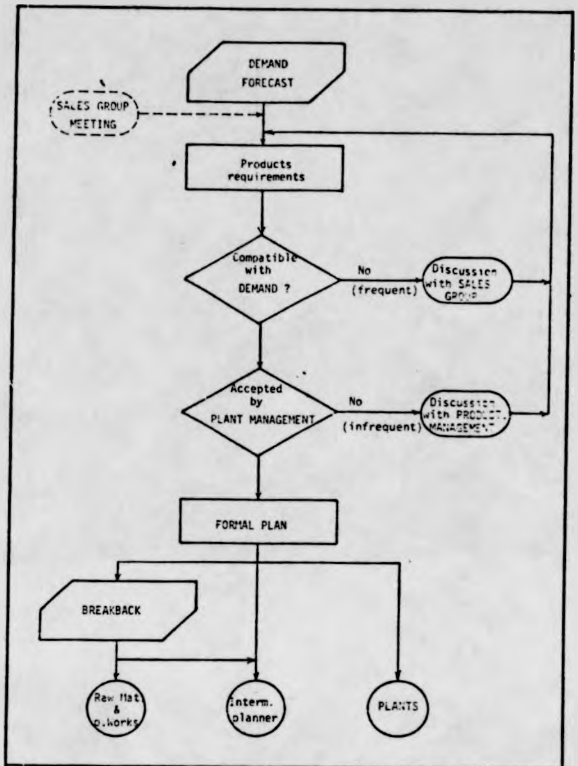

Figure 3.6 - Monthly planning process for the final products planner

The major contributor to the complexity of the task that each planner has to perform each month is the output generated by the computerised system 'Demand Forecast'. This system provides the planning team with the quantities that need to be available to satisfy the demand forecast and the firm orders for the sales products in the next twelve months, taking into account the current stocks. Given the accuracy of this system the planning task in any month would consist of deleting the first month's plan from the current six month plan and adding a one month's plan at the end. The reality is quite different. Indeed when forecasts are compared with the firm orders, which usually are received three months before the required delivery date, the differences are often very substantial. This frequently entails starting again from scratch and drawing up a completely new plan for the next six months.

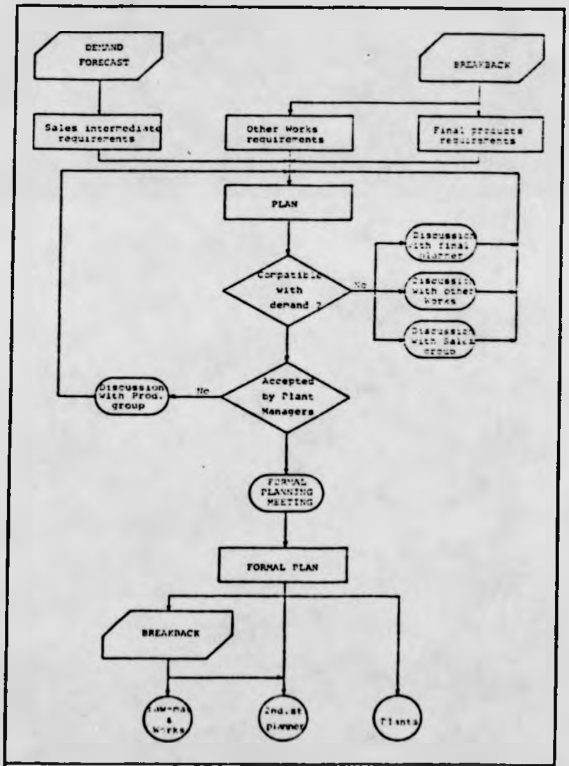

Figure 3.[illegible] - Monthly planning process for 1st. stage intermediates planner

When the initial discussions with the planners took place they agreed that the forecasting system was the major cause of time-consuming planning every month because of the slow response the system gives to changes in demand patterns. Nevertheless they recognised that without its output they would not be able to plan at all. In my initial proposals I made this point and suggested that this system should be considered for study and possible modification. However, the proposal was turned down on the grounds of difficulties in involving the relevant Department at the time and lack of resources.

Another important aspect of the monthly exercise is the negotiation with the Sales and Production Groups to define a mutually acceptable plan. The objectives of both groups are obviously divergent and to some degree in conflict and the planners play the role of mediators because they are the ones that can appreciate both sides and to some extent can take them into consideration.

The majority of the negotiation problems happen with the Production Group, for two main reasons:

1) The setting-up times are dependent upon the sequence of products and it is not realistic to enumerate the possible combinations and rank them even if only two products at a time were considered.

2) The efficiency of the manufacturing process, although guided by the theoretical utilisation defined under laboratory conditions, depends on the state of the plant and knowledge about the product. With a new product one cannot expect more than 40% of manufacturing efficiency but as the product becomes better known by the production staff the efficiency can be substantially raised. This is another factor that is often a matter for negotiation between plant management and the planners and again should be left to the planners to take into due consideration when developing the plan.

The other category of activities in which the planners are engaged is the updating of the agreed plan in between the formal planning cycles. This updating is effected during the weekly meetings that each planner has with the management of each Cost Centre and via more informal discussions which usually take place over the telephone during the week and are caused by the occurrence of a non-planned event.

This activity is similar to the management of a permanent crisis. Indeed most of the problems that are faced by the planners are vital for either the manufacturing or the marketing functions of the Division or both. In most of these problems swift action needs to be taken to avoid short or medium-term infeasibilities in the production plan or stockouts of sales products. The process of responding to this type of problem requires the ability for rapid generation of several alternatives capable of becoming the basis for negotiation between the planner and the Production and Sales Groups, and often some of the other planners.

The two problems that more often provoke a crisis and require reorganisation of the formal plan are the following:

1) An order not previously included is received by the Sales Group which asks the planner whether it can be satisfied. The level of complexity associated with this enquiry varies from staightforward to very intricate, depending on the willingness of the Sales Group to trade-off with some other product previously planned, given the availability of the appropriate intermediate materials.

   Sometimes such an enquiry triggers a planning exercise that involves the whole of the planning team and the plant management of different Cost Centres to ascertain the possibility of taking a chain of decisions that would satisfy the new demand. This problem happens with sufficient frequency to justify a special investigation into the type of aids that could help the planners. In Chapter 7 this particular problem is approached again.

2) The breakdown of a piece of manufacturing equipment and the necessity to re-schedule a given unit because quality specifications of a product are responsible for a substantial loss of production time which, in certain cases, may be as high as 60%. In the opinion of the planners these problems are the cause of 50% of the disturbances introduced into the planning process.

These problems may also require a considerable amount of planning and negotiation time between the planner and the plant management. And, if the duration of the breakdown or the delay necessary to re-process an inferior quality batch is sufficiently large, the planner may need to bring into the process other planners for them to re-adjust their own plans in response to the chain effects that decisions at a given point may provoke.

Again this type of problem needs a tool to help in searching and evaluating alternative decisions under the objectives of people with different functional objectives, in reasonably short time.

So far I have described the organisational environment, the information networks and the main types of decisions that characterise the planning function at Huddersfield Works. It is now worth transcribing the four objectives that in the words of the planning manager define the planning philosophy.

1) Sales orientated: to replenish sales stocks and thereby avoid stockouts and delays in meeting customers' orders.
2) Production orientated: to provide a smooth and stable pattern of manufacture for each plant.
3) Stock orientated: to maintain the total working capital within the limits defined by senior management in accordance with current business requirements.
4) Change orientated: to react quickly to changes in demand and to necessary alterations in the production pattern, but using any available slack in the existing plans to absorb as much of the disturbance as possible.

Yet in the opinion of the planning manager the main considerations for the achievement of these objectives can be grouped into six categories:

1) trade cycles;
2) production losses;

3) stock constraints;
4) shortage of raw materials and intermediate products;
5) changes in business priorities;
6) difficulties which the planning staff have in understanding the implications their decisions have for other parts of the business.

It is important to note that although the objectives of their job are well-understood by the planners, they find translation into operational terms during the monthly planning activity extremely difficult. This is particularly so when modification of plans to account for newly identified disturbances is necessary. There are three basic reasons for this. The first is that the objectives themselves are not mutually exclusive but overlap, and in many circumstances are even in conflict with one another. Thus the overall objective is a compromise between the component ojectives, but a compromise that changes according to circumstances and which may be weighted by the planners in accord with the perceived pressures brought to bear by the various outside departments involved. The second is the logical and computational complexity of the problems with which the planners are usually faced resulting from the interaction between numerous factors such as the number of products involved and the combinatorial nature of their inter-relationships, production lead times, raw material supply, changes in demand and resource availability, etc. The third is the fact that business pressures are usually such that there is little time to generate a reasonable set of alternative plans against which the objectives can be assessed.

A further important observation is that the procedure adopted to tackle a given problem is dependent upon the particular planner involved. Thus when investigating the problem solving tactics of two planners who faced identical situations it was noticeable that each followed the approach most suited to his own cognitive style and way of working. This latter point is investigated in more detail in Chapter 4.

The above are some of the principal factors which have hitherto made it impossible to provide appropriate computer systems for tackling the planning task. Thus although computerised systems have been developed for many of the associated activities, production planning itself has remained a manual process relying on the judgement and knowledge of experienced decision-makers. The success achieved by the planning team in coping with this difficult decision-making situation has confirmed the need to exploit the human attributes of flexibility, adaptability, and creativity in a highly fluid environment.

3.3 Proposals for intervention

From the analysis of the decision-making that has been described so far, two main conclusions were drawn concerning broad guidelines for the specification of a system that would replace the current manual planning process:

1) It should be designed to aid the planners in their decision-making process and not to try to replace them.
   Both in their formal planning activity and in their control and updating process, although more so in the latter, the importance of the planners' experience and judgement is so great that it would be ill-advised to attempt the design of an 'optimising' computerised system. Not only would the definiton of 'optimal' be, at least, controversial but also the combinatorial characteristics of some of the problems would require prohibitive computer resources.

2) It should take into account the existence of all the other computerised systems that produce information for the planners. Failing to do so could put in jeopardy its acceptance, because of the nuisance of keying in data which already exists elsewhere.

On the other hand one should be careful not to strait-jacket the new system by adapting it to the needs of all the others with consequent and unnecessary loss of flexibility. Two typical cases of this problem are the links with the 'Demand Forecast' system about whose survival in the present format there were doubts, and the frequency of transferring data from 'Production Records' to the new system to avoid out-of-date information in the latter but to allow information that had not yet been introduced in the formal channels to be keyed in by the planners if they felt that it should be taken into account immediately.

3.3.1 A long-term scenario of a network of DSS's

From these broad guidelines a long-term scenario of computerised systems was developed. The idea was to try to reach an agreement about the long-term objectives of all the parties involved in the project. At that time, apart from three members of the planning team and myself, there were one OR analyst from the Management Services Department of the Division and a Systems Analyst from the Research Division of the Company (Corporate Laboratory).

That long-term scenario is depicted in figure 3.8, which represents a network of computerised systems to support the planning function and other adjacent areas of decision-making. The relevance of this conceptual view is two-fold:

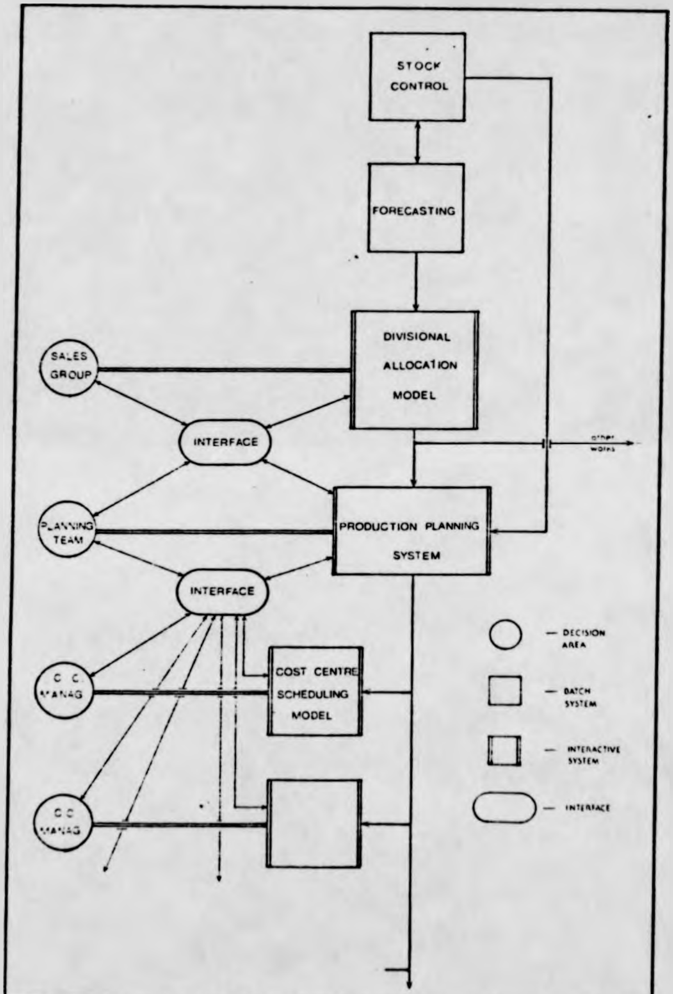

Figure 3.8 - A long term scenario of a Decision Support Systems network

1) The detection of the decision areas (Planning Teams of the five Works, the Sales Group of the Division,

and the Cost Centres that compose each of the Works) where the provision of a Decision Support System seemed to be important due to the semi-structured nature of some of the problems.

2) Given the amount of negotiation that takes place between the three decision areas both during the formal planning processes and between them, it seemed sensible to assume that the quality of the problem-solving process could possibly be improved if each manager could use his model to communicate with the other decision makers. This idea is represented by the 'Interfaces' depicted in figure 3.8. Their function would be that of transforming the decision taken by each of the users in his own system, into a pictorial representation of the consequences in the other users' systems. In this way it would be possible for a decision-maker to communicate a point of view in his own language and the interface would 'translate' its meaning in the language of the other parties involved.

Of this network several scheduling models already exist in the form of visual simulation models. Also the Divisional Allocation System exists in batch form (LONG TERM PLANNING). None of the above mentioned interfaces yet exist, and although there is a clear interest in them, they were, and still are, an idea that needs to be investigated.

It was possible to reach agreement about the long term objective in a series of exploratory discussions involving the interested parties and it was decided to accept the scenario as a guideline for the team that would be in charge of specifying a Production Planning System.

3.3.2 Broad specification of the Production Planning System

The next stage of the project was to define the broad specifications of the Production Planning System, namely to define how it would be linked with the existing computerised systems and what kind of structure it should have. It was not without difficulties that the team managed to define those specifications. The problems that arose from the multiple experiences and backgrounds of the persons involved in the team proved to be a barrier to the definition of a mutually agreeable specification. Later, in Chapter 4, this experience is analysed in more detail but in this section, for the sake of consistency, I restrict the discussion to the outcome of this work.

With regard to the links between the Production Planning System and the other systems, namely Production Records, Demand Forecast and Breakback, it was decided that the new prototype system would have its own independent data base.

This would be linked with the Production Records via an interface program called 'Roll Forward' that could be run once a month. Its function is to inspect the Production Records data base and roll forward by one month and update the information currently stored in the Production Planning System. This batch program would also produce an exception report stating the differences between what had been planned and what had been achieved.

It was also decided to keep the manual links between the other two systems (Demand Forecast and Breakback) and the new prototype system, which means that the planners would introduce the production requirements into the Production Planning System and the information required by the Breakback would be provided in the form of a printout generated when the formal plan was agreed. The possibility of automating this latter link was studied and it was concluded that it would not bring any special problems, but as the actual input of data in the Breakback is not done by the planners it was decided to leave the link as it currently works.

It was decided to split the internal structure of the Production Planning System in two. One system would run in batch mode to generate an initial plan (Initial Plan Generator - IPG) and a Decision Support System (Plan Refinement System - PRS) that would enable the planners to improve that initial plan and amend it whenever necessary. The advantage of this structure is that it relieves the planners of the more structured problems and thus saves their time to be used in problems for which their judgement is more relevant and necessary. This system would be run immediately after the Roll Forward job to produce a plan that would take into account the new data available for the monthly planning cycle. After its run the planners would have access to a new starting point, much more elaborated than if they had to start from scratch, and the exception report produced by the Roll Forward would enable them to take into account the deviations from their previous plan.

The study of the specifications for an IPG revealed that conventional Material Requirement Planning (MRP) would be the appropriate type of system to use for the generation of an initial plan. Because this technology is sufficiently well known it was decided that either the IPG could be developed or a commercial package bought in when the PRS was developed, since for the latter research had yet to be carried out. At the time it was agreed that, initially, the Roll Forward program would play the role of an IPG. In Chaper 8 this decision is reassessed with the experience gained through the implementation of the PRS.

In figure 3.9 the Manual Planning System depicted in figure 3.3 is replaced by an Initial Plan Generator and Plan Refinement System. This exhibit also depicts the links between those two systems and a projected 'Performance Analysis' program.

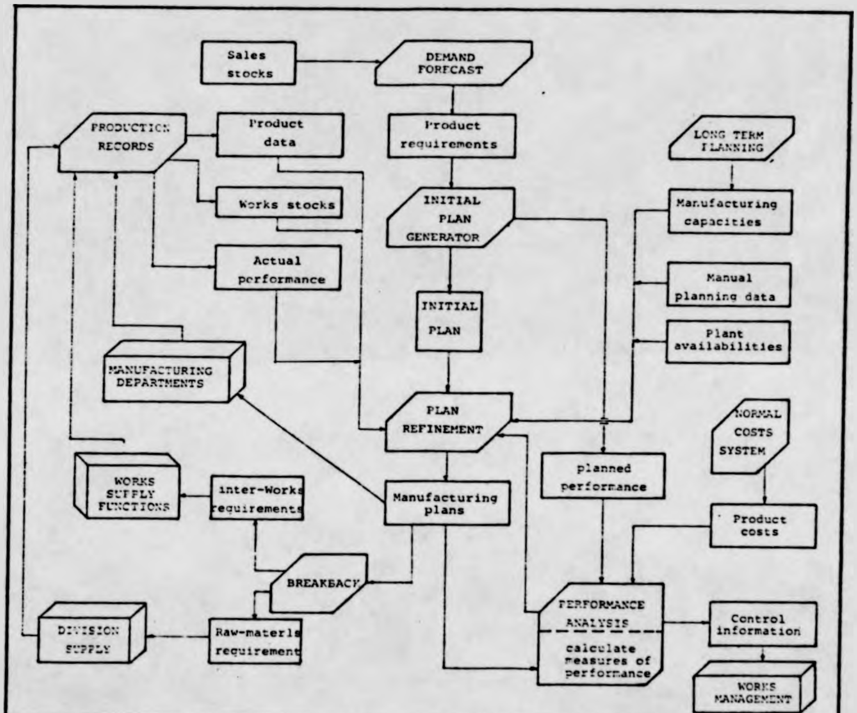

Figure 3.9 - The network of computerized systems with the Initial Plan Generator and the Plan Refinement System.

3.3.3 Objectives of the intervention

An important outcome of the exercise of defining the long-term scenario was that it enabled each of the parties engaged in the project to spell out their objectives in an attempt to discover whether it would be feasible to carry on together.

At that time there were three entities involved in the project, namely the Organics Division (represented by the planning manager, two senior planners and an OR analyst), Corporate Laboratory (represented by a senior manager in charge of the project management and a senior Systems Analyst), and the University of Warwick research team composed of my supervisor and myself.

The objectives of the Organics Division were guided by the question:

> Can a system be developed to aid the planners at Huddersfield Works to improve the quality of the production plans?

According to the planning manager to have an affirmative answer to this question the system would need to support their decision-making in three complementary areas:

1) Planning
2) Stock control

3) Profitability

It is curious to note that the investigation of the third area demonstrated that it would not be possible to provide any kind of help in this domain because the data to back it up was held by the Sales Group and they were not prepared to release it to the planning team. Apparently because profit depends both on the product and the customer and therefore it would be very difficult to transfer the information to the planning team.

The broad objective of Corporate Laboratory was very much in line with that of the research team following the 'modus vivendi' established during previous projects in Visual Interactive Simulation. This broad objective can be described by the question:

> Is it possible to improve the quality of complex and semi-structured decision and control procedures for production planning situations using visual interactive modelling?

For myself this question, put into a real problem context, was a very attractive challenge that could be used to justify the investigation into the possibility of developing a DSS generator with the advantage of having a real, complex and large situation in which different ideas could be tested.

A DSS generator was understood to be a flexible framework that would help the design of DSS's for different applications. Among the themes that needed to be investigated were the following:

1) Is it possible to design a generalised dialogue and display manager that can provide different decision makers with the interface to use a computerised system for solving complex and semi-structured problems?
2) What type of model structure is required to cope with an evolutionary decision problem?
3) What kind of data base should be used in a DSS? Should it be considered part of the DSS generator or is it better to leave it outside and design a flexible interface that can allow communication with different data bases.

In Chapter 5 I discuss some of the relevant design principles to be taken in consideration for the development of a DSS generator and its connection to a data base. In Chapters 6 and 7 I discuss possible answers to questions 1) and 2) above.

4. PROJECT DEVEOPMENT

"Much of what is new to a programme is likely to be introduced or induced by interaction with other programmes"

(H. Boothroyd, 1978)

The objective of this chapter is to describe the life of the project, how it was influenced by the different objectives and backgrounds of the persons and organizational units involved, and what steps were adopted to carry it to a mutually acceptable stage.

In the first section the multi-disciplinary approach characteristic of OR and DSS methodologies is matched with the perpsective of action research, and the advantages and shortcomings of both are discussed in the context of this project. Next the initiative of developing a micro-system to overcome those shortcomings,and that system subsequent developments into a learning vehicle are described. Finally, in the last section, the reasons for adopting a prototype development as the project objective, rather than committing the different parties to a full scale system, are discussed.

4.1 The perspective of action research and the multi-disciplinary approach

Action research is an approach developed at the Tavistock Institute of Human Relations on the basis of Lewin's (1947) work, which attempts to characterise a possible way of undertaking research in a social context. It is based on the following premises: (1) that it is not possible to confine research in the social sciences to laboratory conditions and (2) that real problems can hardly benefit from theory because of the difficulty of the people involved in the actual social arena acquiring the relevant language and getting a sufficiently distant perspective of their own organisation. Rapoport (1970, p.499) states the objectives and scope of action research in the following way:

> "It aims to contribute both to the practical concerns of people in an immediate problematic situation and to the goals of social science by joint collaboration within a mutually acceptable ethical framework".

This spirit has been very much on everybody's minds from the beginning of the project. For the client organisation the objective was to assess the possibility of using visual modelling in a decision problem with clear organisational and cognitive connotations which had not been successfully treated by any other method before. For the research team in the University the project provided the experimental ground where new ideas could be tested and hopefully it would enlarge the scope of application of that emerging technology.

The experience drawn from the use of this approach in the project has demonstrated its usefulness for both the research team and the client organisation during the whole term of the project. Meanwhile there are some difficulties in adopting the aforementioned spirit. Rapoport discusses these difficulties in what he calls the three dilemmas of action research: ethics, goals and initiatives. My experience in this area is considerably less rich than his, but it is nevertheless worth making a brief reference to it.

On the ethical front, the problems of confidentiality and ownership were most cherished by the client and were an obvious drawback for the research team; agreement on a mutually acceptable contract taking rather a long time. The area of goals and initiatives provided a fair number of conflicts (the objective and specification of the Display Management System which is the subject of Chapter 6, and the role of models that is discussed in Chapter 7, to mention but two) arising in the main because of the gap between the shorter time targets that the clients chose for themselves and the more scientific perspective that the research team had to stand for. It is my feeling that some of these compromises could have been easier to achieve if the research project had not been so tightly limited in time. Summing up the whole project I believe that, in the final analysis, the concessions made by both sides were not too fundamental and in general the benefits achieved paid off.

Rapoport states about the three dilemmas that their

> "resolution in one direction leads away from science (i.e. toward the sort of action which is not theoretically informed and does not have a cumulative scientific character) while resolution in the other direction leads away from action (i.e. to the sort of research that is 'purist'/'ivory tower' in character and lacks relevance to the important current problems of mankind".

He follows these two points to argue that "'good' action research selectively combines elements of both" the resolutions.

In addition to the problems mentioned so far in relation to action research on a real problem with the involvement of a research team, there are conflicts provoked by the different backgrounds of the individuals in charge of technical and research developments.

The comprehensive use of different points of view suggested by Keen and Scott Morton (1978) and which is very similar (if not the same) to the claim of multi-disciplinary characteristic of OR methodology, is a difficult task. In the early stages of the project the different backgrounds of the team members proved to be major obstacles to the development of a common vocabulary. Moreover it was difficult to define objectives and a strategy for the development of the project, because each participant had his own preconceived views. However, during a series of exploratory discussions these different points of view contributed to a rich analysis of the problem area, leading to an agreed long-term scenario for the project, (see figures 3.8 and 3.9). In attempting to progress towards that scenario the lack of a common vocabulary hindered attempts to define the relevant intermediate steps, and hence the analyst members of the team found difficulty in identifying the technical problems likely to emerge. This made it impossible to assess time scales, resources required, etc, and even likelihood of success.

Boothroyd (1978, p.45) refers to this problem in the context of the entered and intervening programmes:

> "A part of the problem is not simply that the theories and proposals and perceptions of action repertoire are different but that the very words and images that go to make up formal statements are different".

I think this same statement is applicable to each of the team members, independently of their belonging to one or the other of the programmes. As an example, the word 'model' had as many meanings as the number of members in the team. The misunderstanding that the different languages lead to may be a source of extra grievance between individual participants and therefore a limiting factor to multi-disciplinary action.

I have no doubt that the use of different skills and experiences is a fundamental ingredient to the success of practical OR (or DSS for that matter), and according to Boothroyd (1978) the most likely source of innovation in both entered and intervening programmes, but from the experience of this project I believe that one needs to acquire or develop a framework where that multitude of skills can be used effectively.

4.2 The experimental micro system

When experiencing the type of problems mentioned above it was decided to undertake an exercise involving the development of a small experimental system, to be run on a micro-computer and accessed via an intelligent colour terminal, with the objective of allowing the team to test out ideas on the displays and interactions to be provided in the DSS. This in turn would provide an insight into the type of problems which the project needed to investigate, and should thus enable the team to clarify its views on the required system. The experimental system was built in six weeks. It must be emphasised that it was very rudimentary, but facilitated an understanding of the magnitude of several major problems, and more importantly gave a broad appreciation of what could be achieved.

Figure 4.1 is an example from the first displays generated by the micro system. The former represents a planning sheet with the product codes on the left hand side and a time scale on top. A series of successive yellow bars represent a campaign, identified by its reference number (e.g. 125 for product 339631), with the number of batches planned for each week. The vertical red bar represents a week of planned maintenance. The product codes displayed in red correspond to the products that have a stock-out planned during the next twelve weeks. The bottom of the screen represents the stock profiles for those products.

The experience of developing this experimental system enabled the technical team to evolve a common vocabulary. It gave an articulated image of the different problem areas and the different stages through which the project had to pass. The definition of the system architecture described in Chapter 5, the broad specification of the user-interface (Chapter 6) and the role of models (Chapter 7) are examples of what was agreed resulting from the micro experience.
It was then possible to achieve the advantages of the multi-disciplinary approach by exploiting the different expertise of each team member with greater effectiveness, because there was a mutually agreed framework within which team members were able to express their knowledge,

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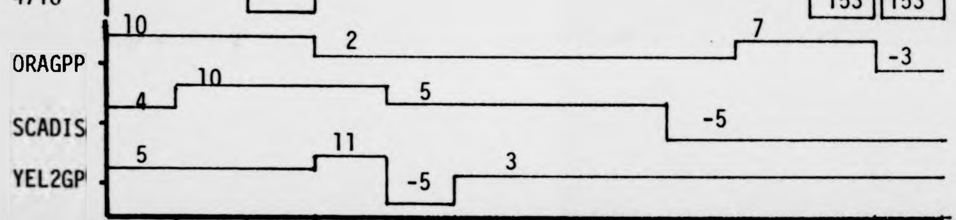
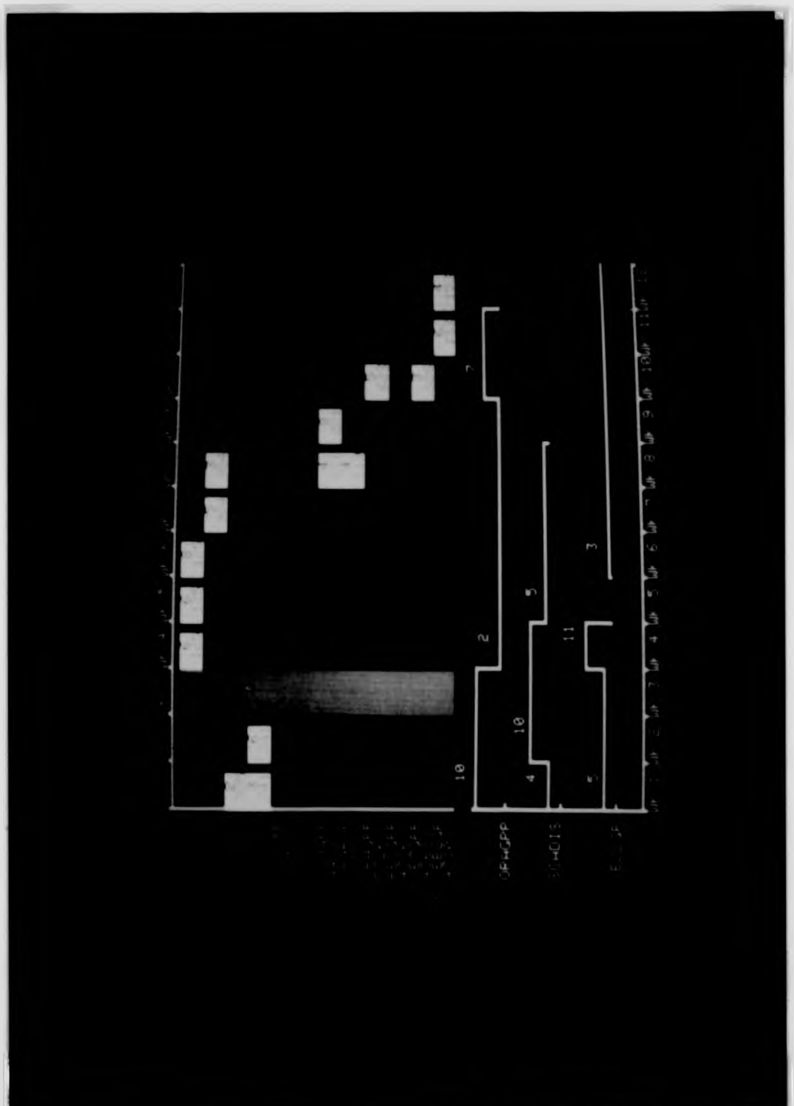
CODE	NAM/OUT	WK 1	WK 2	WK 3	WK 4	WK 5	WK 6	WK 7	WK 8	WK 9	WK 10	WK 11	WK 12
339631	YEL2GP 10653				6 125	6 125	8 125						
339633	REDGSB 2058							5 984	3 984				
339678	RED2GP 6479	2 395											
339748	SCADIS 25118	3 741	6 741										
339627	YEL RP 9841												
339012	RUBDIS 5727												
339098	SCAGPP 4470								4 221	8 221			
339635	ORARSB 835								4 515				
339090	ORAGPP 5726										5 623		
339093	REDGPP 4386												
339788	YE7GPP 4368										3 826		
339626	YEB2GP 4710											6 153	4 153





experience and views. The objectives of the exercise were realised and this proved to be an important stage of the whole project.

Once the original technical objective was achieved it was decided to take the experimental system to the planners. This experience was also fruitful because in that, among other things, gave the end users a flavour of what the final system could look like and therefore created a common point of reference for debate.

This was found to be much more effective than holding discussions based only on a conceptual model. An example of a second display designed after discussions around the one represented in figure 4.1 is depicted in figure 4.2.

In this display the space occupied by the planning sheet was shortened to allow for more information, relevant for planning, to be displayed. The blocks in white and green background represent a campaign. A short name for the product is represented on the green background, and the reference number of the campaign and the number of batches planned in each week are displayed on the white background. The stock information is now represented in figures and it also shows the origin of changes in its values. On the top of the screen the multi-colour bar chart represents two measures of the planned occupation of the plant: the

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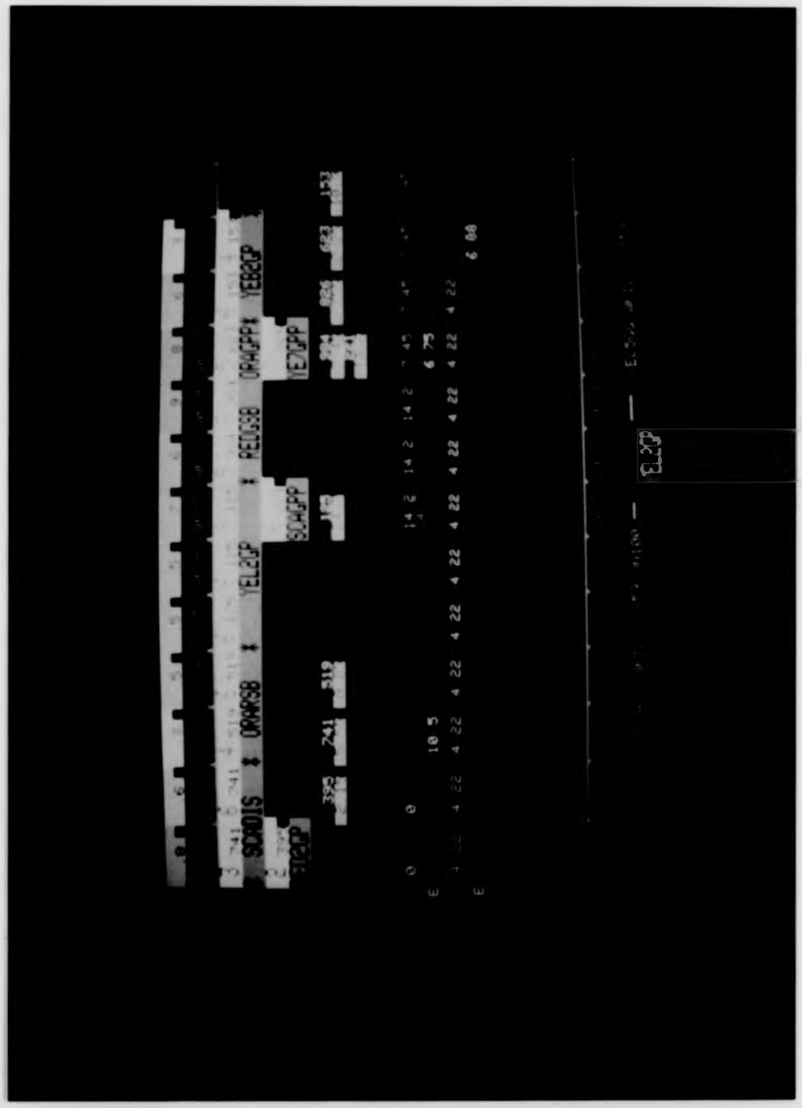
	WK 1	WK 2	WK 3	WK 4	WK 5	WK 6	WK 7	WK 8	WK 9	WK 10	WK 11	WK 12	WK 13
	.8	.6	.3	.5	.5	.5	.7	.6	.9	.8	.6	.3	
	3 741	6 741	4 519	6 519	6 125	6 125	8 125	5 984	3 984	5 623	6 153	4 153	
	SCADIS		ORARSB		YEL2GP			REDGSB		ORAGPP	YEB2GP		
	2 395						6 221			3 826			
	RED2GP						SCAGPP			YE7GPP			
		395	741	519			125			984	826	623	153
		2.15	5.55	9.85			24.7			7.45	.355	2.25	10.6
										221			
										10.6			

	WK 1	WK 2	WK 3	WK 4	WK 5	WK 6	WK 7	WK 8	WK 9	WK 10	WK 11	WK 12	WK 13
YEL2GP													
S	0	0	-10.5	-10.5	-10.5	-10.5	14.2	14.2	14.2	7.45	7.45	7.45	7.45
I							24.7						
E			10.5							6.75			
ORAGPP													
S	4.22	4.22	4.22	4.22	4.22	4.22	4.22	4.22	4.22	4.22	4.22	-.41	-.41
I												2.25	
E												6.88	

WK 1 | WK 2 | WK 3 | WK 4 | WK 5 | WK 6 | WK 7 | WK 8 | WK 9 | WK 10 | WK 11 | WK 12 | WK 13

COPY?

YELACI WK12;CC859;UN100 → Y E L 2 G P → YEL5GG WK12;CC359;UN123
→ YELOW1 WK14
→ YELOW2 WK14
YELINT WK09 → → YELOW3 WK14



figures represent the utilisation in theoretical terms and the background colour is a measure of the same utilisation in terms of what the planners and plant management find acceptable. In this example the yellow shows a plant loaded within the acceptable limits, the blue a plant on overload and the white a plant being under-utilised. At the bottom of the screen a product tree is shown indicating which products are consumed in the manufacturing process of product YEL2GP, and where this product is used.

Figure 4.3 is similar to the previous one with the indication of the available interactions at the top right hand corner. It also shows (white and blue bars) the amount in weight produced in a manufacturing campaign and the time at which the product is available for consumption or export.

The experience of using the micro system with the planners also confirmed the findings of Benbasat (1977) about the variety of cognitive styles and the need to take these into account when designing an aid for decision-making. It was this observation that prompted the decision to investigate the possibility of developing an interface that could cope with that variety. Another important point emerging from this experience was the confirmation of the semi-structured nature of the problem solving process used by the planners.These two were probably the most decisive points in favour of the hierarchical structure of models described in Chapter 7.

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	WK 1	WK 2	WK 3	WK 4	WK 5	WK 6	WK 7	WK 8	WK 9	WK 10	WK 11	WK 12	WK 13
	.8	.6	.3	.5	.5	.5	.7	.6	.9	.8	.6	.3	
	3 741	6 741	4 519	6 519	6 125	6 125	8 125	5 984	3 984	5 623	6 153	4 153	
	SCADIS		ORARSB		YEL2GP			REDGSB		ORAGPP	YEB2GP		
	2 395						6 221			3 826			
	RED2GP						SCAGPP			YE7GPP			
		395	741	519			125			984	826	623	153
		2.15	5.55	9.85			24.7			7.45	.355	2.25	10.6
										221			
										10.6			

YEL2GP													
S	0	0	-10.5	-10.5	-10.5	-10.5	14.2	14.2	14.2	7.45	7.45	7.45	7.45
I							24.7						
E			10.5							6.75			
ORAGPP													
S	4.22	4.22	4.22	4.22	4.22	4.22	4.22	4.22	4.22	4.22	4.22	-.41	-.41
I												2.25	
E												6.88	

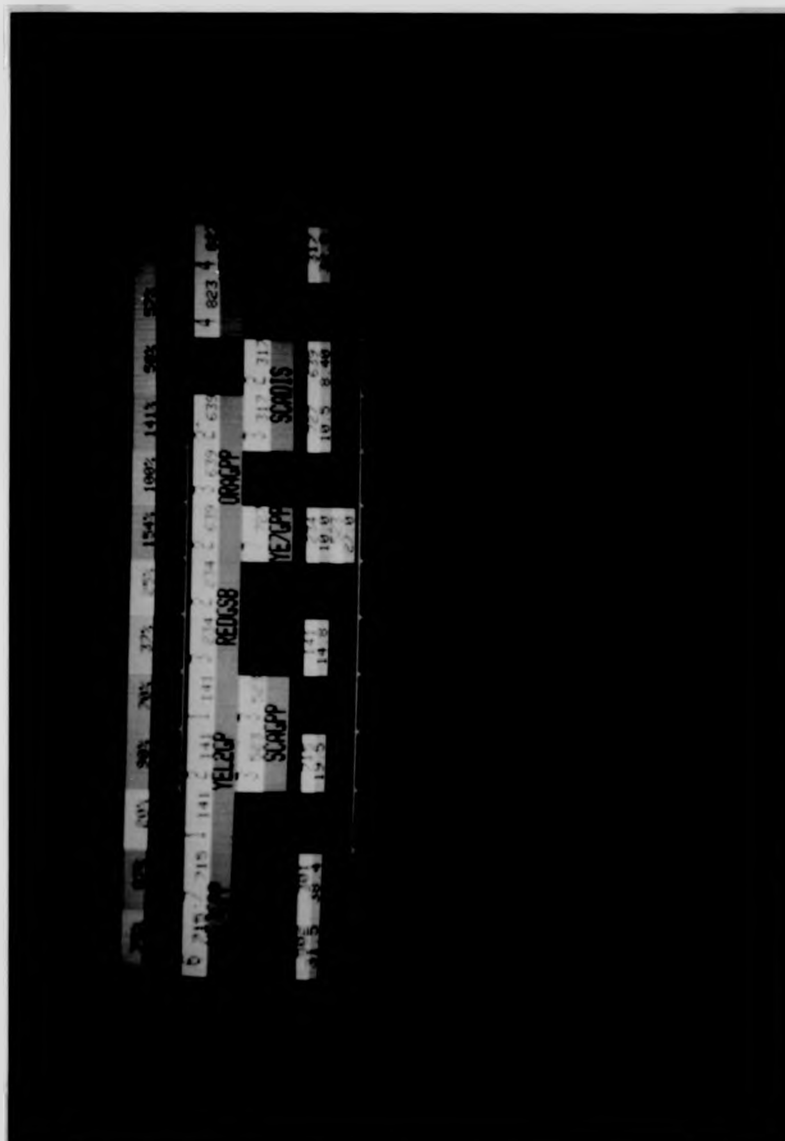
WK 1	WK 2	WK 3	WK 4	WK 5	WK 6	WK 7	WK 8	WK 9	WK 10	WK 11	WK 12	WK 13

COPY?

YELACI WK12;CC859;UN100 → Y E L 2 G P

YELINT WK09 → Y E L 2 G P

Y E L 2 G P → YEL5GG WK12;CC359;UN123
→ YELOW1 WK14
→ YELOW2 WK14
→ YELOW3 WK14



The exercise also provided a useful medium for communicating to senior management, at a very early stage, the concepts which the technical team were exploring. This had the effect of establishing the technical team with a high credibility, early on the study, a circumstance not common in research projects, and as a consequence the relevant resources were made available to allow the project to proceed with the full commitment of all involved.

The major inconvenience resulting from the use of this micro system was that it raised unduly the expectations of the planners who, for some time, did not realise the rudimentary and even cosmetic nature of the system. Thus the system created the impression that most of the development was complete and that an operational prototype was imminent, whereas in fact the project had only just started.

This experimental system could have been more helpful if it had been possible to keep the development of the project in the micro-computer. This would have provided a smoother learning tool for the end users than the two stage approach of building up a limited micro system and then starting the development in a main frame computer. However, the state of the art in the micro computers field was not,at that time, sufficiently advanced to allow this path to be followed.

Overall the development of the micro system and its use as a focus for discussion made a valuable contribution to the project. It helped to unify the team, establish its credibility with the client management, and led to an agreed specification for the prototype to which the technical team and the planners were commited, together with a practical plan for its implementation.

4.3 The choice of a prototype

The idea of a prototype fits very well with the concept of the evolutionary design process for a DSS suggested by Keen and Scott Morton (1978). The recognition that a computerised system is a prototype is likely to restrain the different people involved (both users and analysts) from considering it as an end in itself, and from thinking that it will provide the answers to all the decision-making problems. A DSS must be considered as a means to a better understanding and as an agent for improving the decision process in its organisational environment and therefore, if its development is made through a prototype, it is less likely that the myths of finality and completeness will be expected by the end users.

Boothroyd (1978, p.77) discusses this point in the broader context of OR intervention in the following way:

> "In any action programme ... the bundle of theories has to be used without having been proved to be true. There is no action programme which can justifiably claim to provide certainty. Abandoning the claim of certainty is one of the key steps in moving towards a description of human affairs that is not patently false. It leaves behind the magical belief that somewhere we can find a programme that can provide us with the theories and correct proposals. It pushes participants in sponsoring, entered and intervening programmes away from the expectation of certainty toward an expectation of permanent conjecture, enquiry, review and innovation - always provided we can bear the emotional exposure".

This enthusiastic recipe for successful OR intervention requires that all the participants have the state of mind (or emotional toughness?) to constantly proceed in that aggressive mood. I think the idea of a prototype induces in all the participants the courage to contribute positively to its development without the organisational difficulties so often associated with critics to a 'finished' product. This reason alone would be enough to decide in favour of aiming for a prototype rather than a finished system.

In addition to this philosophical reason for opting for a prototype there were others of a more practical nature, which also contributed to the decision. One was the complexity of the problem solving methods used by the planners that were difficult to identify explicitly. Glimell (1975) states that "the atoms of problem solving are known while their combined processing properties are poorly explored". It would therefore be ill-advised to try and develop complete models of decision-making instead of providing a framework that could help the decision-makers themselves to make their processes explicit.

Another important element in the decision to develop a prototype was the complexity of the network of computerised systems with which this DSS will need to communicate and the difficulty in foreseeing the impact of its implementation in terms of reviewing the protocols of the network.

But to achieve the objective of being an agent of change in the decision process enabling ultimately users and analysts together to specify the final operational system, the prototype needs to be a tool with which decision-makers can actually work on real problems as part of the decision process, rather than a 'toy' with which they make a few experiments when time permits. Therefore it was decided that the prototype should provide the planners with facilities to enable them to carry out their normal function and improve as much as possible the effectiveness of the planning activity. It was also considered fundamental that it should be ready in a reasonably short time to avoid the degradation of the initial motivation.

5. DSS DESIGN PHILOSOPHY

"The central design challenge is to allow for solutions to an endlessly and rapidly evolving set of problems, taking into account changes in one's own comprehension of the problems as well as changes in the problem themselves".

(W. Starbuck, 1974)

5.1 Introduction

The concept of Decision Support Systems has become a cry for those (managers, practitioners and researchers) who are concerned with the limitations of traditional management sciences in providing the framework in which real help can be given to decision-makers. This does not mean that the concept is well-defined but it is clear in most of the literature that the emphasis is on support rather than system.

It is claimed that the difference of this approach is the comprehensive use of the points of view provided by the different management sciences. Both Keen (1980) and Kochetkov (1980) report on the usefulness of this approach when compared with the traditional ones in the USA and USSR respectively.

Keen (1980) argues that the distinctive approach provided by DSS is characterised by four concepts which contribute to the design strategy:

1) Task context: It was already mentioned that DSS centres its attention on semi-structured problems or tasks. That author states that to give context to those tasks one needs to decompose them into

sub-tasks which must be associated with discrete intellectual operations (e.g. calculating a sum, comparing two variables, etc). In a structured task not only can the sub-tasks be explicated but also the sequence in which they are processed is determined. In semi-structured tasks one is only capable of defining the sub-tasks and that does not mean that all of them must be used all of the time. This conceptual view is important to the extent that it hints that in the design process of a DSS one should try to isolate all the sub-tasks and include them so that decision-makers can use the system and one can learn the sequence and combination in which they are used.

2) Adaptive design: This concept distinguishes the development life cycle of a DSS from that of an interactive information system. It is argued that the focus of attention must be to implement an initial system that can then be modified and firmed up with the involvement of users rather than to aim for a clearly defined final system. It is on this basis that the development of a prototype, already discussed in Chapter 4, is a start. Furthermore the availability of DSS generators, which will be discussed later in this chapter, is an important point to enable the

development of an initial system fairly quickly.

3) Personalised interfaces: To achieve the aim of supporting the problem solving process of semi-structured tasks, where the experience and intelligence of each of the decision-makers is a fundamental ingredient, a DSS must be able to adjust to different cognitive styles. This is a necessary condition to guarantee that the evolution of the system can meet the individual's expectations.

4) Implementation: To implement a DSS is a much more complex task than to implement a final system that meets a set of previously agreed specifications. Indeed its shallow initial contents mean that it is going to require a fair number of modifications to be introduced very quickly once the users start experimenting with it. To be able to meet these requirements the DSS architecture must be flexible and the ability of combining programmed sub-tasks should be ready to use.

These concepts establish the four directives that must be followed in the design and implementation of a DSS. Before describing the architecture of the system developed to match these principles I will discuss next three levels from which a DSS can be seen and how these can be used to match the objectives of the different parties involved in the project.

Figure 5.1 represents the three different views of DSS as defined by Sprague (1980) and the interrelationships between them. Starting from the top the exhibit depicts the specific DSS's, DSS generators and finally the tools.

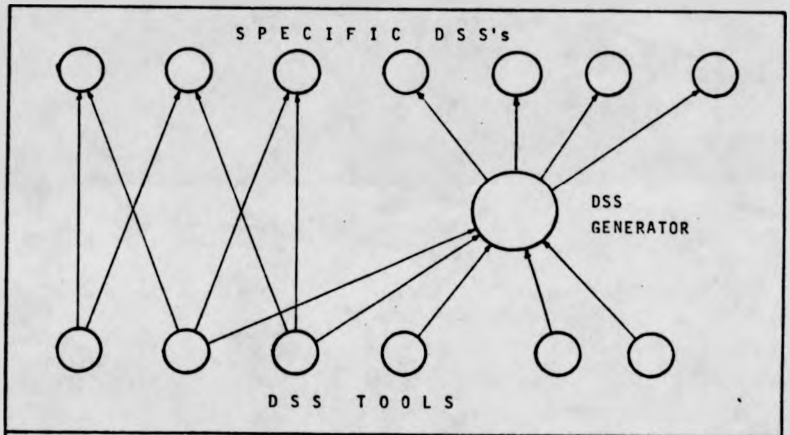


Figure 5.1 - Three levels of DSS
Source: Sprague (1980,p.10)

A specific DSS is an application to be used by one or more users and to support their decision-making process in a given task domain. A DSS generator is a library (I prefer this designation rather than package because of the flexible use it should provide) of subroutines that can be put together to build a specific DSS quickly. The tools are the hardware and software elements which enable the development of specific DSS's and DSS generators. Graphic generating routines are an example of those tools.

It is relevant here to relate these three levels of DSS with the concept of action research on which this project was based. The objective of the client organisation, particularly Organics Division, was the development of a specific DSS to be used by their production planning staff. My aim was that, by participating in the development, it should be possible to extract the most fundamental features and hence at the end it would be possible to put together a DSS generator that could be used to build up other specific applications.

It was the initial intention to use, as much as possible, the tools already available from the Visual Interactive Simulation previously developed for other projects, like the Input/Output library and internal data structures. The action research proved that these were not always sufficient, particularly in terms of the latter. Therefore some effort was also devoted to this area to match the needs of this application in terms of the man/machine interface and the use of a data base. They will be described later when the reasons for their development can be put in context.

5.2 DSS Architecture

The two objectives of the design of the general system structure depicted in figure 5.2 were to isolate the DSS concepts that could later be the embryo of a DSS Generator, and to produce a modular framework for the application modules that was capable of evolving in concert with the requirements that its use would demand.

The main components of that structure can be divided into two large categories: The Generator and specific application modules.

The blocks that form that first category are the following:

1) Control Unit: This unit has the central function of linking the Generator and application software. It is formed by a set of very simple software tables where the application modules are connected.

2) User Interface: This block is comprised of display and dialogue management systems whose function is to provide the communication protocols between each user and the Control Unit via the Input/Output tools.

3) DSS Master: It is a set of files where the information necessary to initialise each run of

the specific DSS is stored. It is controlled by the Control Unit via a set of data handling tools.

4) Input/Output tools: It is formed by a group of subroutines and data structures that enable the User Interface to display messages and images generated by the system, and interpret the commands given by the users.

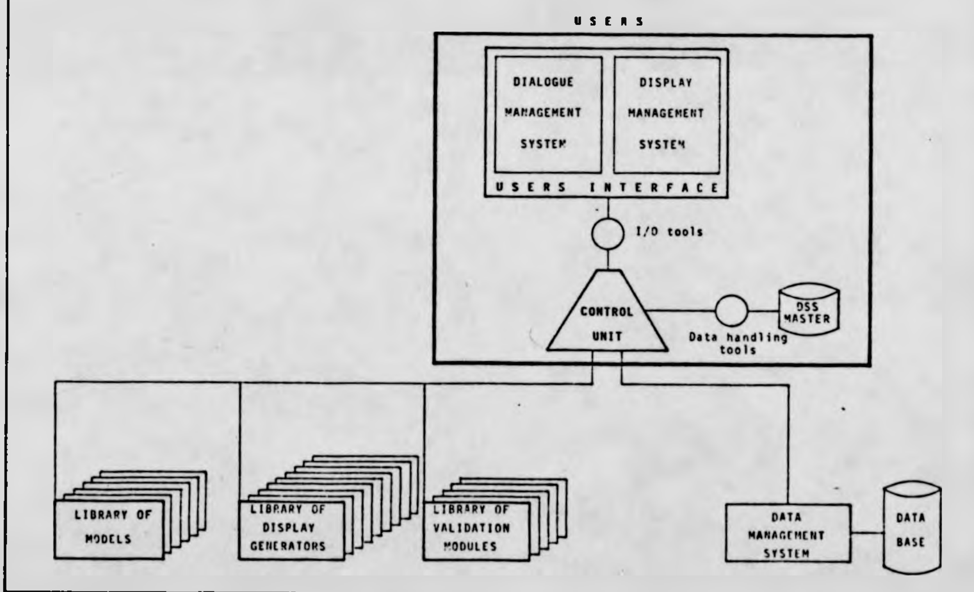


Figure 5.2 - General structure of the system: conceptual view

5) Data handling tools: It is formed by a group of subroutines that create and maintain the Generator internal data structures.

Later in this chapter a section is devoted to the discussion of the DSS tools. Because of their central role in the whole structure, the User Interface, and the Control Unit together with the Library of Models, are discussed more extensively in Chapters 6 and 7 respectively.

The specific application software, which is problem dependent, is controlled by the Control Unit and is formed by the three libraries (models, display generators and validation modules), and by the data base and its management system.

It is arguable whether the Data Base and its management system should be included in the DSS Generator. There is no conceptual restriction to its inclusion but there are a few factors that have led to the decision to leaving it out. Probably the most important one is the team's lack of experience of data bases and hence their inability to assess whether a particular structure of data base is the most appropriate for all types of data. Moreover in every real situation there is a different configuration of already installed computerised systems and therefore the effort to provide a generalised interface with all the possible networks was difficult to estimate. Later in this chapter I describe the structure of the Data Base in detail.

A discussion of the three libraries will be given in detail later in the next Chapter. Here only a brief explanation is given. These libraries are basically structures where modules can be plugged in. The library of models contains sub-task and task models and is directly used by the Control Unit. The display generators are all the subroutines that enable the display management system to form, update and delete images on the screen. The validation modules are used by the dialogue management system to validate the access of different users to the branches of the dialogue tree or to particular groups of data. These modules also contribute to the simultaneous control of the two interface systems to guarantee the consistent display of information.

5.3 DSS Tools

In terms of hardware the DSS is only dependent on an intelligent colour graphic terminal, for which already existed a colour graphic interface program that caters for the communication between the terminal and any host computer. This terminal provides a light pen and a set of sixteen function keys that can be used for input/output by the DSS generator.

On the software front the DSS tools can be grouped into three classes: DSS master, input/output and data handling.

The DSS master is composed of a set of files. Among its functions the three that are most relevant are:

1) The storage of a master description of the dialogue tree and the displays available. This master is tailored to the individual requirements of each user at the start of every run via an initialisation subroutine which reads from the data base his specific characteristics.

2) It gives the facility to take dumps independent of the Data Base that are useful for the DSS usage monitoring.

3) The storage of the data structures that form the skeleton of the Control Unit and the two User Interface systems.

This DSS master was developed for previous Visual Interactive Simulation projects and was used without structural modifications.

The block of input/output tools is formed by a group of subroutines that enable the host computer to communicate the graphics interface with the terminal. In addition to the more usual I/O facilities it also provides the ability to input text strings using the light pen. The only tool developed specifically for this project was one that enabled the dynamic programming of function keys. In previous projects each of those keys was programmed for a single task.

With regard to the data handling tools, both the existing data structures and their handling subroutines were substantially extended to cope with character attributes and the use of more flexible lists of integers and/or characters. These new structures were necessary to address the data base by storing the relevant key fields. They are extensively used in the display and dialogue management systems.

5.4 The organisation of the data base

My contribution to the definition of the data base was only to help specify its structure. It was implemented by other members of the technical team. Because of its fundamental role in a DSS, I am going to discuss some of the factors that influenced its current design.

The traditional design of data bases using tree plexstructured, and pointer-linked logical representations is inflexible and their growth or adaptation to new program demands or data contents can be expensive. Relational data structures present the simplest yet most flexible means of defining data (Martin 1977, p.202-228).

In simple terms, a relational data structure consists of a number of two-dimensional tables wich have the following properties (Martin (1977), p.203):

1) Each entry (row) in a table represents one data item; there are no repeating groups.
2) They are column-homogeneous; that is in any column all items are of the same kind.

3) Each column is assigned a distinct name.
4) All rows are distinct; duplicated rows are not allowed.
5) Both the columns and the rows can be viewed in any sequence without affecting the information content or the semantics of any function using the table.

In addition to the flexibility and simplicity of representing data, this technique provides the analytical procedures (normalisation) by which relational data structures can be derived from a collection of data items relevant to a given problem. Martin (p 226 - 227) lists nine advantages of this technique when compared with traditional ones. He concludes expressing the hope that in future relational data structures will be the universal form of data bases.

For those reasons, but mainly because of the importance of its flexibility to the design of DSS, the data base was designed as a relational structure and software management was provided by a proprietary package (RAPPORT) - supporting relational structures and usable by FORTRAN programs.

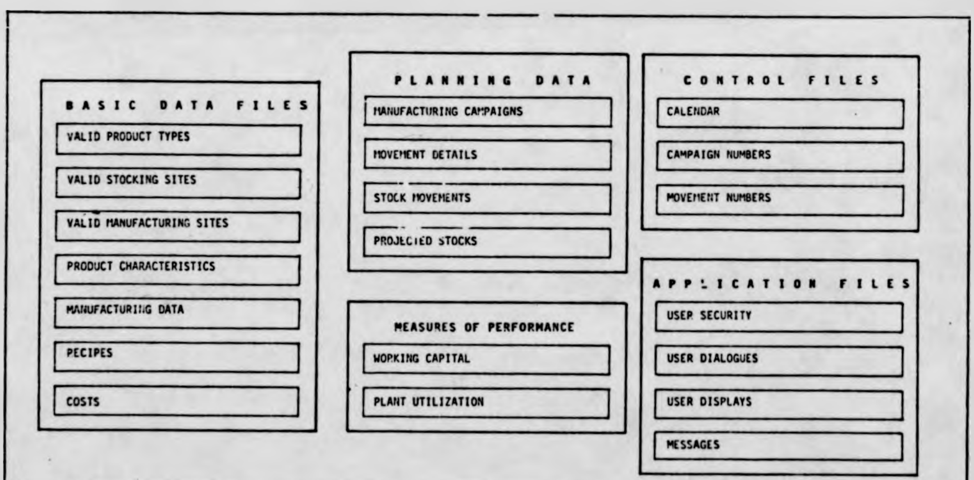


Figure 5.3 - Data base files

One of the advantages of this type of data base is that it does not require the formal representation of relationships between items of different files as the traditional types do. Figure 5.3 represents the contents of the data base in terms of files. A more detailed specification of each file is provided in Appendix 1.

Although the division of files under five headings has no implication in terms of either their physical or logical representation, such grouping is intended to give a more clear, but necessarily broad, view of their purpose. The basic data files contain information already existent and, in the majority of cases, is copied from other computerised systems. The planning data is the result of the decision-making process and it represents the plans for the next 52 weeks in terms of manufacturing and movements of materials. The measures of performance files represent the value of the plans when compared with certain targets (e.g. cash limits, direct expenses absorption). The control files contain the information needed by the system to control the data base. Finally the application files are used for user dependent information which is required to tune the DSS to the needs of each user.

The advantages offered by relational data structures are achieved at the expense of performance. Martin (1977, p.225) argues that it does not necessarily need to be so and depends on the way the logical structure is represented physically. Nevertheless, to reduce the impact of this drawback in the project a number of redundant files were included in the data base to support various enquiry and display requirements of this application. An example of these is the file of projected stocks whose 52 values could be derived from the opening stock and the stock movements information. Apart from increasing the speed of access to those values often used in the decision-making process, this organisation of data enables the fast maintenance of a stockout marker for each product and hence the product records can be sorted according to that marker to produce an organised list of products with prospective problems. Other redundant files are the ones concerned with measures of performance. Here data space is sacrificed to permit fast access to summaries, which would need a search of several hundred records accompanied by at least 52 additions and the same number of multiplications per record. The performance achievable without this redundancy would be unacceptable in a DSS, or any on-line enquiry system for that matter.

5.5 Summary

In this Chapter, after discussing the four directives for DSS design proposed by Keen (1980) (task context, adaptive design, personalised interfaces, and implementation), I described the architecture of the system focussing the attention on the three levels proposed by Spraghe (1980) from which the DSS concept can be seen (specific DSS, DSS generator, and DSS tools).

The basic design objective was to isolate the DSS generator from the specific application modules and to provide the framework where these could be plugged in.

The overall structure was justified and the main components of the generator, which will be the subject of subsequent chapters, are briefly described. The decision to leave the data base and its management system outside the generator is also discussed.

The last two sections of the chapter are devoted to DSS tools and the data base. The reasons for including these two more specific points in this chapter are:

1) The DSS tools were mostly available from previous projects and were only improved to support a more general man-machine interface and the use of an external data base. Therefore, unless the very technical details were described (which would not be consistent with the rest of the thesis), they could not justify a chapter in themselves.

2) My involvement in the design of the data base was small and its implementation was carried out by other members of the team. So to dedicate a full chapter to this matter would give it a much higher emphasis than the weight it had in my work.

6. INTERFACE DESIGN

"... the system, as seen by users, is the interface. They are - and should be - uninterested in the clever coding, hierarchical structuring, relational data bases, table driven software, ... that carry out their requests. They are very sensitive to the quality of the interface."

(Keen and Scott Morton,1978 p.182)

The role of an interface is to enable the user or users of the system to communicate with the computer or, to be more precise, with a data base and a set of models which describe relationships among the information held in the data base. One may consider the interface to be composed of two parts: hardware and software.

The hardware used in this project is an intelligent colour graphics terminal which includes the possibility of use of a light pen and programmable keys in addition to a common keyboard.

The software is basically formed by two complementary systems - the Dialogue Management System and the Display Management System - whose description is the subject of this chapter. Before describing those two systems I dedicate the next section to a discussion of some of the principles that were adopted in their design.

6.1 Requirements for a DSS interface

Friendliness is an attribute frequently attached to interactive computer systems. Stevens (1981) discusses this point in relation to a large spectrum of systems (from word processing to medical consultation aids) and concludes that the term in itself is meaningless. If it is not put into the context of the purpose of the system and its potential users it does not provide any guidance to the designer. In this section I am particularly interested in the discussion of the characteristics that an interface should have to be friendly to a more restricted class, that of DSS users.

Next I discuss the eight points that were more relevant for the project. I am not claiming that they provide a cut-and-dried method for the design of interfaces but hopefully they can be used as a check list of fundamental points that designers can use to define the appropriate interface for each particular case. These issues are interdependent and their importance may vary from application to application.

6.1.1 Purpose

The main purpose of a DSS is to be helpful to the decision-maker in his problem solving process. This concept encapsulates a variety of ideas, some of which are contradictory. For instance, it should be easy to use in the sense that it should accommodate a number of different situations characteristic of a semi-structured process; on the other hand, it should stimulate changes in the decision making process and therefore should be able to cope with the evolution that the system induces. Its general structure should be transparent to encourage user participation in the evolution of the system but transparency and flexibility are not always easy to put together.

6.1.2 Context definition

At any stage of the use of the system the interface should provide the decision maker with the information that is relevant to his current problem. Again this principle is elusive. The semi-structured nature of the decisions requires that the interface should enable the user to choose the information that most appropriately defines the problem. One of the conclusions that can be derived from this last point is that the fixed format screens characteristic of most information systems are not necessarily appropriate for a DSS interface.

6.1.3 Naturalness

The issue of interfaces capable of dealing with natural languages (English or any other) has been discussed by many authors. Fitter (1979) after discussing the ambiguities of natural language suggests that for the purpose of man-machine communication "a natural language is one that makes explicit the knowledge and processes for which the man and computer share a common understanding".

This definition provides a lead to interface design and suggests that one should not be too ambitious in natural language recognition to avoid losing both the explicitness and the common understanding. Hayes et al (1981) discusses these two problèms very extensively with the help of an example of a data retrieval system. In the case of a DSS the task domain that provides the framework for its use usually allows for a small subset of a human language to be used, and it does not seem to be paramount the provision of a 'humanoid' language.

One additional point that I would add to the previous definition is the necessity of the context in which the dialogue between man and machine takes place to be understood by both partners. Here the word context is used in the narrower field of dialogues and not in that of problem (or decision) definition addressed in the previous sub-section.

6.1.4 Control

The problem of control has been thoroughly discussed by Fitter and Sime (1980) who conclude that there is a need for the system to make itself clearly understood so that decision makers can be responsible for the decisions the system has helped him to take. The use of dynamic displays is one way forward to the accomplishment of that requirement. Their usage in the applications of visual interactive simulation proved that it is possible to 'open' to non specialist users models that without that technology would be difficult to understand and hence have the chance of being controlled.

But there is more to control than just this point. In the DSS the system will only provide adequate help if the user is able to control the sequence of steps he wants the machine to do. Again flexibility is an important factor: it is unrealistic to assume that one can foresee all the possible uses of the system.

6.1.5 Personalised

The problem solving process used in semi-structured problems is finely connected with the cognitive style of decision makers. Thus it seems important that a DSS interface should include the capability of being tuned to different users. This point has been often mentioned in the literature but not many applicable principles have been suggested. Although the problem is difficult to resolve in a generalised manner, the possibility of individualised dialogues, displays and even models should be considered for inclusion in a DSS. The way they may be used depends on the application; however,their existance is in itself a stimulating lead to look for its appropriate use. Even if the personalised interface is only formed by cosmetic niceties, if they contribute to job satisfaction and motivation for users' participation in developing the DSS, (e.g. sense of ownership), it is worth the trouble.

As with all other concepts discussed above there is a problem with personalised interfaces. If the DSS is to be used to support negotiations between different decision-makers the existence of personalised interfaces may prove to be an obstacle to the achievement of that end. I have no clear answer to this problem and it requires more action research, but from the experience of this project I am inclined to think that personalised interfaces are appropriate when decision makers with different functional positions are negotiating. When the negotiation is between managers of similar functions the personal displays may decrease the level of mutual control and even erode the context definition. Later in the conclusions of the Display Management System I discuss this matter in more detail.

6.1.6 Evolutionary

I discussed above the issue of an evolutionary DSS to support the ever-evolving problem situations and the decision makers own adaptation to that change. It is clear that the flexibility necessary to cope with this has to be achieved mainly in the modelling and searching areas. However the interface needs to adjust to the use of new models and should not become a cause of trouble to the users. Furthermore there is a need to account for the increased familiarity with the system by the users.

6.1.7 Ease of use

Many authors have discussed this point in relation to naive versus expert users, and ad hoc versus regular users (e.g. Cuff, 1980). Stevens (1981) makes an examination of this problem and concludes that out of a context it is almost as meaningless as the word friendly. The type of interface required in a system that is to be used by ad hoc users only will be necessarily different from that of a DSS designed to support decision makers who use the system regularly. In this project it was decided that training was essential to enable the decision makers to learn how to work with the interface. However, it was not assumed that they would find it easy to use in the first instance.

In a DSS for regular use I interpret ease of use by the negation of what it should not be: a nuisance for the user in his decision making process.

The provision of help facilities is, nevertheless, very important. Not only in the initial days of training and implementation, but most importantly to help regular users when they access parts of the system they do not know so well. If correctly designed they are much more attractive than the manual 'that seldom is in the right place at the right time'.

6.1.8 Immediate response

This matter has been pointed as a decisive contributor to other concepts previously discussed, such as naturalness and context definition. It is important that the system makes clear to the user what it is doing by a rapid response to his command and by following a logical order in the dynamic updating of the displays. For instance, if the user asks to change a manufacturing campaign it is logical that the display of the plan is updated first and only then the implications of that change in stocks, utilisation and other measures of performance are shown.

In addition to this software consideration this project showed the need to re-assess the use of CPU-sharing main frames. The variability in response time has proved to be the major cause of users' impatience and frustrations. The rapid evolution of micro-computer technology (both hardware and software) may well provide a better starting point for the implementation of interactive systems. Further investigation into this area is needed and may prove to be very valuable.

The eight points discussed above were the guidelines for the development of the two component systems that will be described in the remainder of this chapter. It is worth emphasising that the objective of their development centred on the design of a generalised framework which could be used for other DSS's and this application was used as a stimulator for ideas and a ground for experimentation and testing.

6.2 Dialogue Management System

A dialogue management system is a controller which makes a certain number of dialogue elements available to the user, interprets his input in context, and transmits his requirements to the system for execution. Before describing it in detail I discuss the problems of integrating the principles mentioned in the previous section in its design.

In relation to the experience of visual interactive simulation Brown (1978, p.134) commented that "the keyboard is a cumbersome method of communication and one which would be alien to most non-technical users", and suggested that the use of light-pen and direct speech should be investigated. The latter was ruled out in this case because of its non-availability in the hardware that was to be used. In addition to the light-pen, the use of function keys as primary input devices was considered desirable to increase both the speed and comfort of input, and to curb the number of input errors that the use of a normal keyboard is likely to generate.

With regard to ease of control, the problem of dealing with a large number of possible commands (or dialogue elements), was not previously met in the application of visual interactive simulation. Thus, the structure in which the interactions were arranged was not appropriate for a DSS for more complex problems, and a desirable feature of the system for this project was the organisation of the dialogue elements such that the decision maker is able to use the full power of a DSS in an effective manner without being confused by the range of options available to him.

The development of a tree structure with the dialogue elements grouped appropriately is aimed at that requirement and has the potential advantage of putting together those interactions that the decision maker wants to use in sequence during his problem solving process. This type of structure also has the advantage of reducing the input by allowing global variables which are common to a particular cluster of dialogue elements to be defined when the gate which gives access to that cluster is passed through.

A structure of the form just described has two main disadvantages:

1) It soon becomes cumbersome for an expert user who

wants to move more freely from one group to another;

2) There are commands which need to be accessible at any time during the problem solving process, and the dialogue control returned to the point where the decision maker was.

There are two complementary ways of approaching the first problem. The contents of each cluster of dialogue elements being made user dependent can be designed and modified to adjust to the requirements of each user so reducing the frequency of changing from one cluster to another. In addition, the provision of a dialogue management system which can modify the way an expert user can look at the tree structure, transforming it to an apparently flat one with all the commands accessible at any time with the use of context, reduces the trouble of constant conscious change from one cluster to another.

The problem of commands that need to be accessible at any time (e.g. HELP, REFORM, DUMP, etc) can also be solved by grouping them in a special high priority cluster whose contents are inspected whenever the user inputs a command.

Given the objective of developing a DSS generator one important characterstic is ease of use of the dialogue management structure by the analyst (or mid-user as they are called by Smith, 1980) who wants to design other applications and keep them tuned with the evolutionary requirements of the users.

6.2.1 Description

The structure of the master tree, which is stored in the DSS master file, is illustrated via the example of the one used for this project in figure 6.1. This tree has three layers of clusters:

1) session;
2) function;
3) interaction;

and it is formed by a variable number of data structures which represent dialogue elements. Each of them has two attributes - name and number, and a list of entities. This list contains an entry for each of the dialogue elements of the immediately lower level, which are made available to the user by opening the corresponding branch. Each entity in the list is formed by a short name of the dialogue element and a variable number of pointers. An example of the use of this tree is presented in Appendix 5.

On the top of the tree there is the element •HEAD• which enables the DSS control structure to initialise the dialogue management system at the beginning of each run.

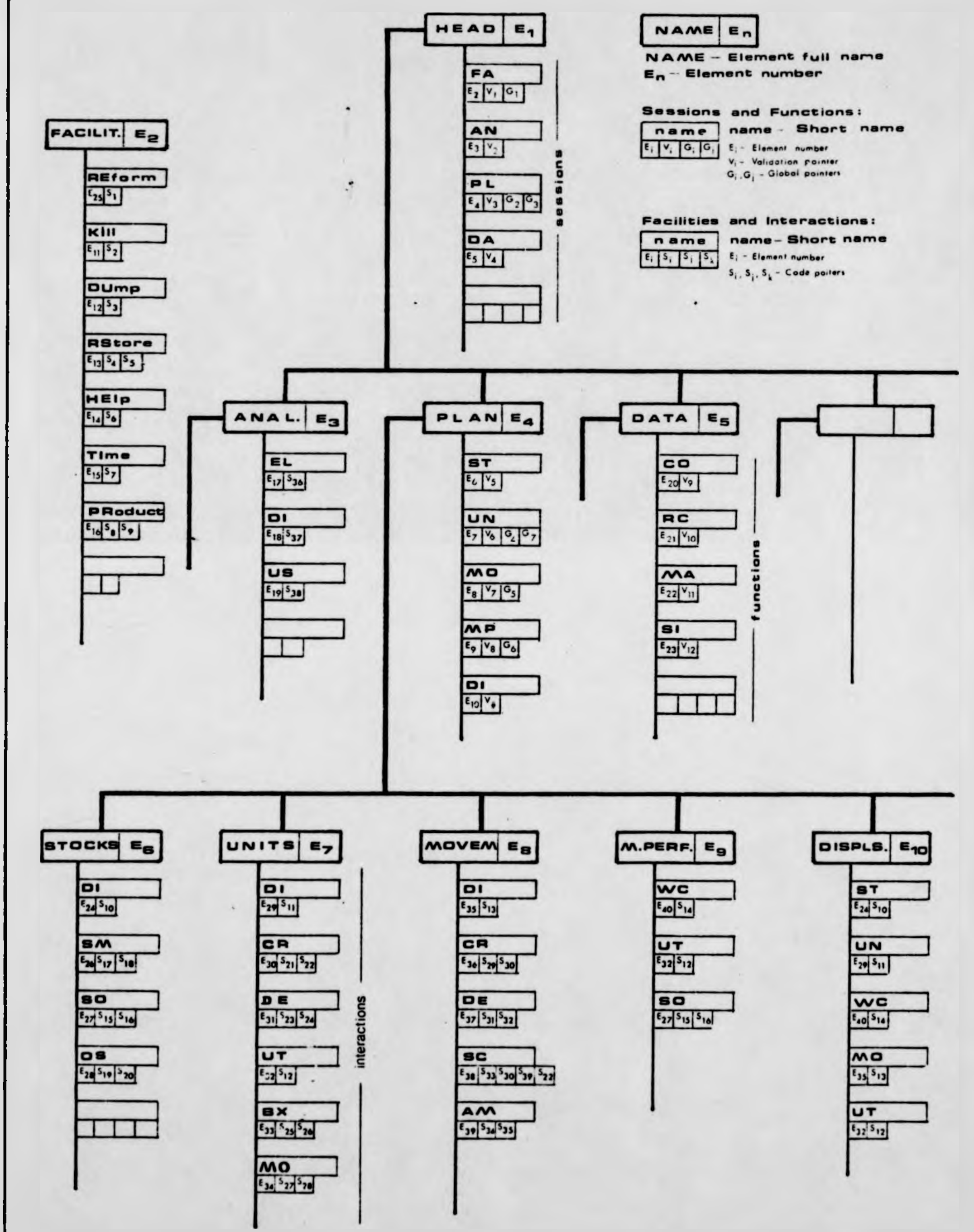


Figure 6.1 - An extract of a dialogue structure

Tuning to the current user is made by inspecting the data base user's dependent file where the connection links that need to be cut are stored.

The first entry in the list of 'HEAD' is always an entity with name 'FA' and a pointer (E2) to an element whose name is 'FACILITIES'. The names of the commands that need to be available at any point of the dialogue are stored in the list of that element. In addition to 'FA' there are variable number of entries that can represent, for instance, the different type of sessions the user has available. In this project there are two real sessions - PLANing and DATA amendment, plus one entry which gives access to 'ANALYST' commands. These are of primary concern for the analyst debugging and tuning activities; the latter should not be present in the dialogue structure of decision makers. In addition to the names and pointers (e.g. E4) to the elements that open each session branch, there are slots that can be used as pointers to table driven software for validation (e.g. V3 in PL) and global variables definition (e.g. G2 and G3 in PL). For instance, a decision maker may be allowed to plan only a subset of the products and/or manufacturing sites. The G pointers can be used to prompt for global variables and display generators which map information that is common to the whole session. The use of these pointers is optional, and although they may be made user dependent that feature was not implemented in this project.

Similarly, at the next lower level - FUNCTIONS - the list in the PLAN session can contain entries like ST (stocks), UN (manufacturing units), MO (movements), MP (measures of performance), DI (displays). These entries contain name, an element number, and optionally pointers that again can be used for validation, global variables definition and display generators. As an example, if the decision maker chooses UN he will be aked to identify the manufacturing unit, the system will then check whether he is allowed to access that information and, if the answer is positive, will display the current plan for that unit.

Finally at the lowest level, in each cluster there are a number of entries that identify interactions. Among others, that will be referred to later, there is one particular advantage in structuring interactions in this way: their names do not need to be unique and can be interpreted in context. In the example shown in figure 6.1 the first three entries in the functions UNITS and MOVEMENTS have the same name - DI (display the plan or movements), CR (create a campaign in the plan or a movement), and DE (delete a campaign or a movement). This structure also allows for the same interaction to be requested from different places, eventually with different names. For instance, the interaction DI in the UNITS function will have the same consequence as the UN interaction is the DISPLAYS function. For that it is only necessary that from the second or third pointer onwards they are equal in both entries.

The set of pointers at the interaction level has a different meaning from those of session and function. The first is necessarily a pointer to an element where the description of the interaction is held to be used by the HELP facility. From the second pointer onwards they serve as pointers to executable table driven software. When the interaction gives access to a model it is usually wise to use the second pointer for the subroutine where the data is input and the remainder for the actual models. The reason for this will be better understood in the next chapter where the models structure is discussed. As an example, the interaction SC (schedule) in the function MOVEMENTS is meant to allow for the entry of the details of an export and subsequent planning of a manufacturing campaign to satisfy that demand if there is not enough available. The same can be done manually by creating the movement (CR in MOVEMENTS) and the subsequent creation of a campaign (CR in UNITS). In figure 6.2 the detail of these entries is depicted. In SC the second entry allows for the input of data that is different from the other two interactions but the third and fifth are the second of CR in MOVEMENTS and

CR in UNITS, respectively. The fourth represents a searching process that will be described in detail in section 7.1.

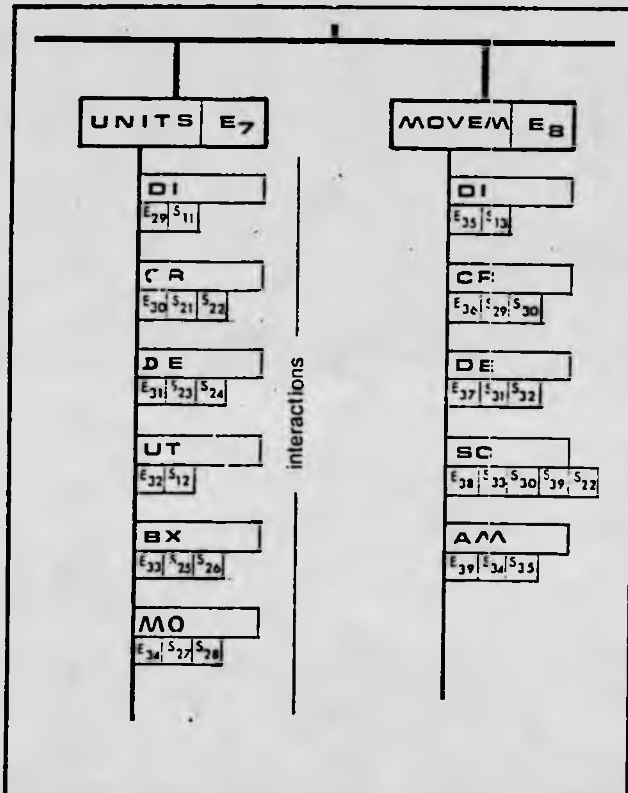


Figure 6.2 - An example of the use of pointers

The problem of dialogue elements that must be available at any time is solved, as was referred to above, by inserting all of them in the special data structure FA. Whenever the decision maker inputs a command a first check is made to see whether it matches with any of the entries in data structure. If it does the second and subsequent pointers in the appropriate entry are used to execute the code that was asked for and the control of the dialogue tree is then returned to the point where the decision maker was before asking for that facility.

In addition to some standard facilities like the first five entries in the 'FACILITIES' element, more can be provided for each user. They can be particularly useful for modifying global variables that were defined at the higher levels of the tree. For instance, if simulated time is defined when the session PLAN is opened, the decision maker may well want to see the information concerning the same products and/or manufacturing units he has been working with at some point in the future. That can be done by a facility like TIme which, after prompting for the time in which the decision maker is interested, reforms the physical screen by moving the windows of the logical displays currently mapped along the time scale. In the same way it is possible to provide other dialogue elements to modify variables that are global with or without the same effect on the current screen.

The use of function keys and light pen as main input devices was one of the targets set up initially. Before exploring their use it is worth mentioning the limitations of the hardware. The terminal used in the project has sixteen function keys. The dialogue management system enables the analyst to use these in two distinct ways. He can allocate to four of those keys a permanent function leaving the remaining 12 to be managed by the system which dynamically allocates to them the dialogue elements that are directly available at any time.

Of the four permanent function keys two are used for functions like EXIT and GO. These are function extensively used throughout the system and their use has an effect which is context dependent. For instance, EXIT when an interaction is being asked by the system will transfer the command to the next level up in the dialogue tree and thus make available to the decision maker the set of functions included in the current session. In this project EXIT has also been used inside the interactions in the data input section where they have the effect of setting the data base and the current displays to the state they were in immediately before that interaction was invoked. The function GO has been used in this project to by-pass data input prompts and take default values. However the analyst may use this function key with a different meaning, wherever that is appropriate.

The other two permanent keys may be used for any function by the analyst. In this project they have been used for facilities which are used frequently, like REform and TIme.

The twelve dynamically allocated keys are used to indicate which of the possible dialogue elements the decision maker has available at a particular time. The correspondence between the keys and the dialogue elements is achieved by a logical display mapped on the lower lines of the screen containing the list of short names of those dialogue elements displayed above the keys. The use of function keys limits the number of dialogue elements in any cluster to 12.

The use of the light pen was assumed to be more important for application dependent input, because the function keys secure almost all the system input. However, as all the dialogue elements that are available at a particular time are displayed, the light pen can be used as an alternative to the function keys.

It was stated above that an expert user could look to the dialogue tree as a flat structure by using commands in context. This was achieved by the use of decomposition and interpretation of input. The first restriction is that the user will not be able to use either the function keys or the light pen if he wants to jump across the dialogue tree. Whenever the keyboard is used to input a command the system decomposes it in groups of two characters and, depending on where the control of the dialogue is at that moment it will execute the commands in the requested sequence.

For instance, if the system is currently asking for an interaction inside the UNITS function (stage 1 in figure 6.3) and if the user wants to go to the interaction WC (working capital) in the function MP (measures of performance) he can follow the tree structure (dotted line): Pressing EXIT will pass the control to the element PLAN (stage 2) and display the functions available in that session. By pressing the function key allocated to MP first (stage 3) and then the one allocated to WC he gets to where he wants. Alternatively, if he is familiar with that part of the structure, he will achieve just the same result by keying in MPWC (continuous line).

The dialogue management system also provides the analyst with facilities to monitor the use of the system by different users. There is a logging facility which records the sequence of commands used by the decision maker together with the time and input device used.

6.2.2. Conclusions

Insofar as this project can be considered a representative experiment, and allowing for its short duration, the dialogue management system has proved to be effective in providing a communication support. However, some of the

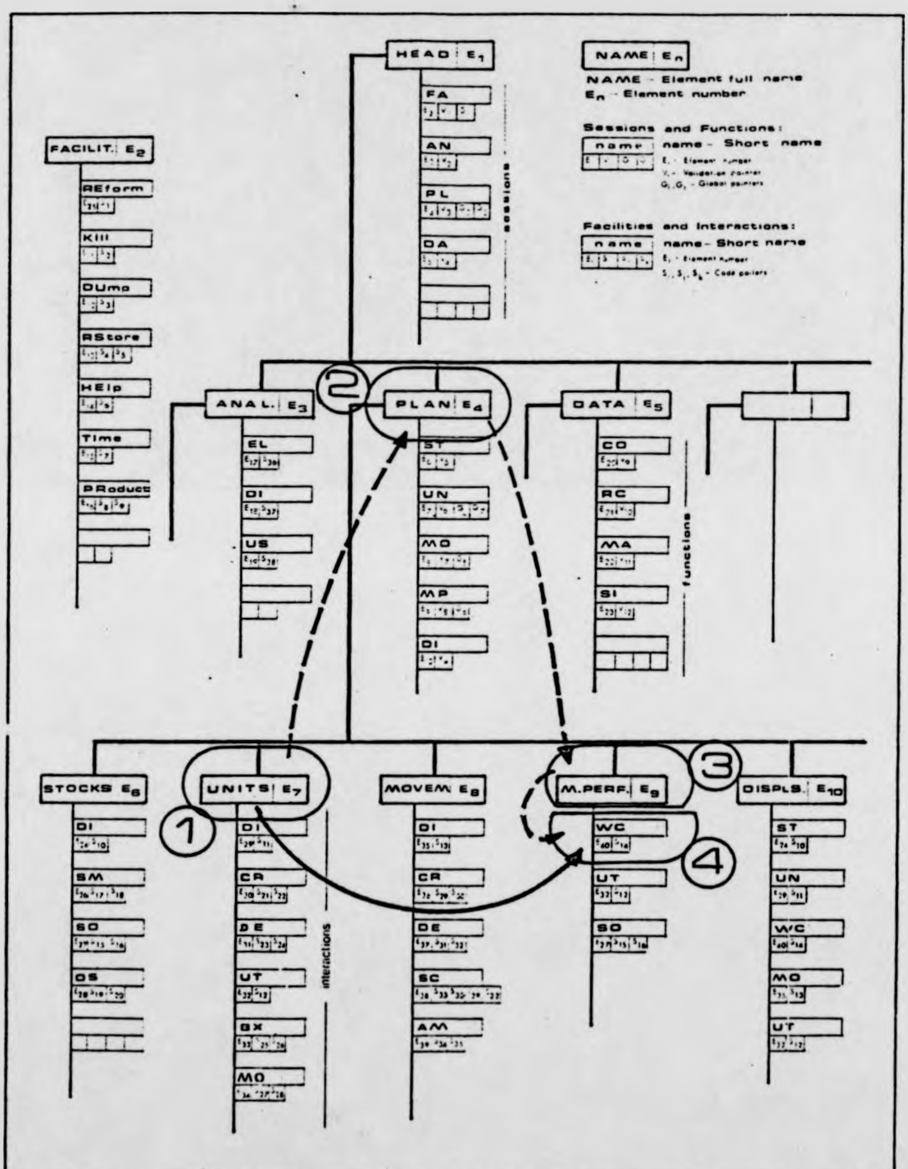


Figure 6.3 - An example of the use of context in dialogues

features were not used in quite the way I had expected. Among these, the ones worth reporting are function keys and light pen, the personal tuning possibility, and the monitoring facilities.

1) Function keys : Their use by the planners was quite intensive during training and in the first month of operation. After that they have been used much less frequently, except for the four function keys allocated to permanent functions which still are used; (for instance, the functions EXIT and GO have never been input using the keyboard by any of the users).
When asked why he stoped using the other function keys, one of the decision makers mentioned that he was very familiar with the structure and had no problem in moving around because he knew exactly where to go and how to get there straight away. He also mentioned that they were useful as a vehicle to understand the dialogue structure, but now he felt that the action of keying in, say MVCR, was more meaningful than to press function keys.
These remarks highlight two points: the flexible tree structure provides a meaningful framework for dialogue design, and the function keys seem to be a good teaching vehicle for that.

2) Light pen: With regard to this input device, insofar

as the two decision makers currently using the DSS are concerned, it is useless. From observation I think that there are two reasons for that attitude. First it is not very reliable and if one is not precise in pointing at the relevant string, the light pen may take the line above or below and then the decision maker will need to repeat the input. Secondly, its use implies that the light pen is picked up from its support and put back after its use, which may be a waste of time if only used for the odd input.

I do not think that one should discard its potential use on the basis of this experiment. It is worth monitoring it in other applications to check whether these conclusions can be generalized.

3) Personal tuning : This feature has only been used initially to form a default structure which is being used by both decision makers. However, because of the limited experience gained so far in modifications and enhancements to the models provided, it is too early to draw definitive conclusions about it. Furthermore once more complex models are provided they are more likely to be personal. In addition to that it has already proved useful to distinguish the dialogue structure of decision makers from that of analysts.

4) Monitoring : The use of this facility has been poor. My attitude towards its future inclusion would be either to enhance it and take more information which would need to be application dependent, or discard it altogether. As it stands now it only provides information about the input device used to select a dialogue command and the time spent inside this command. When it was specified I was hopeful that the time was a reasonable measure of the complexity of decision making, but other factors like line noise and slow computer response are responsible for most of the deviation from a very stable average. This feature was also intended to support the tuning of the personal dialogue structure but, as referred to above, the familiarization with that was very rapid and the decision makers are happy with it.

One additional interrogation is whether the three level tree is the appropriate structure for a DSS generator. In this project it has been adequate. However, one should try to evaluate its value in other environments. I am inclined to suggest that its scope should be application dependent and thus the analyst should be able to choose the number of levels to be used.

6.3 Display Management System

The eight design principles enumerated in the first section of this chapter are also valid for the implementation of a display management system. If the dialogue structure provides the decision maker with the elements to communicate with the computer, the displays work in the other way: they form the language the computer 'speaks' as far as the end user is concerned.

Those principles are more difficult to implement in the design of displays than in dialogues. This is probably so because the human is eventually able to get round the use of a restricted vocabulary to make the computer do what he wants, but he cannot be effective in his decision making process without the relevant information.

Hayes et all (1981) summarize the conflicting objectives of display management in the following way:

"- The user should always be able to arrange windows to see the parts of the display that interest him, but

- the system should automatically position displays so that the user needn't intervene;

- the screen should be exploited to provide the largest possible working context for the user, but

- the layout of the screen should be kept simple to avoid confusion."

My research objective in designing the display management system was to depart from the concept of logical displays used in visual interactive simulation (Hurrion,1980) and develop a more complex framework that should be sufficiently flexible to support a semi-structured decision process.

6.3.1. Description

The concept of logical display provides a very powerful mechanism which allows a number of output logical channels to be orientated to the same physical screen. Hurrion (1980) reports its use in simulation experiments enabling the decision maker to choose the information that is relevant at each stage of his problem solving process. In previous projects the mechanism of logical displays was mainly used to achieve two objectives:

1) To enable the user to switch from spatial displays to summary information when he needed to assess his own problem solving process;
2) To enable the user to choose the type and amount of information that he wants displayed on top of the spatial basic framework.

To support the decision making process of the class of problems at which the DSS generator is aimed, it was necessary to improve the versatility of display generation and management of the physical screen space. This is because the scheduling problems which the visual interactive simulation systems were designed to support required as a basic display a representation of the physical layout under study. In the present class of problems the users' models of their problems are of a logical rather than physical nature. The versatility sought was achieved by extending the concept of a logical display from a switch to an internal data structure.

This data structure, for which a detailed description is presented in Appendix 2, represents a logical display whose size can be considered to be effectively infinite. In each such display a variable sized window is defined and only the picture inside the window is displayed on the physical screen. In each logical display the coordinates of the bottom left hand side corner of the logical window in relation to the origin of the physical screen are also defined. This structure enables the analyst to work always in absolute coordinates and the system, by manipulating the corner coordinates and according to what is currently mapped at the physical screen, to transform them so that they are in the right format to be displayed.

There are two distinct ways in which a logical display can be used:

1) Automatic display: This type of display is achieved through the global variables and the dialogue facilities defined in the dialogue management system. Figure 6.4 is an example of this.
The user has just entered the UNIT function and the system immediately displayed the manufacturing plan for that unit during the time scale previously defined by the user as global at the next level up (PLAN) (see figure 6.1 for reference). Apart from the plan the display also shows some standard information like the state of all the global variables, and at the bottom the dialogue elements available to the user in the cluster of PLAN + UNIT.
The advantage of automatic displays is that they are linked to the global variables and so, if the decision maker decides to change either the manufacturing unit or the time, all the displays will be changed accordingly, unless he has previously asked to delete them.

2) Display by demand: These are used whenever it is not appropriate or relevant to do the automatic mapping. For instance in figure 6.5 on top of the plan is displayed the utilization of the manufacturing unit.

WORKS; WU   COST C: SIBS   UN: 002   PROD: *   YEAR: 81 CP: 05 WK:1 (19)

CP05 WK 1	WK 2	WK 3	WK 4	CP06 WK 1	WK 2	WK 3	WK 4	CP07 Wk 1	WK 2	WK 3	WK 4	WK 5
8 1	10 1	8 1	6 1	6 1	6 1	5 1	5 1	5 1	1 1	1 1	6 2	6 2
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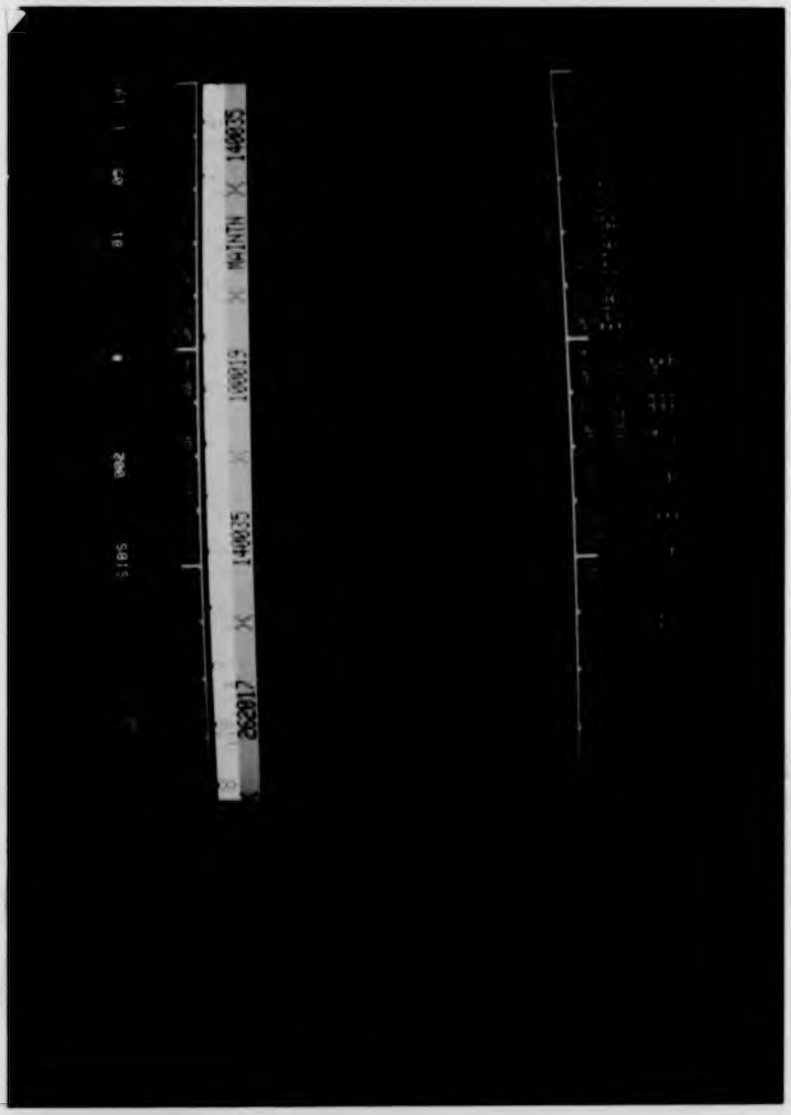
WK 1 WK 2 WK 3 WK 4 WK 1 WK 2 WK 3 WK 4 WK 1 WK 2 WK 3 WK 4 WK 5
CP05 CP06 CP07

MODE:PLanning   FUNCTION:UNit   INTERACTION: Enter Interaction:

2	3	4	5	6	7	8	9	10	11	12	13
ST	SM	CR	DE	TT	MO	AM	BX	AV	UT	BS	ME

MODE:PLanning FUNCTION:UNit INTERACTION: Enter Interaction:

2 ST 3 SM 4 CR 5 DE 6 TT 7 MO 8 AM 9 BX 10 AV 11 UT 12 BS 13 ME



This display could have been automatically displayed in conjunction with the plan but, because it is not so frequently used, it was decided to map it only on request, which in this case can be done by entering UT (utilization).
Although these displays are not automatically mapped, once they are on the system will maintain them consistent with the relevant global variables.

Figures 6.6 and 6.7 show two different displays that could be formed from that of figure 6.5. In the first a set of stock profiles with the indication of the causes of the flutuations (i.e. production,consumption,imports, and exports) is represented. In the second the two red bars show the details of two exports of the product whose profile is displayed below. Figure 6.8 shows another example of a display whose contents were defined in a different sequence.

In a similar way to that described for the dialogue structure, the masters of all the logical displays are stored in the DSS master file and are initialised by adjusting them to the requirements of each user, according to the information held in the user dependent files of the data base.

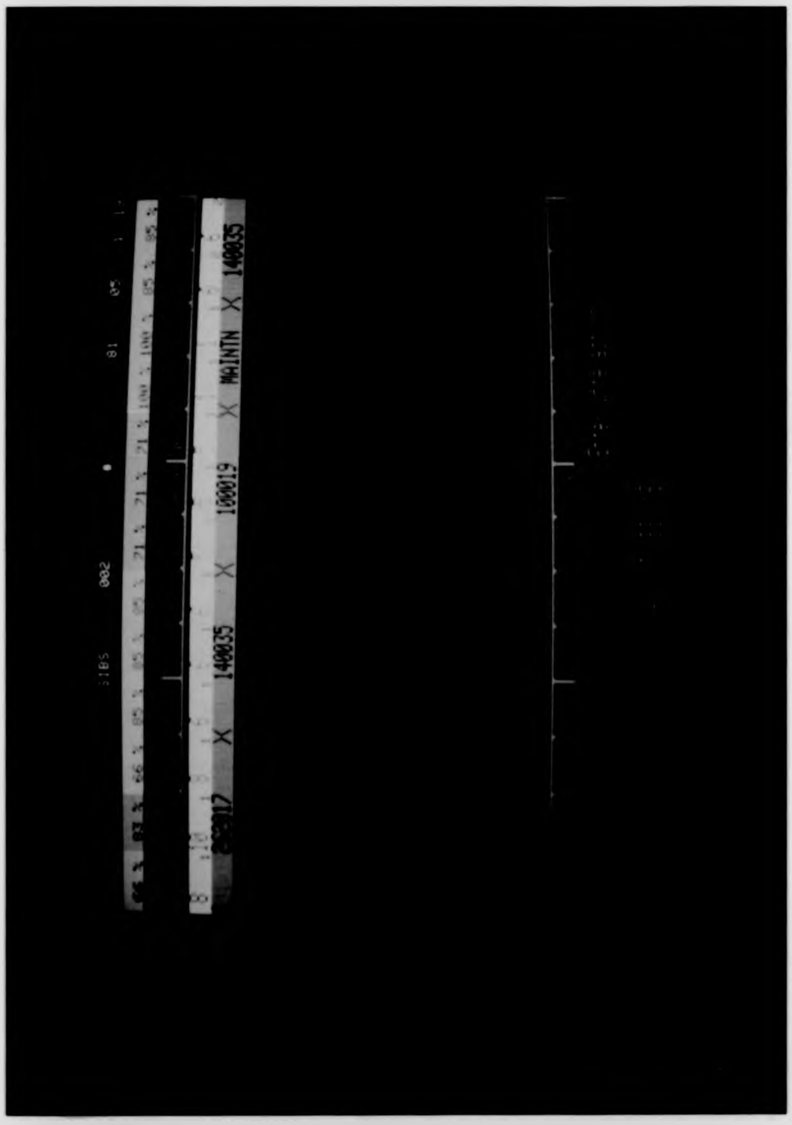
WORKS: WU   COST C: SIBS   UN: 002   PROD: ✦   YEAR: 81   CP:05   WK:1(19)

66 %	83 %	66 %	85 %	85 %	85 %	71 %	71 %	71 %	100 %	100 %	85 %	85 %
CP05				CP06				CP07				
WK 1	WK 2	WK 3	WK 4	WK 1	WK 2	WK 3	WK 4	WK 1	WK 2	WK 3	WK 4	WK 5
8 1	10 1	8 1	6 1	6 1	6 1	5 1	5 1	5 1	1 1	1 1	6 2	6 2
262017			140035			100019			MAINTN		140035	

WK 1	WK 2	WK 3	WK 4	WK 1	WK 2	WK 3	WK 4	WK 1	WK 2	WK 3	WK 4	WK 5
CP05				CP06				CP07				

MODE:PLanning   FUNCTION:UNit   INTERACTION: Enter Interaction:

2	3	4	5	6	7	8	9	10	11	12	13
ST	SM	CR	DE	TT	MO	AM	BX	AV	UT	BS	ME



WORKS: WU   COST C: SIBS   UN: 002   PROD: *   YEAR: 81   CP:05   WK:1(19)

66 %	83 %	66 %	85 %	85 %	85 %	71 %	71 %	71 %	100 %	100 %	85 %	85 %
CP05				CP06				CP07				
WK 1	Wk 2	WK 3	WK 4	WK 1	WK 2	WK 3	WK 4	WK 1	WK 2	WK 3	WK 4	WK 5
8 1	10 1	8 1	6 1	6 1	6 1	5 1	5 1	5 1	1 1	1 1	6 2	6 2
262017			140035			100019			MAINTN		140035	

100019 YELLOW GRAIN SHADE 36

	10.3	10.3	10.3	4.62	4.62	4.62	0.09	0.09	6.34	12.6	12.0	12.0	0.44
P									6.25	6.25	6.25		
C													
I													
E				5.64			4.53				6.80		11.6

140035 GREEN GRAIN 2A   Stockout in CP10

	7.57	7.57	7.57	7.57	16.0	11.9	20.3	20.3	11.8	11.8	11.8	11.8	20.2
P					8.40	8.40	8.40						8.40
C													
I													
E						12.5			8.45				

262017 RED GRAIN SH 982

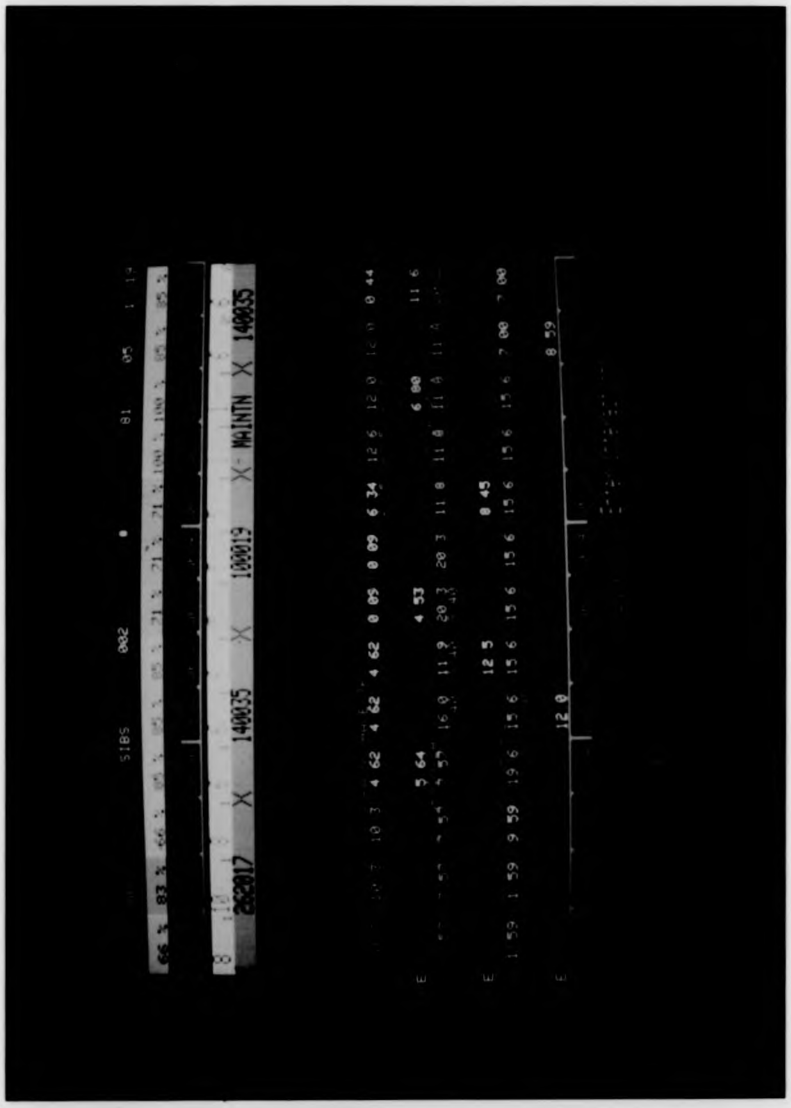
	1.59	1.59	9.59	19.6	15.6	15.6	15.6	15.6	15.6	15.6	15.6	7.00	7.00
P			8.00	10.0	8.00								
C													
I													
E					12.0							8.59	

Wk 1	WK 2	WK 3	Wk 4	WK 1	WK 2	WK 3	WK 4	WK 1	WK 2	WK 3	WK 4	WK 5
CP05				CP06				CP07				

<u>MODE</u>: PLanning   <u>FUNCTION</u>:DIsplay   <u>INTERACTION</u>:   Enter Interaction:

2 3 4 5 6 7 8 9 10 11 12 13

ST SO SM WC UN UT MV


262017
X
140035
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X MAINTN X 140035

WORKS: WU   COST C: SIBS   UN: 002   PROD: *   YEAR: 81   CP:05   WK:1(19)

CP05 WK 1	WK 2	WK 3	WK 4	CP06 WK 1	WK 2	WK 3	WK 4	CP07 WK 1	WK 2	WK 3	Wk 4	WK 5
66 %	83 %	66 %	85 %	85 %	85 %	71 %	71 %	71 %	100 %	100 %	85 %	85 %
8 1	10 1	8 1	6 1	6 1	6 1	5 1	5 1	5 1	1 1	1 1	6 2	6 2
262017			140035			100019			MAINTN		140035	

140035
ref 1
--- 40
12.5

140035
ref 2
--- 40
8.45

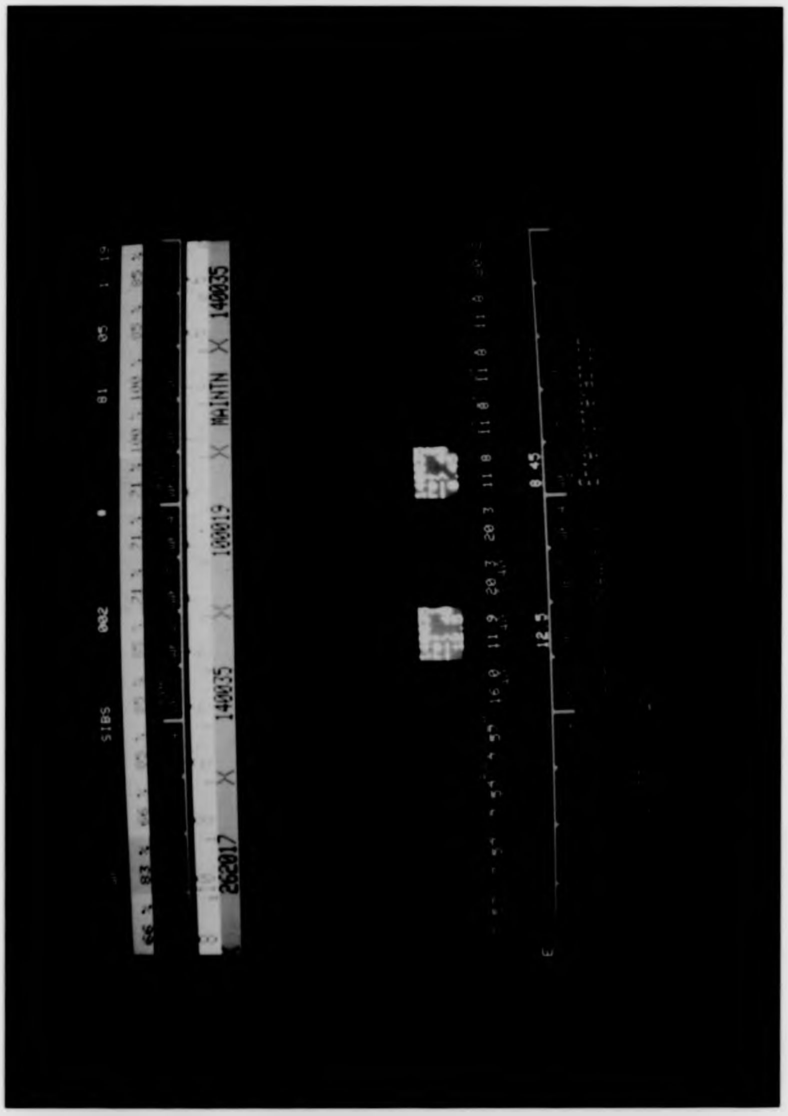
140035

140035   GREEN GRAIN 2A   Stockout in CP10

	CP05 WK 1	WK 2	WK 3	WK 4	CP06 WK 1	WK 2	Wk 3	WK 4	CP07 WK 1	WK 2	WK 3	WK 4	WK 5
	7.57	7.57	7.57	7.57	16.0	11.9	20.3	20.3	11.8	11.8	11.8	11.8	20.2
P					8.40	8.40	8.40						8.40
C													
I													
E						12.5			8.45				

MODE:PLanning   FUNCTION:MVement   INTERACTION: Enter Interaction:

2 3 4 5 6 7 8 9 10 11 12 13
DI ST SM CR DE MO AM



WORKS: WU   COST C: SIBS   UN: 002   PROD: ◆   YEAR: 81 CP:05 WK:1 (19)

000324 ACID B358G (Stockout in CP07)

	Wk 1	WK 2	WK 3	WK 4	WK 1	WK 2	WK 3	WK 4	WK 1	Wk 2	WK 3	Wk 4	WK 5
						140035 ref 1 --- 40 12.5			140035 ref 2 --- 40 8.45				
	15.4	15.4	15.4	15.4	15.4	15.4	15.4	10.6	28.8	9.80	-4.46	-4.46	-4.46
P													
C								4.76	23.8	19.0	14.3		
I									42.0				
E													

140035 GREEN GRAIN 2A

	Wk 1	WK 2	WK 3	WK 4	WK 1	WK 2	WK 3	WK 4	WK 1	Wk 2	WK 3	Wk 4	WK 5
	7.57	7.57	7.57	7.57	16.0	11.9	20.3	20.3	11.8	11.8	11.8	11.8	20.2
P					8.40	8.40	8.40						8.40
C													
I													
E						12.5			8.45				

CP05 Wk 1	WK 2	WK 3	WK 4	CP06 WK 1	WK 2	WK 3	WK 4	CP07 WK 1	Wk 2	WK 3	Wk 4	WK 5
8 1	10 1	8 1	6 1	6 1	6 1	5 1	5 1	5 1	1 1	1 1	6 2	6 2
262017			140035			100019			MAINTN		140035	

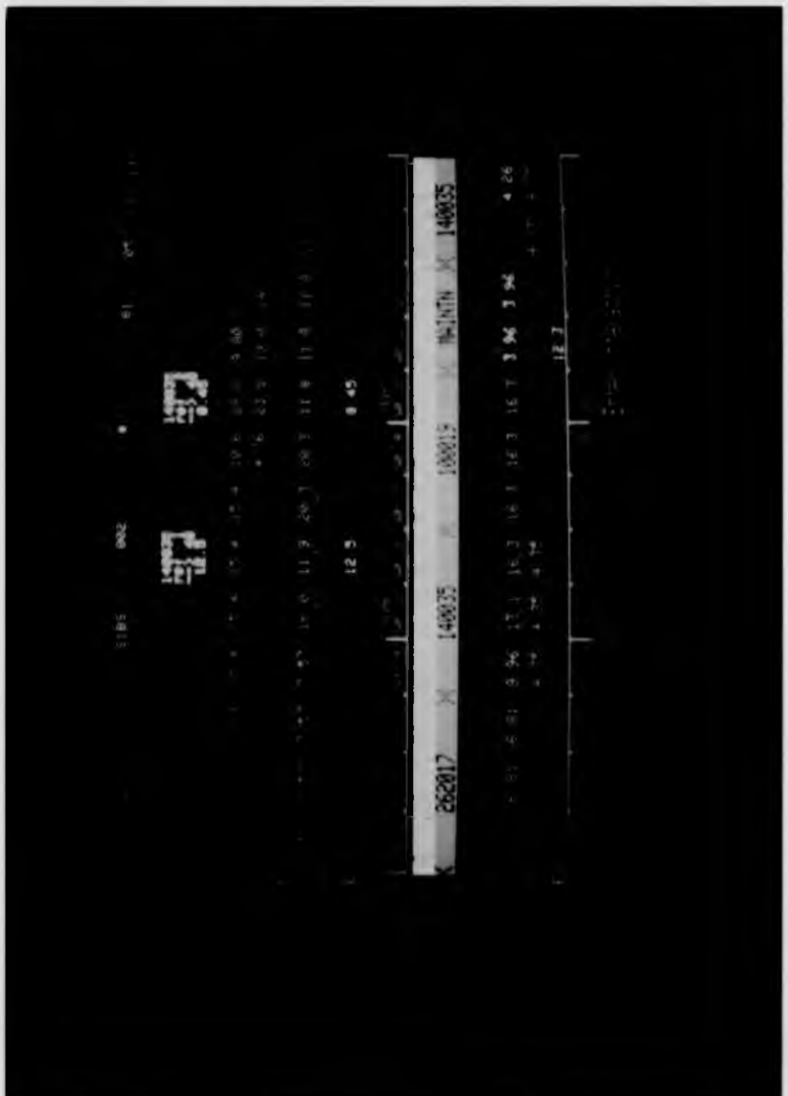
075141 GREEN LIQUID SH 27 (Stockout in CP07)

	Wk 1	WK 2	WK 3	WK 4	WK 1	WK 2	WK 3	WK 4	WK 1	Wk 2	WK 3	Wk 4	WK 5
	6.81	6.81	6.81	9.96	13.1	16.3	16.3	16.3	16.3	3.96	3.96	-0.39	4.26
P				7.50	7.50	7.50							9.00
C				4.35	4.35	4.35						4.35	4.35
I													
E										12.3			

Wk 1 WK 2 WK 3 WK 4 | WK 1 WK 2 WK 3 WK 4 | WK 1 Wk 2 WK 3 WK 4 WK 5
CP05 | CP06 | CP07

MODE:PLanning   FUNCTION:DIsplays   INTERACTION: Enter Interaction:

2 3 4 5 6 7 8 9 10 11 12 13
ST SO SM WC UN UT MV



6.3.2. Conclusions

Insofar as the planners' experience is concerned they seem very happy with the displays and have reported that they are easy to use. Futhermore there have not been any complaints about difficulties in getting the necessary information onto the screen. I think that this attests to the achievement of the objective of being flexible and supporting the information requirements of semi-structured problem solving.

However, the objective of providing personalized displays has not proved to be meaningful inside the same decision making function. In this project for example, to support a meaningful negotiation process between different planners the DSS must generate displays that are fully understood by everybody. Therefore the flexibility to provide user dependent displays has been used very sparingly in this application and only in some cosmetic instances.

Because of its restricted use in this project the conclusions about the display management system are necessarily more shallow than the ones drawn for the dialogues. To appreciate their full potential the displays should be tested in terms of their use for negotiations across different organizational functions. I think it is worth repeating here the need already mentioned in section

6.1 for further investigation in the field of personalized interfaces and their relation with negotiation.

In this chapter I discussed and described the two components of the Interface (dialogue and display management systems). In the next chapter I discuss the issues of modelling in a DSS and present a new structure for model building that can evolve in parallel with the improvement in the understanding of the decision process. The way in which users' access to models is implemented is also described in the next chapter.

7. MODELS AND SEARCHING PROCESSES

"Production scheduling has been a graveyard for practising management scientists for many years. One reason is the complexity of the task and another is that they try to satisfy too many objectives at once with an 'all singing-all dancing' system which they do not fully understand and which the user is unable to use with confidence."

(Poole and Szymankiwicz, 1977).

In the first part of this chapter I propose a new tentative definition of a model that is formally different from the one usually accepted in OR. The need for this new definition is justified by the different perspective of how to aid decision making given by the DSS methodology (which requires that models play a more flexible and less ambitious role), and by the difficulties faced in the project to use the traditional tool-kit of OR.

Based on this definition I develop the concepts of basic and combined models, and searching processes. In section 7.3 I present a conceptual structure where those models can be held and linked together. After discussing the advantages of such a structure I argue that it is not adequate for problems which need a more general model building framework and suggest the creation of one that enables the on-line development of models tailored to specific problems.

7.1 A definition of model

Although the notion of conjectural knowledge may be considered implicit in the OR definition of model as a representation of reality, I prefer to explicitly include the word conjecture in the following definition to emphasize the personal influence on the development of any specific model.

I propose the following definition:

> A model is a set of connected conjectures about the relationships between control, environmental and performance variables.

That tentative definition includes the possibility of either relationships or variables, or both to be expressed in a meta language. Otherwise some models, like a forecasting one, could not be defined by that statement since the control and performance variables are about characteristics of the relationships between past and future.

A set of values of the control variables defines a policy. And the policy space of a model is formed by all possible sets of values that the control variables can take.

The model in itself is passive. To be transformed into a useful tool, one needs either an evaluation method or a searching process, or both. For instance, the most conventional use of a simulation model is to evaluate a given policy in terms of the performance variables. On the other hand the role of a searching process is to reduce the policy space of a model. In some cases the space can be reduced to a single policy (e.g. the result of the simplex method used on a linear programming model), in others it may only result in a smaller set of alternatives, which may or may not be ranked (e.g. the process of selection of a few possible courses of action by one of the participants in a bargaining process, who use an explicit (or implicit) model of his opponents' behaviour).

In this chapter searching processes are always considered separated from models. However, since a model in itself is of little use, whenever I refer to one it implies the existence of an evaluating method.

7.2 The role of models and searching processes in DSS.

It has already been discussed that DSS's are built around semi-structured tasks. Moreover, in section 5.1 I discussed Keen's argument about the need to identify in each task the sub-tasks that can be explicitly described, otherwise the concept of semi-structure is as sterile as that of unstructure.

Keen (1981, p.33) suggests that sub-tasks should correspond to discrete intellectual operations, like "calculating a sum, searching for a value, or comparing two values on a graph". If this is as far as one can go, then a calculator with access to a data base would be all that was required in terms of software and hardware for a DSS. I think one needs to take the definition of sub-tasks in a broader sense, if DSS's are to be a useful tool in complex decision making.

The job of defining sub-tasks only makes sense in a given context, and that is the reason why I am not proposing any alternative definition. A broader interpretation of Keen's definition is probably the best one can aim for. In this project it was very easy to isolate the set of discrete intellectual operations which were used in every problem situation. The full list of those sub-tasks is given in Appendix 3.

Since the sub-tasks are the atoms of decision making they should be the first facilities to be provided in a DSS. I will designate the representation of these sub-tasks by basic models. So, a basic model is a set of relationships between the different types of variables plus an evaluation process that computes the values of the performance variables (one point in the image space) associated with one policy. Figure 7.1 depicts a basic model.

To use this basic model it is still necessary to define the policy to be estimated, i.e. the set of values assumed by the control and possibly environmental variables. These can come from the decision maker, the data base, or from both. The specification of the source of data is obviously problem dependent, but there are some design principles to take into consideration that will be discussed later in section 7.4.

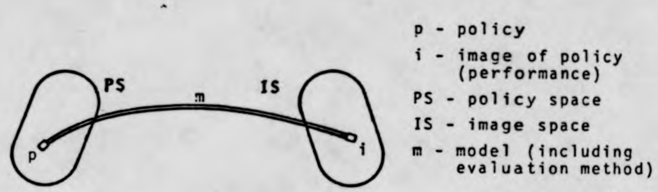


Figure 7.1 - A basic model

But one of the aims of a DSS is to gradually increase the understanding of the decision making process. To achieve that aim the processing properties that connect those models need to be understood and made explicit. In design terms this means that each basic model needs to be built as a module that, if and when the connecting properties are known, can be put together as more complex models.

The fundamental conceptual point about these more complex models is that they should be put together with the involvement of the decision maker, so that they become part of his thought process, i.e. they become a discrete intellectual operation for the decision maker. Thus, in addition to the practical problems of designing those models without the user intervention, it is not conceptually sound to attempt to do so.

I will designate those more complex models as combined models. Figure 7.2 depicts a conceptual example of such a model. For the sake of simplicity only two basic models are used to build this example of combined models. There is no restriction about the number of models used in general, and the whole of the following description is valid for any larger number.

At the top of figure 7.2 the two isolated basic models are represented. I am assuming that the objective is to apply model B2 to the result of B1.

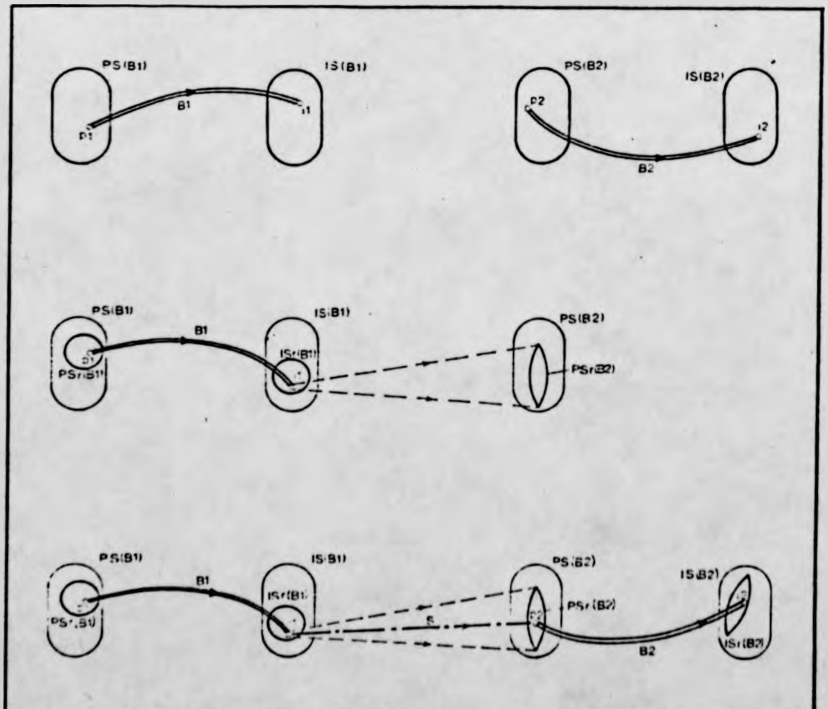


Figure 7.2 - Conceptual description of a combined model

First, to aggregate them it may be necessary to provide input, (both from the decision maker and the data base), which is different from the inputs of models B1 and B2 in isolation or combined. That new input is restricted to a subset of PS(B1), which is represented by PSr(B1) in the middle picture of figure 7.2. The application of model B1 to a particular policy (P1) will result in an image point (I1) belonging to ISr(B1) the image space of PSr(B1), which is a subset of IS(B1).

The problem now is to transform the point I1 into a policy upon which the model B2 can operate. Let me consider an example: If model B1 represents the creation of an export of a product, its evaluation process will produce the consequences of a given policy in terms of performance variables and, in particular, it could show a projected stockout for the product. If model B2 represents the creation of a manufacturing campaign then it could be used to get rid of the stockout. But there are many alteratives for the characteristics of that possible campaign (e.g. when, where and how much needs to be manufactured?). These alternatives are represented in the middle part of figure 7.2 by PSr(B2) which is a subset of the policy space of model B2.

To find the policy P2 in the restricted policy space of B2 a searching process is required. As discussed above, the description of that process can be achieved by increasing the understanding of the problem situation by the decision maker who, at a certain stage, is able to describe it explicitly. One necessary characteristic of the searching process is the inclusion of an objective function that enables the choice of one among the feasible policies of model B2.

Once the searching process is explicit it is possible to use it to determine the policy P2. In the example above it could be something along the lines:

> Plan a manufacturing campaign capable of producing as little as necessary to end the stockout situation or the minimum campaign size, whatever is larger, in the default plant without exceding the planning rates and as late as possible to avoid the stockout.

If, for any reason, that particular plant is fully loaded prior to the projected stockout, then the system should transfer the control back to the decision maker who should be able either to define an alternative policy or to exit from the combined model. This does not mean that in future, once a new higher level of searching is understood, one cannot provide a more complete algorithm which would be able to trade off between different products that are manufactured in the same plant.

Assuming that P2 is found by the searching process S the application of model B2 is straightforward and will result in the image point I2 depicted in the bottom picture of figure 7.2.

To show how these combined models are implemented, figure 7.3 represents the example of figure 6.2 already discussed in chapter 6. In the MOSC interaction the second entry allows for the input of data which is different from the other two interactions (MOCR and UNCR) but the third and fifth pointers are equal to the second pointers of those two basic models. The fourth pointer represents the new searching process.

S33 - input for new combined model
S30 - pointer to MOCR model
S39 - pointer to new searching process
S22 - pointer to UNCR model.

It is worth repeating two points previously discussed in Chapters 5 and 6 because their relevance can now be better understood:

1) The possibility of introducing a new model by

simply setting up the appropriate pointers in the dialogue structure and including new subroutines representing either models or searching processes or both in the library of models.

2) The importance of all the basic models having an independent data input, so that when combined models are built, the basic ones can be used straight away.

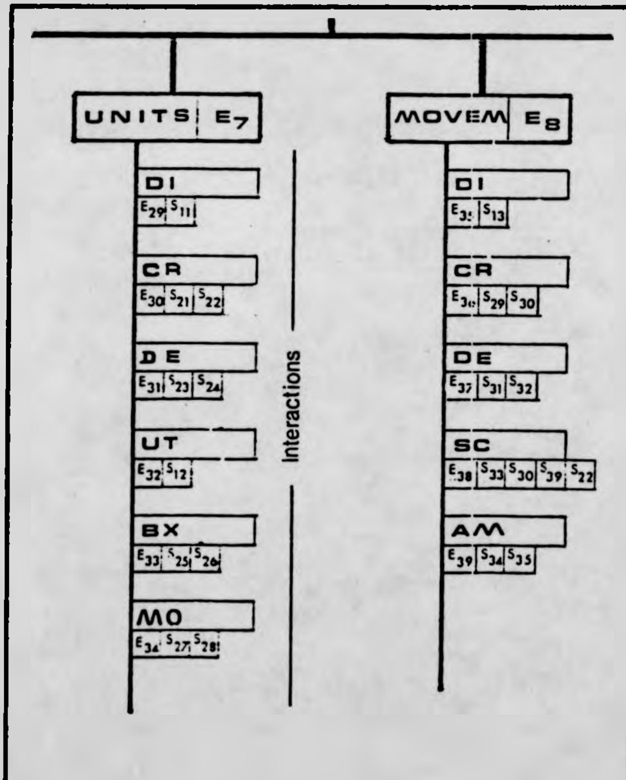


Figure 7.3 - An example of the assembly of a combined model using pointers

Bonczek et al (1981) in what is probably the most comprehensive work about the role of models in DSS propose a predicate calculus which can be stored in axiomatic format. These axioms are basically logical operations and are used on the assumption that "modelling knowledge inherent in an organisation can be represented as a set of AND/OR fragments" (p.359). Moreover these authors claim that the modelling knowledge provided by those axioms "is sufficient to determine all possible models that can be formulated in the organisation" (p.359).

These authors propose that a model is "a plan for information processing that involves some transformation of information" (p.12). This definition seems restrictive and it can only be seen as a particular case of the models defined earlier in this chapter.

Returning to the definitions of basic and combined models, Bonczek et al assume that the image space of a basic model is either included in the policy space of all other basic models, or that there is a one-to-one relationship between each image point of a basic model and a policy on any other basic model policy space. This means that there is no need for a searching process to transform the former into the latter.

Another possible explanation to justify Bonczek's theory is that it considers searching processes as models. In that case it would be enough to join them with the models as I defined before by the AND/OR fragments. The description of the two concepts by a single word does not appeal to me because in semi-structured decision-making most of what is unknown is bound to be searching processes, this apart from policy definition. Thus, it seems conceptually more sound to keep the two separate.

Furthermore, if searching processes and models are identified to each other, then the use of logical axioms do not appear to be very useful, since they cannot be the only operations to describe unstructured processing methods.

Bonczek's theory, although useful for some kind of models, in particular those based only on information processing roles, do not provide an answer to the models of decision-making in complex production planning situations and in particular that studied in this project.

The experience of this project demonstrated that basic and combined models do not provide the expected full support that was anticipated when they were first built. Later in section 7.4 I discuss some of the limitations of these models and present a conjecture about a complex model building framework that could extend the scope of models and searching processes in DSS.

7.3 A conceptual view of a model structure

Departing from the definition of basic and combined models presented in the previous section I developed the structure to accomodate those models, which is represented in figure 7.4. The idea behind it is that having as a basis a complete set of basic models (lower layer of boxes in the figure) it would be possible, by the incremental understanding of the decision process, to start filling the next layers of the triangular structure with combined models.

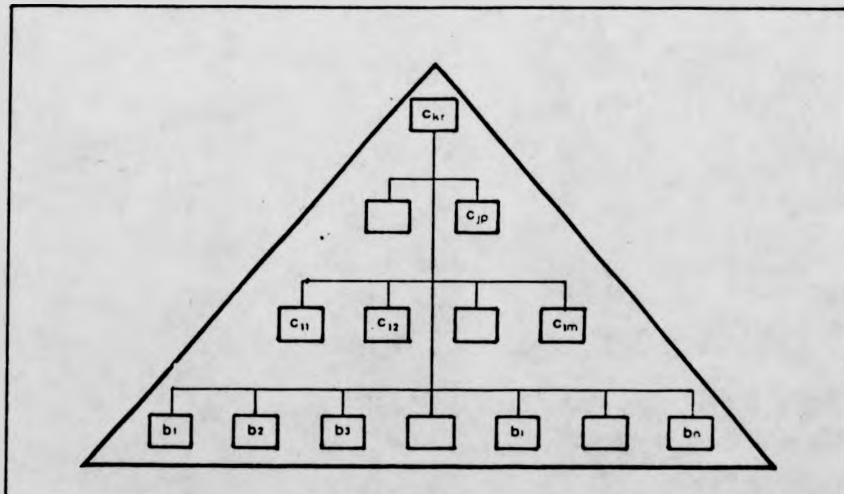


Figure 7.4 - A conceptual view of a model structure

Moreover, an interesting characteristic of this framework is that it enables the decision maker to choose the level of control he is interested in exercising over the system.

It is arguable whether a closed structure as that depicted is appropriate. It means that any decision process can ultimately be structured and programmed in a complete model (highest box in the figure). This seems to be too strong an assumption to be acceptable. Even if the managerial activity could be explained at a level that was not previously possible that will only mean that decision makers will change their terms of reference for the problem domain and will move to new semi-structured areas. To cater for this evolution I would be inclined to put together in a higher level structure different triangular frames, and do not abandon the closed structure. For this is a good stimulus to the investigation aimed at an increasing understanding of the decision processes. An example of a higher level structure is depicted in figure 7.5.

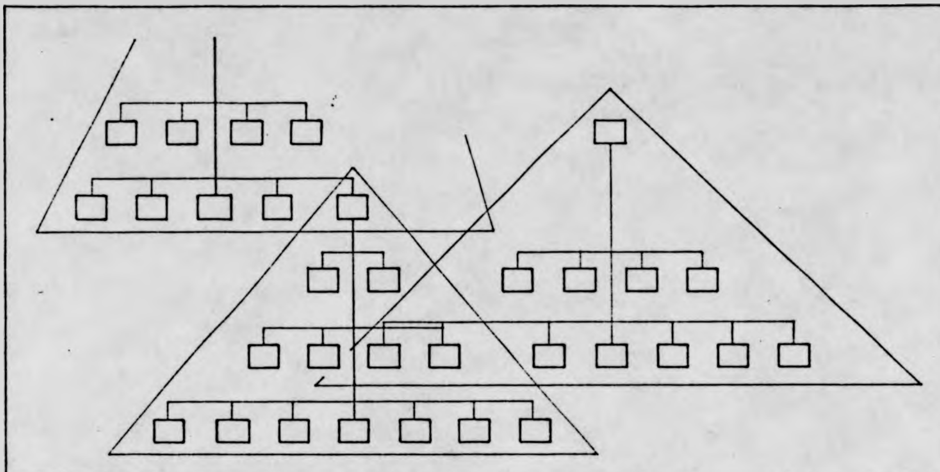


Figure 7.5 - A high level assembly of model structures

7.4 Basic and combined models

To implement a model structure like the one described in the previous section for any particular application the basic models which compose the lower layer of modules need to be developed first. They should be simple to be as universal building modules as possible. They also should represent a comprehensible set of discrete intellectual operations used by the decision makers.

Each basic model consists of two main parts. The first part, in which some kind of input is needed, is used to define the point in the policy space that is evaluated by the second part. It is important to make the distinction between the two parts to enable the combined models to work without any intermediary data input if that is desirable, since in most cases the policy for all the basic models but the first will be generated by the searching processes included in the combined models.

Particular care must be taken when designing the input part of the basic models to produce a flexible interface to policy definition. This is most important in the models with complex data requirements where different combinations of input from the user and the data base are possible. The appropriate use of default values and the order in which questions are asked so that effective by-passes can be achieved are the key points for success in this area. In the example of a basic model flowcharted in Appendix 4 one demonstration of default values and by-passes is provided.

The evaluation part of any basic model is in charge of updating the data base and the displays to reflect the changes provoked by the operation of the model on the policy defined by the user. In the design of this part attention must be given to two points. The first is concerned with the efficient operation of the system and it is particularly important in a multi-user data base environment. Since the data base will only be consistent when all the appropriate files are updated, the actual modification of their contents should be put as near as possible to each other to reduce the time lag during which the affected records are kept locked for access by other users. The second point concerns the sequence in which the different displays are updated so that the decision maker can see some logic in it.

To install a combined model, once the relevant searching processes are understood and programmed, all that is required is to connect them into the library of models and to create one (or more if appropriate) entries in the dialogue structure with the relevant pointers. This is done by an external program that amends the contents of the dialogue master structure which resides in the DSS master file.

Because the way a user accesses a model is through the dialogue structure and since this is user dependent, any basic or combined model can be made user dependent and thus the system can grow to match the individual expectations of each user.

7.5 Conjectures about a searching framework

When the structure for basic and combined models was first designed I assumed that it would support all the modelling activity of the decision makers. This proved to be a naive assumption because there are problems which are intrinsically (and not perceptually) semi-structured and for those it is not possible to define the searching rules that enable the linking of basic and combined models.

Since most of the intrinsic semi-structured problems need to be investigated via an exploratory process, which will include both the evaluation of alternative points in the policy space and the use of alternative models, a flexible searching framework should be devised to enable the building of more complex models at run time.

The framework devised, which is not yet implemented but is fully specified, was designed taking into account three main considerations: (1) the relative roles of human judgement and heuristics; (2) the problem of a multi-user data base environment; (3) the organisational boundaries that influence the current decision making process.

1) The semi-strucured nature of the production planning makes it impossible to develop a finite set of models which would completely satisfy the decision process. As described in Chapter 3 the planners may

set different objectives and use different search strategies for problems that seem formally identical, depending on the requirements of the Business Department or the perceived complexity of modifying the plan. For these circumstances it would help if the planner was able to develop a complex model for each particular problem using basic or even combined models in conjunction with his own searching abilities, and possibly built-in heuristic rules.

Another characteristic of planning is the combinatorial nature of the problems, and this considered together with the scale of most of those problems means it is virtually impossible to define searching rules that could generate a reasonable number of sensible alternative solutions.

Two extreme approaches are possible. The task may be left entirely to the decision maker, or a comprehensible set of heuristic rules may be identified and used to perform the same job. Both alternatives seem unacceptable and the possibility of taking advantage of the synergism of a mixed solution was investigated. This idea is not new. In 1971 Press suggested the use of balanced systems "where both partners are active, where either may suggest operations or execute them, and where the order of the steps in the problem solving process is jointly determined". Madeo et al (1980) describe the experience of using a business game in a controlled environment from which they concluded that when the decisions were not too easy a guided search performed far better than either a totally algorithmic or totally human search. Another reason for choosing a mixed structure of heuristics and human search is that one hopes that the perceptual semi-structured problem solving strategies will become understood and it will then be possible to design algorithms to perform them, leaving to the decision maker the intrinsically semi-structured parts.

2) To pass from a controlled and experimental environment like the one used by Madeo et al (1980) to the real world brings another type of problem, namely the management of a data base in a multi-user environment. When the solution of a problem requires access to and modification of data that may be needed by other users, and involves using a search procedure that can take a significant amount of time, the action of locking the appropriate records on the data base is not acceptable.

To cater for this problem the framework for the complex models was designed to execute the models on a dummy copy of the relevant records of the data base during the search phase. When a solution is eventually found, the system will execute the data transactions inherent to those models on the real data base and determine, by comparison with the dummy records, if there are any differences derived from a change made by another user. If there are, the system will provide an exception report and ask if the user wishes to review the situation using the new data.

3) Any decision process is strongly linked with its organisational setting and there seems to be little doubt that the tools used by decision makers, influence the associated organisational structure. Taking as an example the experience of the Huddersfield project, although the planners would prefer to plan a product chain rather than a group of manufacturing plants, this is not viable because without a computerized aid the number of interactions between planners would be so large that it would be difficult to cope with all the negotiations required in the time available.

When designing a DSS, which is fundamentally an aid to decision making, it is important that it is not made dependent on the current organisational structure. At the same time it is not acceptable for a DSS to impose on the decision makers some perceived 'best' organisation since this will be an ever evolving perception. A DSS is an agent of change and not a revolution in itself.

The framework devised to cope with the three considerations outlined above is composed of several data and control structures that enable the decision maker to search for solutions of semi-structured chain problems using the basic and combined models defined earlier in this chapter. Those data and control structures are to be added to the data handling tools of the DSS generator already described in Chapter 5 and will use the same internal data arrays.

An example of how a complex model can be put together to investigate possible solutions for a last minute requirement for a final product is described next. Let me assume that the relevant final product is represented in figure 7.6 as product 1. This figure represents the partial product chain for 4 stages of manufacturing leading to that product (e.g. products 2, 3, 4 and 5 are used to manufacture product 1.

The planner may try to resolve the first problem by using the combined model described in figure 7.2 which creates an export for the required amount at the relevant date and than creates a campaign of batches that will make available the quantity necessary to avoid a stock out.

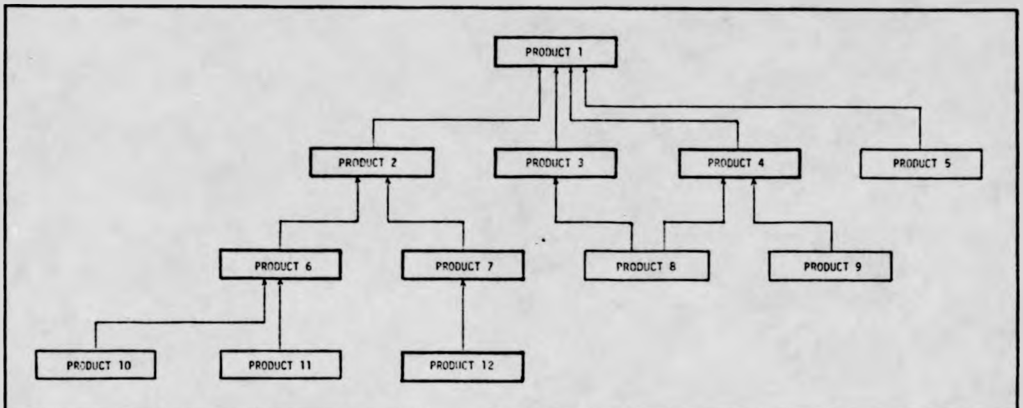


Figure 7.6 - An example of a product chain

The difference between the use of this combined model here and in the earlier example is that the decision maker is now interested in finding a complete solution for this problem and that requires an investigation through the product chain to make sure that feasible solutions exist, and to choose between them.

For that the system generates a new master data structure (M1) which contains the set of relevant records copied from the data base and has associated with it a set of basic or combined models (in the example the combined model c1) which will operate on the dummy data. This first step is represented in terms of models and in terms of the searching framework in figure 7.7.

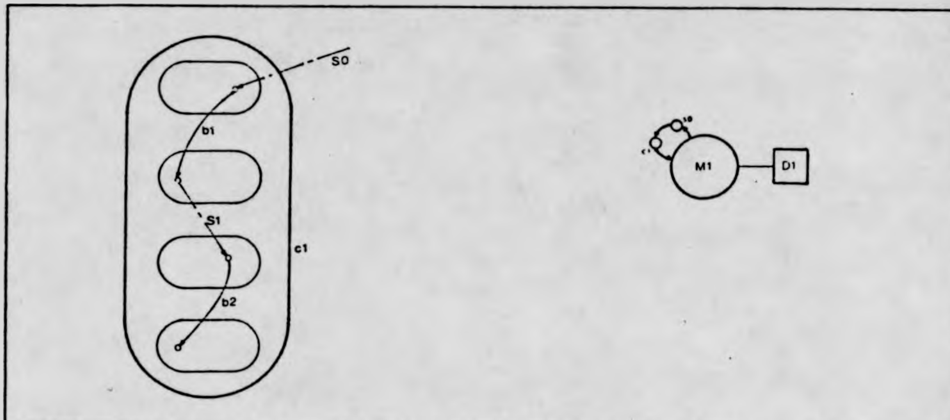


Figure 7.7 - First step in building a complex model (right) and equivalent model representation (left)

The result of the use of model c1 and in particular of the manufacturing campaign created will be reflected among other variables in the stock of the consumed products (products 2, 3, 4 and 5 in the current example - see figure 7.6). The initial data and these results will be represented in logical display D1 which is also linked with the data structure M1.

Suppose that three of the four consumed products (e.g. 2, 3 and 4) present a stock out due to the previous action. To resolve those 3 problems the planner may try to create three manufacturing campaigns for those products using the basic model b2. Let me assume for the sake of simplicity that the application of that model b2 to two of the three points of its policy space, which were defined by the searching processes S2, S3 and S4 will solve the problems of the relevant products and do not result in any stock out of the consumed products 8 and 9 (see figure 7.6 for reference). However the application of the same model to solve the stock out of product 2 fails because it is only possible at the expense of over utilization of the plant. The application of model b2 to three policies is represented in figure 7.8 which also represents on the right the development of the searching framework.

Figure 7.8 represents the three new master structures M2, M3 and M4 which contain copies of the relevant records from the data base. In M3 and M4 the asterisk denotes that no further investigation along those paths is needed for the moment. The function of the control C1 is two fold. Firstly it generates the master structures which represent the three problem areas and enables the decision maker to find other non-standard problem areas that he may want to analyse. Secondly it keeps trace of the paths being formed to manage the housekeeping of the model building which enables the system, once the model is complete, to update the real data base.

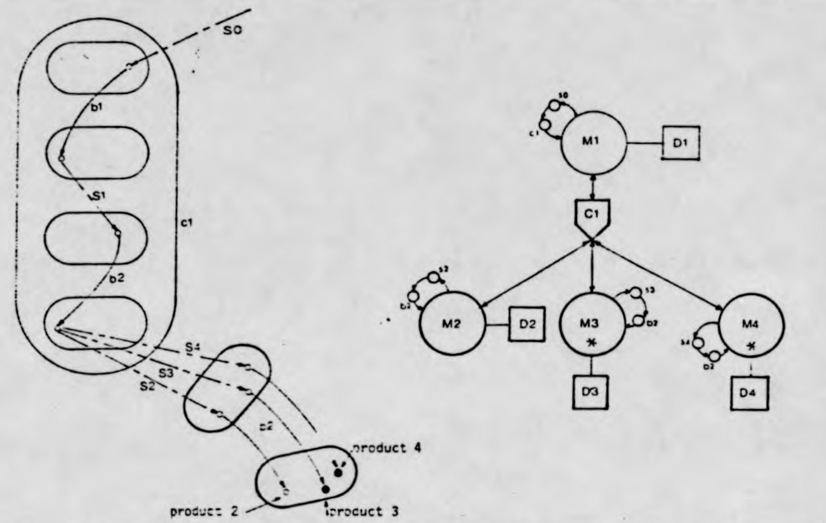


Figure 7.8 - Second step in building a complex model (right) and equivalent model representation (left)

Since the stock out of product 2 was not satisfactorily resolved by the application of model b2 the planner may want to try a couple of alternatives. For example (see figure 7.9 for reference) he may advance one campaign already planned (basic model b3) for that product by moving the remaining plan backwards (basic model b4), or he may delete one campaign (basic model b5) of another product and create a new one for product 2 (basic model b2). Suppose he chooses the latter. Figure 7.9 shows both representations of this step towards a complex model. The alternatives generated are represented by A21 and A22 which have associated with them, similar to the master structures, a set of models (b's) and possibly human orientated searching procedures (s's). The application of model b2 to M2 does not appear any more because it was considered a bad solution.

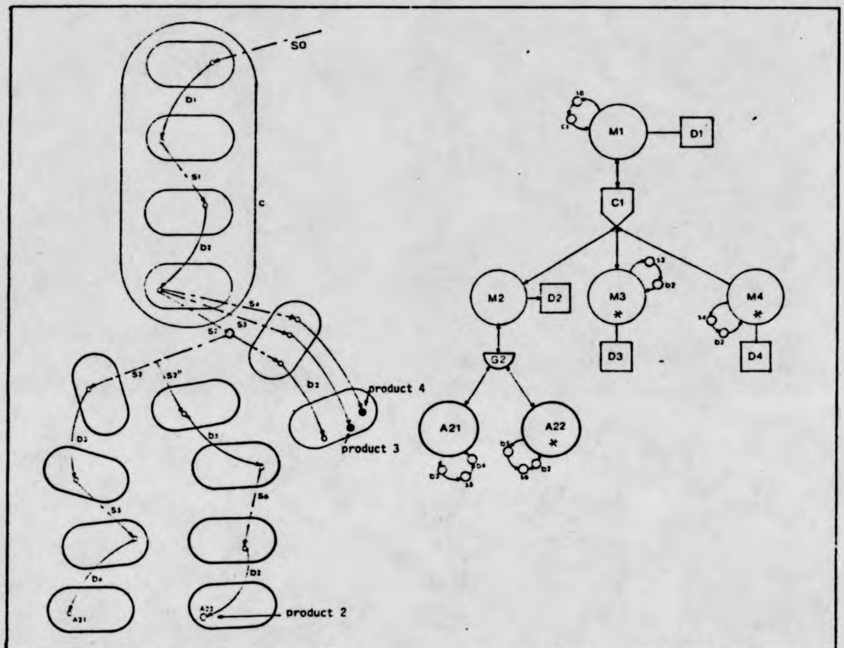


Figure 7.9 - The use of alternative generators in complex model building. (Third step for the example of figure 7.6)

The alternatives A21 and A22 are generated via the generator G2 which may have its own programmed way of finding them or which may allow the user to do so. The role of the generators is very similar to that of the controllers, the only difference being that each option does not have a display associated with it, but shows the relevant information on the display linked to its master data structure instead to facilitate the comparison of alternatives.

In figure 7.10 is represented the full complex model built for the example of figure 7.6.

It may well happen that during the course of this exploration one decision maker generates a problem that is outside his area of responsibility. In that case another planner may be brought into the process to help find a mutually acceptable solution and the searching framework would support this negotiation process. If later the organisation of the decision process evolves to give full responsibility for a product chain to a planner then the framework is still suitable for a single decision maker or to enable multi-negotiation processes.

There are however a few problems that need to be investigated concerned with the use of personal models in cases where more than one planner is necessary to find a solution to a mutual problem.

At the end of this complex decision process one or more decision makers will eventually find an acceptable solution and the system will then proceed through the decision path to make all the transformations required to the data base and report any relevant discrepancies that may affect the validity of the solution found.

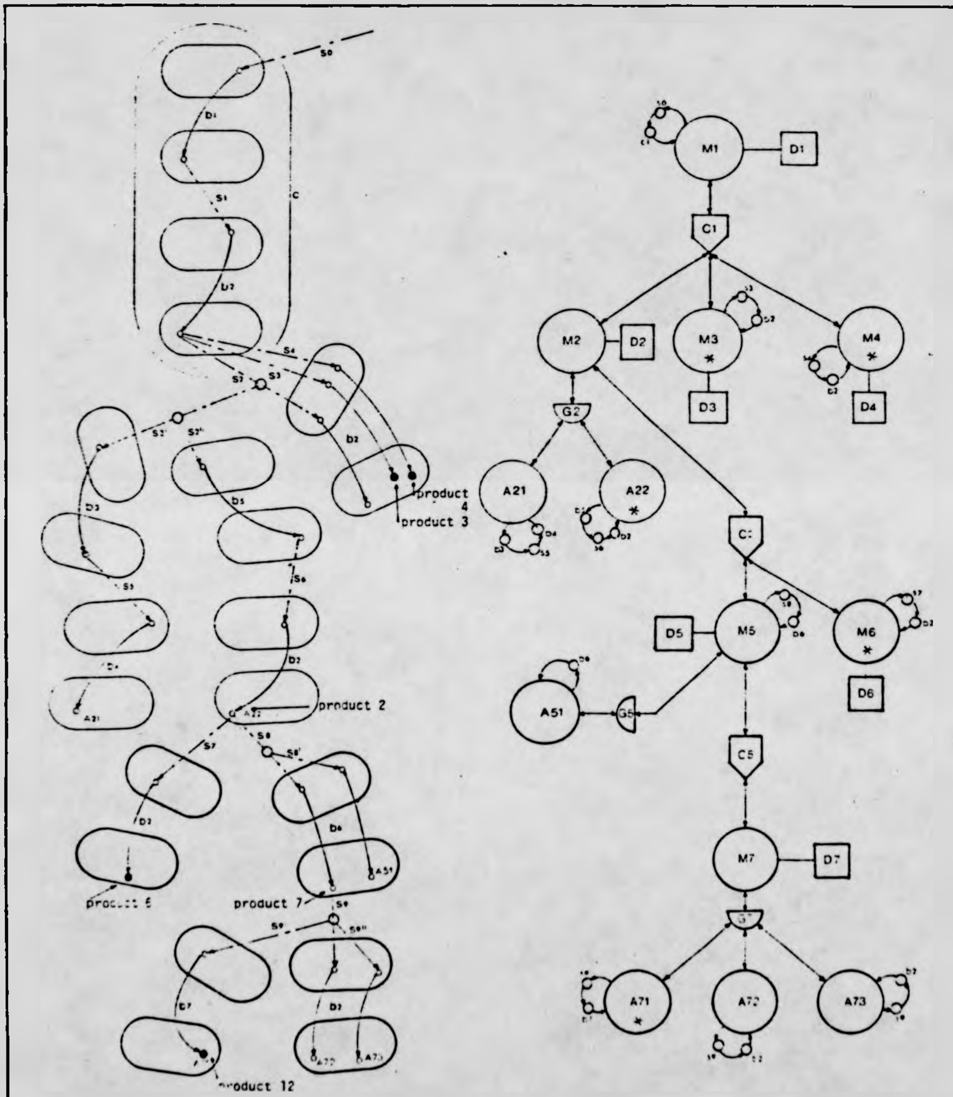


Figure 7.1' - A complex model for the product chain of figure 7.6

7.6 Conclusions

I started this chapter presenting a new definition of model that matches the modelling requirements of semi-structured problems. Then I discuss the benefits of separating models from searching processes to distinguish the structured from the semi-structured parts of any problem.

In section 7.3 I presented a conceptual view of a model structure that was implemented in the current DSS generator and which enables combined models to be quickly assembled from basic models, once the searching processes used by decision makers are understood.

I also argued that such a structure is only adequate to represent the modelling capability of perceptual semi-structured problems and does not provide much help for the on-going modelling activity of intrinsic semi-structured tasks. For this type of problem I propose a more flexible searching framework that enables decision makers to develop complex models using the basic and combined ones and possibly a bank of programmed heuristic rules. I also discussed the three basic design issues used, namely the importance of combined heuristic and human search, the complications imposed by a multi-user data base environment, and the need to be as independent as possible of the organisational decision boundaries. This searching framework has not yet been implemented but it is specified in terms of the internal data structures required (Moreira da Silva and Hurrion, 1981).

8. IMPLEMENTATION, TRAINING AND EVALUATION

"The key to successful evaluation is an explicit prior plan, developed during the entry stage".

(Keen and Scott Morton, 1978 p.213)

In this chapter the issues involved in the implementation of the DSS prototype at Huddersfield Works are discussed. One section is devoted to the description and appraisal of the training programme set up, and another one to the process of evaluation followed in that application. Finally in the last section I summarize the conclusions for that particular case and propose some recommendations that may be pertinent to other applications.

8.1 Implementation

The emphasis given to the implementation in a DSS is greater than is traditional for OR projects, for one reason: A DSS project does not end with implementation. On the contrary this is a continuous activity which feeds back quite heavily into the design phase.

I have already discussed the importance of evolution in a DSS, which can only be achieved if during the implementation the learning provided by the actual use of the system by decision makers can be continuously built in. In the last four chapters I described the different principles adopted in the design of the overall structure, the interface and the models to provide the system with the ability of being adjusted to new requirements.

In this section I discuss some of the decisions taken earlier in the project and appraise the organisational problems involved in the implementation of the current application. The comments that follow must however be considered with care, since the experience of four months on which they are based may prove to be too narrow.

In Chapter 3 I discussed the problems associated with the interfaces between existing computerized systems and the DSS. In particular figure 3.9 represents the proposed integration of the two systems - Initial Plan Generator (IPG) and Plan Refinement System (PRS) - within the complete network. I also described the decision not to develop an IPG initially, since there was no research involved in its design and it could be bought in if the research into the PRS proved successful. Moreover I mentioned that it was assumed that the Roll Forward could play the role of an IPG, by considering the previous month plan as the initial plan to which it would be sufficient to add a new plan for the twelfth month.

The reality showed that this assumption was too strong. Indeed the number of modifications to the previous month plan, in particular in respect of products requirements, is far greater and has wider implications in the plan than anticipated. As a result the monthly job of adjusting the previous month plan to the new requirements proved to be very expensive in terms of planning time and a frustrating exercise for the planners involved. The full specification of an IPG is now in progress and hopefully it will be installed soon.

This is a typical example of how one system can be rejected on the basis of the wrong criterion. The system has not been designed to help planners generate an initial plan and consequently does not provide any guidance towards that job. On the contrary it is cumbersome to operate for that purpose.

Problems with other systems interfaces were also expected and there were plans to implement them at a later stage. What was not anticipated was that manually loading data which the decision makers know is present in some other computerized system is a very frustrating task, even if the effort required is small, because they perceive it is possible to save them the effort.

An additional problem met during the implementation concerns programming errors. In spite of the care invested testing by the technical team, the number of errors detected in the first weeks of operation was large.

In addition to the three technical problems discussed above there are a few organisational problems that are worth discussing.

8.1.1 Organisational issues of implementation

The implementation of a new system is always a sensitive issue for, in some way, it is a source of instability to the established working rules. This means that it should be considered as a process of change and, as such, needs to be managed.

On the logistic side two documents were prepared. One is the Users' guide (Boulton et al,1981) and the other contains a training package (Connaughton et al,1981) with exercises about all the individual facilities of the system. In section 8.2 the problems involved in training are discussed more extensively.

Keen and Scott Morton (1978,p.189-211) argue that the role of the implementor of a DSS is that of a 'facilitator' whose objective should be that of meshing the technical developments in to the organisational, political and behavioural context. To accomplish this objective it was decided to form an implementation team which includes the project manager, the planning manager, the designers of the system and each of the planners once they started training. The meetings of this team are the forum for critical assessment of the implementation and for the discussion of problems encountered and the way they should be solved.

In addition to this formal team the technical group maintained their informal contacts with the planners on a daily basis. The complementary role played by these two forms of contact was very important. Once the system starts to be used in the real environment the process of change is initiated and it is essential for the route to a new point to be well managed, otherwise there is the risk of an anarchical move towards nowhere.

The informal contacts, which usually took place during and immeadiately after planning sessions, were usually very rich in terms of new suggestions both about the system and the decision process. From these suggestions common proposals were sketched and presented to the next meeting of the implementation team where they could be discussed with a broader perspective. Some of these proposals were accepted for immediate realization, some were deferred and others abandoned. The important point is that the presence of senior managers in these meetings guaranteed that the necessary resources were made available and therefore each task could be planned and controlled.

In addition to these two groups a more senior Divisional steering committee was also formed to approve the evaluation criteria, to control the implementation of the prototype, and to issue guide lines about future developments.

One issue usually pointed as a necessary ingredient for successful implementation (e.g. McLean et al,1980) is to have the committment of the users and more senior managers. During the whole project there has been a very firm interest both from the planners and senior management. Neverthless, the retirement of the planning manager who was one of the most keen initial supporters of the project brought a few problems. His substitute was moved from another department and consequently only was introduced to the project when this was in an advanced stage of design. Because he had not participated in the initial discussions it has been difficult to get his full support in spite of substantial efforts by the technical team to involve and inform him, and pressures from above and below.

Although it is important to get the commitment from the users, this project proved that it is also fundamental to gather support from more senior managers to decrease the risk of being too dependent upon personalities.

Another aspect worth recording here is concerned with the idea of action research and its associated problems. During the early stages of implementation the steering group decided that the next technical work should orientated towards the widening of the application of the system to other Works of the Division. While my prefered area of research would have been the investigaton on combined models and the development and implementation of the searching framework specified in the previous chapter, so that the evolution of the decision process was stimulated.

8.2 Training

It has been assumed from the beginning that there was the need for some kind of formal training for each planner. Futhermore it was decided to do so on an individual basis so that the trainer could test the training package against different decision makers.

The training package (Connaughton et al,1981) is based on data for two Cost Centres with seven manufacturing units each and a total of 40 products. The package consists of one or more examples of all the possible data amendments, displays and model commands. In addition to these there are validation exercises that each trainee should solve after being trained in each particular area of the system to check whether he was familiar with the operations.

The use of the training package with the first planner was slightly longer than what expected due to several errors in the programmes. It was completed in 12 sessions with a total of 21 hours.

One of the limitations of the package is that, because it was not designed by someone with experience of planning, the exercises only address themselves to an examination of the proficiency in operating the system in an environment that is far from realistic.

It seems sensible that in future the package should be redesigned with the participation of an experienced planner so that new trainees could be offered more realistic examples.

8.3 Evaluation

Evaluation is probably the most difficult stage of any DSS. Since a DSS is addressed to the improvement of the effectiveness of decision making rather than its efficiency there are no yardsticks against which its value can be measured.

Also because decision making and the environment in which it takes place are dynamic and since the DSS must evolve in parallel with them it is difficult to judge its value against the contents of a rigid plan without the danger of evaluating against the wrong criteria. Finally personnel turnover and the difficulty of isolating the factors that contribute for changes in the decision process are additional considerations that may restrict the scope of an evaluation.

Keen and Scott Morton (1978, p.213-225), in spite of these problems suggest that the presence of an evaluation methodology is of critical importance, and propose that a prior plan should be drawn. This must include a wide spectrum of factors, ranging from quantitative to qualitative, whose importance and appropriateness should be reviewed during the on-going implementation.

For the current project it was decided to establish a plan based on those authors' proposal (Swann et al,1981) that was approved by the Division steering committee and accepted as a working tool by the implementation team. That document enumerates the factors upon which the evaluation should be directed and identifies the specific difficulties that may be faced.

Later in this section I present those criteria and the results accomplished so far. (Since the evaluation is scheduled to finish at the end of the first quarter of 1982 these conclusions are not final). First I describe the two most difficult obstacles to evaluation that were faced in this project.

1) Rationalization of Huddersfield Works: It begun late in 1981 and consists of a drastic reduction of manufacturing units due to be phased out during one year and the consequent increase in the number of products manufactured in the more modern plants.

To achieve this there is a need to build up the stocks of many intermediate products which has been achieved by frequent changes in the product mix of each Cost Centre. These modifications to the product mix have not always been supported by the data stored in the DSS data base.

It was on the assumption that this data was very static that the decision not to develop interfaces with some of the computerized systems was taken. The nonexistence of those meant that the planners had to modify themselves the data base contents at short notice at the expense of a considerable amount of time.

Adding this problem to the one already mentioned of the initial plan generation means that the planners were compelled to spend a great deal of energy and time (on one occasion 20 hours) to put the system in shape for the actual planning activity. This happened at the beginning of the monthly planning exercise which is a time when planners are under great pressure. The consequence of this chain of problems was that in two consecutive months the introduction of the system as the planning aid was abandoned because it could not cope with the urgency. The planner opted for his manual system with which he was more confident.

Finally at the third attempt he used the system but did so in parallel with his manual planning charts because he lacked confidence in the accuracy of the data. This was an exhausting experience because his manual practice dictated the sequence of planning which is not necessarily the one that matches the advanced facilities provided by the computerized system. This event was neverthless useful because it was the starting point for a new proposal about the decision process that I will describe later in this section.

In addition to these problems the rationalization also put in jeopardy the possibility of using most of the quantitative factors included in the evaluation programme, since their past values are almost meaningless in terms of the current production situation.

The false starts mentioned above also delayed the introduction of other planners to the actual use of the DSS and, as a consequence it has not been possible to assess whether the claim that lag times between finished products and intermediates can be reduced, is true or false. Because only one stage of the product chain is being planned with the DSS.

2) Personnel turnover: Two persons involved in the current project were moved during its two years life. One is the planning manager already referred to above and whose hesitant commitment has provoked a few small but neverthless important delays at some particularly critical stages of the implementation.

The other one was a member of the technical team who had very good relationships with the different levels of decision makers. Because of his central position on behalf of the Company in the design of the prototype, his promotion caused a gap in the Company knowledge of the DSS structure and this has influenced the rhythm of developments required during the implementation.

In the next two sub-sections I describe the quantitative and qualitative factors that were included in the evaluation programme and discuss the results available from the experience had so far.

8.3.1 Quantitative factors

There are two categories of quantitative factors included in the evaluation programme: (1) factors affecting the business, and (2) computer service measures.

1) Factors affecting the business:

i) Lead times - The influence of the prototype on this factor cannot be assessed because only one stage of intermediates have been planned with the system.

ii) Reliability of delivery dates - There is no information about this factor because no final products have been planned with the help of the system. However, even when the final products planner uses the system this factor will only show any possible modifications if the great majority of the products are planned with the system.

iii) Stock holding - Again it does not seem that much will be learned in the short term from this factor because of the rationalization programme initiated by the Division is provoking the building up of stocks that is not comparable with recent past history.

iv) Plant utilization - The same rationalization programme inhibits comparisons being made with past information.

v) Planners workload - Initially this was much higher with the system than manually because of the several data problems already mentioned, the lack of an IPG, and the fact that only one planner was using the system for real which implies that much informaion that would have been readily available in the system (e.g. consumptions of materials) had to be got from other planners. More recently, in the December planning activity times were monitored and the total planning time (including the generation of an initial plan) were already slightly below the manual times. It is worth mentioning that the use of the system provides information that was previously not available (e.g. the future value of stocks per product and in different aggregations).

The planner was happy with the results of this experience and he was confident that the time could be cut even further once the IPG is operational and his colleagues are working with the system.

This does not mean that the amount of time the planners spend on this task is important in itself but only that they will have more time for exploring alternatives and refining the plan to a more effective position.

2) Service measures

The system measures relate to the mechanical aspects of operating the system and include: i) availability of computer, ii) speed of response, and iii) reliability of hardware and software. Permanent monitoring has been made of these factors and the main conclusions are:

- The computer services, which are provided by a mainframe of another ICI Division, have not been the best one could hope for and more recently scheduling restrictions that are far from desirable have been imposed on its access.

- The variability of response time that is characteristic of main frame machines seems to be a significant source of frustration. This had already been detected in previous projects of visual interactive simulation and the current experience confirmed it. It is not so much how long it takes that worries the planners, but fundamentally the variations in the time required for a given operation, mainly when display generation is involved.

- Most of the hardware has been very reliable and the only cause of problems was the telephone line that at 1200 baud transmitted a significant amount of noise that sometimes badly disfigured the displays. Recently a new private line has been installed and the problem has disappeared.

- Initially the software reliability was not as good as it should have been, but for the last two months there has not been any major problem.

8.3.2 Qualitative factors

Included in this group there are two categories of factors: 1) factors affecting the decision making process, and 2) system ergonomic factors.

1) Effect on the decision making process: The decision making process involves weighing and balancing the various quantitative factors outlined in the first part of 8.3.1. Hence in assessing the value of the system, consideration must be given to the effect that the system has on the decision making structure. Such an effect cannot be quantified and its assesment can only be based on the planners' judgement. The evaluation programme includes the following six areas that should be monitored:

i) Range of factors taken into account when making decisions;

ii) Exploration of alternative courses of action;

iii) Level of commitment to plans by all parties;

iv) Duration of planning process;

v) Robustness of plans;

vi) The use of the system as a training aid.

With the reduced experience gained so far one cannot expect to have answers to all these areas. Not only the number of times the system has been used for real but also the limited range of products and manufacturing units being planned with the help of the system restrict the possibility of a fair assessment on most of those areas. There are, however, two issues on which the system has provided the means to make advances in the decision making process.

One is the information provided about future levels of stocks in different forms of aggregation. This is considered by the planning manager as very relevant for the control of future working capital levels in the Works. Obviously the limited experience does not enable more specific conclusions to be drawn, but there is a very clear enthusiasm about its possible use.

The other is the willingness for changing from horizontal to vertical planning. Since the early days of the micro system I witnessed a clearly growing interest in this possible development. Out of the planning exercise of December, already referred to above, a new common proposal (drawn up by one planner and myself) about the process of planning has been put forward and will be experimented within March.

Each planner is in charge of a group of plants in which products that form three or four layers of the product chain are manufactured. In the manual planning process the planners gave priority to the scheduling of the plants and only afterwards looked at the chain effects, and amended the loads on plants. They manifested the impression that this process of planning is responsible for increasing the working capital because semi-manufactured products are often held for longer than necessary.

The reason why they have not used the chain approach in their decision process is that the amendment of a unit plan is a very laborious task involving many calculations which are difficult to perform manually in the available time.

The new proposal suggests a chain approach as a first stage and only afterwards a revision of the resulting plan to check for the feasibility of the unit loads. The perceived advantage of this process is that the result of the first stage forms a target in terms of the minimum value of the working capital that the planners can try to achieve when considering the other factors.

Furthermore, it is my conviction that, if this experiment is successful, it may provide the lead to the establishment of a comparative measure of performance of the overall plan in terms of how much is spent in stocks to improve other more local measures of performance.

The lack of such an overall measure of performance has been frequently voiced by the planners as a critic limitation of their decision making process. This does not mean that any attempt to optimise this variable should be made, but only that it provides an additional measure of the quality of the plan as a whole. One such a measure is, at least at the conceptual level, very important because it is better to weight an overall measure with local considerations than the other way round.

It is relevant to reinforce the need for constant effort orientated to the evolution of the system. I sometimes fear that these opportunities will not wait for long and, if no positive action is taken to satisfy the emerging needs of decision makers, may be lost. And this has been the reason why many OR projects initially developed to aid decision makers in planning have finished as tools for the accounting function with little or no utility for the planners' problem solving process.

2) System ergonomic factors

The reaction of the users to non-quantifiable features of the system was also considered in the evaluation programme and the following points were included:

i) Design of displays
ii) Design of interactions
iii) Hardware features (e.g. light pen and function keys)
iv) System documentation.

Most of the general comments about these issues were already reported in Chapter 6. Here it is worth noting that a few modifications were made after the implementation had started to satisfy suggestions made by the planners. In particular, new display controls were introduced and a few polishing amendments were implemented in data input routines.

All the modifications in these areas were made very quickly and they have a very important contribution to the decision makers' sense of ownership and perceived flexibility of the system, and hence to a successful implementation. If these cosmetic modifications are made in this way they encourage new comments and this can only be good.

Another aspect that is worth repeating is that of personal interfaces. Only the continuous monitoring of the use of the system by different decision makers and the satisfaction of their eventual suggestions can provide the ground for the evaluation of those features of the system.

8.4 Conclusions

In this section I summarise the most important points learned during the implementation of the system at the planning function of Huddersfield Works. Then I propose five guidelines that may contribute to decrease the number of problems faced with the implementation of other systems.

The implementation of the DSS prototype has probably been the most demanding stage of its life. I started the chapter making a critical analysis of some of the earlier decisions about the scope of the project, mainly those concerned with the links between the prototype and existing computerised systems. The decision of not installing an IPG was also appraised.

Then the organisational structure, composed of a Divisional steering group and an implementation team, that was set up to implement and evaluate the prototype was discussed. I argued that in parallel with these formal structures it was important to maintain informal contacts between the users and the designers because it was through those that most of the proposals for evolution appeared. It is the function of formal structures to assess the importance of those proposals in a broader context, to define priorities and to allocate the relevant resources.

The problem of dependency on personalities in implementation was discussed and the consequences of the disappearance of two persons from the project were also reported.

In section 8.2 I described the outline of the training package used in this project and the limitations of its design by analysts were critically discussed. I also proposed that the package should be amended with the colaboration of one decision maker so that it becomes more realistic and hence more useful in future.

Finally the evaluation programme that has been in operation was described and the results collected so far were reported and discussed on the basis of the limited experience.

Out of the experience provided by this project I propose the following five guidelines that I think are of general application:

1) It is important to take into careful consideration the likely consequences of decision makers being asked to perform routine tasks, and in particular data input, because even if temporary, they may be dissuasive of their participaion in the evolution of the DSS or even of its use.

2) Set up a formal organisational structure for the implementation/evaluation with clear guidelines about which factors must be monitored, but make sure that those should be kept under scrutiny. In parallel maintain intensive informal contacts between users and designers because they are the most likely source of proposals for improvement.

3) Diversify the network of support for the system across the same function and across the organisation hierarchy to minimise the dependance upon personalities that may be moved.

4) Try to get the collaboration of a decision maker in the formulation of the training package so that the exercises are realistic and do not put the trainees in a school-like situation.

5) Prepare a task force that keeps the system evolving with the learning process provided by the implementation, or the intended mesh of the DSS in the decision making process is likely to be jeopordized.

9. CONCLUSIONS AND PROPOSALS

This thesis reported the results of the action research project initially aimed at the development of a decision making aid for a complex production planning situation. The stimulus for its initiation came from two different sources. On one side the complex decision making problem of the planning function at Huddersfield Works for which there was no computerised aid. On the other side the ongoing research programme at Warwick University aimed at the development of visual interactive simulation models for real problem situations.

The initial terms of reference of this project can be better described by the following questions:

> Is it possible to extend the use of visual interactive modelling to decision areas where simulation is not the most appropriate technique?
>
> To what extent is it possible to develop a general framework that can be used to build visual interactive decision making aids for complex problems?

This chapter summarises the conclusions of the research carried out in the pursuit of answers to those two questions. In a final section I also put forward two topics that are worth further investigation.

9.1 Conclusions

In this section I decided to discuss the conclusions already drawn in previous chapters under three separate headings: 1) methodologic issues; 2) technical issues; and 3) specific application issues. The rationale behind this division is to put together the conclusions accordingly with their degree of generalisation.

9.1.1 Methodological issues

There are two main points worth discussing under this heading. The first is related to the action research nature of the project and the second concerns the value of the methodological frameworks provided by OR and DSS.

With regard to the action research topic I believe that the project reported in this thesis is an example of its approach. It is difficult to imagine how the stimuli for the technical development achieved would have been possible without a challenging real situation as the one treated. Simultaneously, the realisation of a prototype which was developed and implemented at Huddersfield Works would have been very difficult to achieve without a research programme (internal or external) formally set up to address the different types of technical problems discussed in Chapters 5, 6 and 7.

This does not mean that an action research project will always produce positive results both in action and in research terms. Or that it is easy to overcome the different types of difficulties that are bound to appear.

Referring back to the three dilemmas (ethics, goals and initiatives) of action research proposed by Rapoport and discussed in Chapter 4, I do think that research programmes in Universities should put together the ethical principles they recognise should constitute the platform for action research projects; so that problems of ownership and confidentiality could be dealt with pragmatically and a priori.

With regard to the dilemmas of goals and initiatives, these depend much more on the individuals engaged than on the two programmes (action and research) and therefore it is difficult to define statutary principles.

In Chapter 2 I discussed some of the conceptual issues associated with aiding decision making and argued that OR (or at least the OR as it appears in the professional journals) is not providing a sensible service as far as non-structured problems are concerned. This does not mean that the terms of reference of OR do not include that possibility but rather that its mainstream of work has been dedicated to the formulation of models of structured or assumed structured problems.

The methodological framework based on semi-structured tasks proposed by DSS is not only more sound conceptually but also more useful. Undoubtedly there are hiatus in its approach but these seem to have started being filled with the growing use of the methodology in different areas of decision making.

One area in which I do not accept the proposals of the DSS promoters is the one concerned with the role of analysts. As argued in Chapter 2, I believe that their function goes much further than the technical developments and they are fundamental both in the analysis phase and during implementation. The example of the change in the decision making process achieved during the implementation and reported in Chapter 8 is one example of this point.

The decision processes in which negotiation plays an important part is one case that has not yet been seriously approached by any of the specific DSS reported in the literature. As argued in Chapter 6 this type of situation may well show that some of the concepts about personal interfaces may need to be revised.

One problem faced in this project and for which I did not find much help in either the OR and the DSS methodologies regards the multi-disciplinary approach that both sponsor but take for granted. In Chapter 4 I described the problem of finding a common vocabulary among the members of the technical team and how these were reduced with the development of a micro system. Although it may be considered a methodologic issue I prefer to discuss this topic in the more restricted section about the project (9.1.3) because I am not sure that the learning gained with this experiment can be generalised.

The same hesitation applies to the prototype approach. Although my feelings about its appropriateness, based on conceptual and practical considerations discussed in Chapter 4, are stronger I feel that it still depends on the nature of the project. I would like to see the possibility of a prototype that would not need to pass through re-design but could evolve in a continuous manner.

Based on the experience acquired in this project next I summarise the strong and weak methodological points of DSS.

1) The DSS decision analysis based on semi-structured tasks and their division in discrete intellectual operations form a very sound framework from which decision making processes can be seen in a realistic

perspective. Furthermore, this same concept gives useful hints towards system design, implementation and evolution.

2) The DSS has taken a more sensible advantage of the computer hardware and software technologies towards decision making aids than any other of the management sciences.

3) The role reserved for the analyst by DSS is very restricted and I feel that the OR tradition in this area is more adequate. It does seem vital that there is an inquisitorial mind constantly challenging the decision process, both in the early diagnostic stages and during the implementation and use of a DSS.

4) Promoters of DSS are reluctant to accept complex models. I share this reluctance as far as their inclusion in the initial design of a system. However, I suspect that there is a need for more formal investigation in both model structures and complex models that can cope with the evolution of a decision process. I believe this is a field in which OR can take a lead, if it is able to free itself from the techniques that form its traditional repertoire.

9.1.2 Technical issues

In this section I discuss the most relevant conclusions from the technical developments achieved during the action research project and which constitute most of my research contribution. Initially I discuss the claim that a DSS generator has been designed and then I summarise the conclusions already presented in Chapters 6 and 7.

It is not possible to defend exhaustively the claim of a DSS generator, since this can only be tested by its use to build specific DSS's for many different situations, which could not have been treated in the available time. Therefore this claim should be considered as a proposal that requires further testing before it can be fully accepted.

Nevertheless, since it was designed following the methodological principles accepted by the DSS promoters and most of its characteristics were motivated by a real and complex decision situation, I believe that it provides a framework capable of being used in different situations.

So far, it has been used by the Pharmaceuticals Division of ICI to build another specific DSS for production planning at the divisional level. This other application was built in three months without my involvement and is now being implemented. It uses a similar data base design and some of the basic models and displays implemented in the original system. However, new models and displays were specifically designed for this application and there was no need to modify the generator.

The most important characteristics of the generator are:

1) The interface management, composed by the dialogue and the display management system, is independent of its own contents. These are supplied externally, stored in the DSS master file and can be tuned to each user from data stored in the external data base in user dependent files.

2) The conceptual model structure, materialised in a software table, can be incrementally expanded by the addition of new modules into the library of models.

3) The generator is independent of the external data base since it works with data extracted from its own master file. The use of a different data base will only require that the initialisation routines, which are specific to any application, and written to adjust the master structures to the specific needs of each user.

4) All the components of the generator work with the same internal data array via a set of low level routines that constitute the data handling tools.

Considering the interface, its most important global characterstic is that it is personalised. This matter was extensively discussed in Chapter 6 and it is reasonable to draw the conclusion that the need for, and the requirements of, personalised interfaces have to be more thoroughly investigated to ascertain how they can be used in more general decision situations which are bound to include negotiation, both inside and across organisational functions. What this research project showed is that they are possible and this conclusion has not been reported elsewhere. Furthermore, since the interface is included in the generator, it has some degree of generality.

In relation to the dialogue structure, one of the components of the interface, its most distinctive features are:

1) The possibility of being used as a conventional tree, or as a flat structure where commands are interpreted in context, or any mix of those two processes depending on the expertise of each user.

2) It constitutes the single control language with

which users access models, displays and the data base.

3) It can be tuned to the requirements of each user via the modification of the user dependent files of the external data base.

4) It provides an external process of expanding the models to which a decision maker has access, and therefore ensures that the DSS is able to grow in parallel with the new requiremens of the decision making process without recoding existing routines.

5) Via the use of global variables that are associated with the higher levels of the tree it is possible to maintain consistency among the images displayed, without demanding extra work from the analyst.

6) It enables the validation of access to the two higher levels of the tree.

The display system, which forms the other half of the interface, has the following main characteristics.

1) Since it does not rely on fixed format screens, as most traditional management information systems do, it enables the decision maker to choose the mix of information that is relevant for each

problem solving process.

2) Because the routines that generate and update the images are stored in a library which is independent of both the dialogue and the models structures, it enables the analyst to modify the display formats without any changes to the other sections of the programmes.

3) It contains a management system that keeps the whole screen, consistent with the requirements of the decision maker, independently of the mix of displays mapped, with minimal intervention from the user and with very little programming effort from the analyst.

4) The personalised tunning of the displays is achieved by the modification of the contents of the user dependent files and without any coding effort.

Finally the last of the technical developments that is worth summarising in this section concerns the models and searching processes extensively discussed in Chapter 7.

The definition of model presented in that chapter is a tentative proposal orientated towards the modelling requirements of semi-structured problems. The advantage of separating models from the searching processes was justified on the grounds that the latter are likely to represent the non-structured parts of decision making while the former can represent the structured sub-tasks (or discrete intellectual operations).

These concepts extend the single methodological framework so far proposed (Bonczek et al, 1981) for dealing with the role of models in DSS.

The application of that definition to the development of basic and combined models was then presented and the conceptual structure where they are held was justified on the basis that it provides the framework for constant evolution of the modelling capabilities of the system. This can be achieved by orientating the energies of both decision makers and analysts towards the incremental understanding of the perceptual semi-structured decisions. The largest benefit of the conceptual structure is that, while it allows more aggregated models to be easily added to the library, it still does not withdraw the ability of using the basic models and therefore enables the decision maker to choose the level of control he wants to intervene in each particular situation.

Finally, I argued that the above structure does not help the decision maker in intrinsic semi-structured problems and proposed a searching framework that enables him to develop complex models using the modules held in the triangular structure in an environment of combined heuristic and human search. The characteristics of this searching framework with respect to its independence from the organisational boundaries and possibility of being used in a multi-user data base environment were also discussed.

9.1.3 Specific application issues

With regard to the work related with the development of the specific DSS for the planning function of Huddersfield Works there are two levels of conclusions that are worth summarising in this section: about the management of the project and the ones related with the results achieved.

In relation to the management of the project the most important issue was the development of the micro system described in Chapter 4. Its major benefits were to help unify the technical team with common vocabulary and objectives, and to establish its credibility with senior management and the end users. These led to an agreed specification of the prototype to which the technical team and the planners were commited. And overall the micro system provided the framework where the different expertises of the team members were articulated.

The value of this type of experiment was already discussed in section 9.1.1 but I decided that its conclusions lacked enough evidence for it to be possible to claim that a similar type of approach should be followed in the early design stages of any DSS. There are two reasons for this. First I believe that it depends very much on the homogeneity of the design team in terms of its members' backgrounds and professional competence. Secondly if a DSS generator is available it is more effective to use it to build a small system which can be the embryo for the incremental design of the overall system.

Given the action research nature of this project the micro system was also useful because it enabled the different research topics to be put into perspective at a very early stage and hence enabled the planning of the research effort that would be more difficult to achieve simply on a on-going basis.

Considering the learning about the implementation of the specific DSS the conclusions can be better summarized by the five guidelines already proposed in Chapter 8:

1) It is important to take into careful consideration the likely consequences of decision makers being asked to perform routine tasks, and in particular data input, because, even if only temporary, they may be dissuasive of their participation in the

evolution of the DSS or even of its use.

2) Set up a formal organisational structure for the implementation/evaluation with clear guidelines about which factors must be monitored, but make sure that those should be kept under scrutiny. In parallel maintain intensive informal contacts between users and designers because they are the most likely source of proposals for improvement.

3) Diversify the network of support for the system across the same function and across the organisation hierarchy to minimise the dependance upon personalities that may be moved.

4) Try to get the collaboration of a decision maker in the formulation of the training package so that the exercises are realistic and do not put the trainees on a school-like situation.

5) Prepare a task force that keeps the system evolving with the learning process provided by the implementation, or the intended mesh of the DSS in the decision making process is likely to be jeopardized.

9.2 Proposals

The objective of this section is to propose, on the basis of the results achieved in the research reported in this thesis, the terms of reference for the areas where further research is required.

First it is worth emphasizing that the suggestions put forward below require a practical environment, and preferably they should be investigated in an action research programme.

The following are the mainstreams that should be addressed:

1) The investigation of decision making situations where negotiation plays an important role and the simultaneous study of the developments that are needed in terms of interfaces. This study should be mainly orientated to the definition of the objectives and scope of dialogue and control protocols and to the investigation of the importance (and possible specification of the characteristics) of personalised interfaces for negotiation.

2) The research into the validity of the concepts of basic and combined models, and of the searching, in other areas of decision making. With regard to the

searching framework it would be particularly interesting to assess the extent of its applicability to aid decision makers with intrinsic semi-structured problems.

It would be interesting if these two topics could be researched with the use of the DSS generator described in this thesis, because it would also provide the relevant information to assess whether the claim of a generator can be sustained.

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APPENDIX 1 - DATA BASE FILES SPECIFICATIONS

This appendix includes the specifications of all the files used in the DSS for Huddersfield Works. They are structured accordingly with the principles enumerated in Chapter 5 and constitute a relational data base since the primary key defines uniquely each record and there are no repetition of fields in each record.

1. Valid Product Codes (VALCODES)

This file holds information about valid groups of products

a) Primary key

ACODE - Valid product code

ATYPE - Classification

b) Dependant fields

ACDESC - Description

2. Valid Stocking Sites (VALWORKS)

This file holds the codes for valid stocking sites, and whether stock details are to be maintained.

a) Primary key

AWKSCD - Site code

b) Dependant fields

AFLAG - Flag to indicate whether stock details are to be maintained

AWKNAM - Description of site

3. Valid Manufacturing Sites (MANFSITES)

This file holds the valid manufacturing sites and related information.

a) Primary key

AMWORK - Works code

AMCC - Cost Centre code

AMUNIT - Manufacturing unit code

b) Dependant fields

AMSNAM - Description

AMBUDG - Budget code

4. Product Characteristics (BPRODD)

a) Primary key

BPRODC - Product code

b) Dependant fields

BNAMEF - Full name of product

BNAMES - Short name of product

BPRTYP - Product type

BPROGP - Product group

BEQUPR - Equivalent product for accounting

BPLSWT - Planning switch (planned or not planned)

BLRCIN - Latest recipe index

5. Manufacturing data (BMANFD)

a) Primary key

FPRODC - Product code

FWORKS - Works code

FCC - Cost Centre code

FUNIT - Unit code

b) Dependant fields

FAPIND - Alternative or prefered manufacturing site indicator

FBXSIZ - Standard batch size

FTHRAT - Theoretical rate of production

FPRATE - Planning rate of production

FOFSTM - Standard offset time between manufacturing and availability

FMINCS - Minimum campaign size

FMAXCS - Maximum campaign size

FCAMTP - Standard campaign size

FAVLTP - Availability type (weekly / at the end of campaign)

FORUNT - Other required manufacturing unit

FAVLFC - Standard availability factor, to cater for inferior quality production

6.Recipes (RECIPE)

a) Primary key

RPRODC - Product code

RMATCD - Code for consumed material

RINDEX - Recipe index reference number

b) Dependant fields

RCNQTY - Quantity of material consumed per unit of quantity manufactured

7. Costs (COSTS)

a) Primary key

CPRODC - Product code

CSITE - Stocking site

b) Dependant fields

CPCOST - Plant cost per unit of quantity manufactured

DMATCS - Material cost per unit of quantity

DDIREX - Direct expenses per unit of quantity

8. Manufacturing campaigns (PMANCP)

This file holds information of all the planned manufacturing campaigns.

a) Primary key

PPRODC - Product code

PWORKS - Works code

PCC - Cost centre code

PUNIT - Unit code

PREFNO - Campaign reference number

b) Dependant fields

PCAMTP - Campaign type (continuous / discrete)

PAVLTY - Availabilitytype (weekly / at the end of campaign

PSTYR
PSTPER - Starting date in form YEAR,WEEK

PDURTN - Campaign duration

PAVOFF - Availability offset

PBXSIZ - Batch size

PAVFAC - Availability factor

POTHUN - Other required manufacturing unit

PRCPPT - Recipe index number for this campaign

Note: Apart from the starting date and the duration, all the dependant fields are identical to those of file BMANFD. This is so to enable planners to take into account particular situations and to be able to update the plans with information about what is actually happening.

9. Movement details (MOVEMT)

This file holds the details of all the planned imports and exports of material.

a) Primary key

MPRODC - Product code

MSNSIT - Sending site code

MRCSIT - Receiving site code

MREFNO - Reference number

b) Dependant fields

MYEAR
- Movement date in form YEAR,WEEK
MPER

MQTY - Movement quantity

10. Stock movements (STKMVTS)

This file contains the planned stock movements originated by production, consumption, imports and exports for all the planned products.

a) Primary key

SMPROD - Product code

SMSITE - Stocking site code

SMTYPE - Movement type (production / consumption / import / export)

b) Dependant fields

SMOVE (52) - Amount moved in each of the 52 weeks

11. Projected stocks (STOCK)

This file holds the quantities of the projected stock at the end of the next 52 weeks.

a) primary key

SPRODC - Product code

SSITE - Stocking site code

STYPE - Stock type (in-process / finished)

b) Dependant fields

SOPSTK - Opening stock

SSTKEN (52) - Stock at the end of the 52 weeks

SSOUTM - Marker indicating the month in which the first projected stockout occurs

SLWARN - Lower warning level

SUWARN - Upper warning level

12. Working Capital (SUMWCAP)

This file contains the amount in sterling of working capital held in a stocking site for each group of products.

a) Primary key

WSITE - Stocking site code

WPRTYP - Product type code

WPROGP - Product group code

b) Dependant fields

WOPVAL - Opening value

WSTVAL (52) - Stock holding cost at the end of the 52 weeks

WUWLEV - Upper warning level

13. Plant Utilization (SUMPLUTD)

a) primary key

VSWORK - Works code

VSCC - Cost Centre code

VSUNIT - Unit code

b) Dependant fields

VSUT01 (52) - Utilization as a % of the theoretical rates of production during the next 52 weeks

VSUT02 (52) - Utilization as a % of planning rates during the next 52 weeks

VSUT03 (52) - Utilization in terms of direct expenses absorption

14. Calendar (CALENDAR)

This file holds data to convert dates in the format YEAR, COST PERIOD, WEEK from YEAR,WEEK.

a) Primary key

AYEAR - Year (e.g. 81)

AMONTH - Cost period designation

b) Dependant fields

ASWK - Starting week

AEWK - Ending week

15. Campaign numbers (LMANFNO)

File to generate the next reference number for manufacturing campaigns.

a) Primary key

XPRODC - Product code

XWORKS - Works code

XCC - Cost Centre code

b) Dependant fields

XLNO - Latest allocated number

16. Movement numbers (LMVMTNO)

File to generate the next reference number for a movement of material.

a) Primary key

YPRODC - Product code

b) Dependant fields

YLNO - Latest allocated number

17. User Security (USERSEC)

This file holds user dependant information to secure the appropriate access to data in the other files of the data base. It also stores some default values that are user dependant.

a) Primary key

UUSNO - User code

UPASS - Password

b) Dependant fields

UWORKS - Code for the Works the planner is allowed to access

USRCC - Code for the Cost Centre the planner is allowed to access

USITLV Level of detail for interactions

UTHEAD Dialogue tree heading pointer

UPCIND Flag to indicate whether planner uses product codes or short names

UTIMPD Planning time period (week / month)

UDCOL1

UDCOL2

UDCOL3 5 default colour codes for system and

UDCOL4 dialogue control messages

UDCOL5

18. User dialogues (USERINT)

This file stores the information required to tune the master dialogue tree stored in the DSS master file to the needs of each planner.

a) Primary key

UISNO - User code

UIPASS - Password

UILEV - Designation of level to be deleted from tree

UIGRP - Designation of group to be deleted from tree

UIINT - Designation of interaction to be deleted from tree

19. User displays (USERDISP)

This file holds the user dependant information about the displays (i.e. colours, default locations, size).

a) Primary key

UDUSNO - User code

UDPASS - Password

UDDISP - Display name

b) Dependant fields

UDPRIO - Display priority level (0-5)

UDDKEY - Dynamic location flag (not allowed / allowed)

UDC1

UDC2

UDC3 Five colours to be used in the display

UDC4

UDC4

UDXREF x and y coordinates of the bottom left hand

UDYREF side corner of the window display

UDYMIN - Minimum height of the window

20. Messages (PROGMESS)

This file contains application dependant messages.

a) Primary key

MESSNO - Message number

b) Dependant files

MESSTP - Message type (prompt / error / warning)

MESTXT - Message text

APPENDIX 2 - LOGICAL DISPLAY CHARACTERISTICS

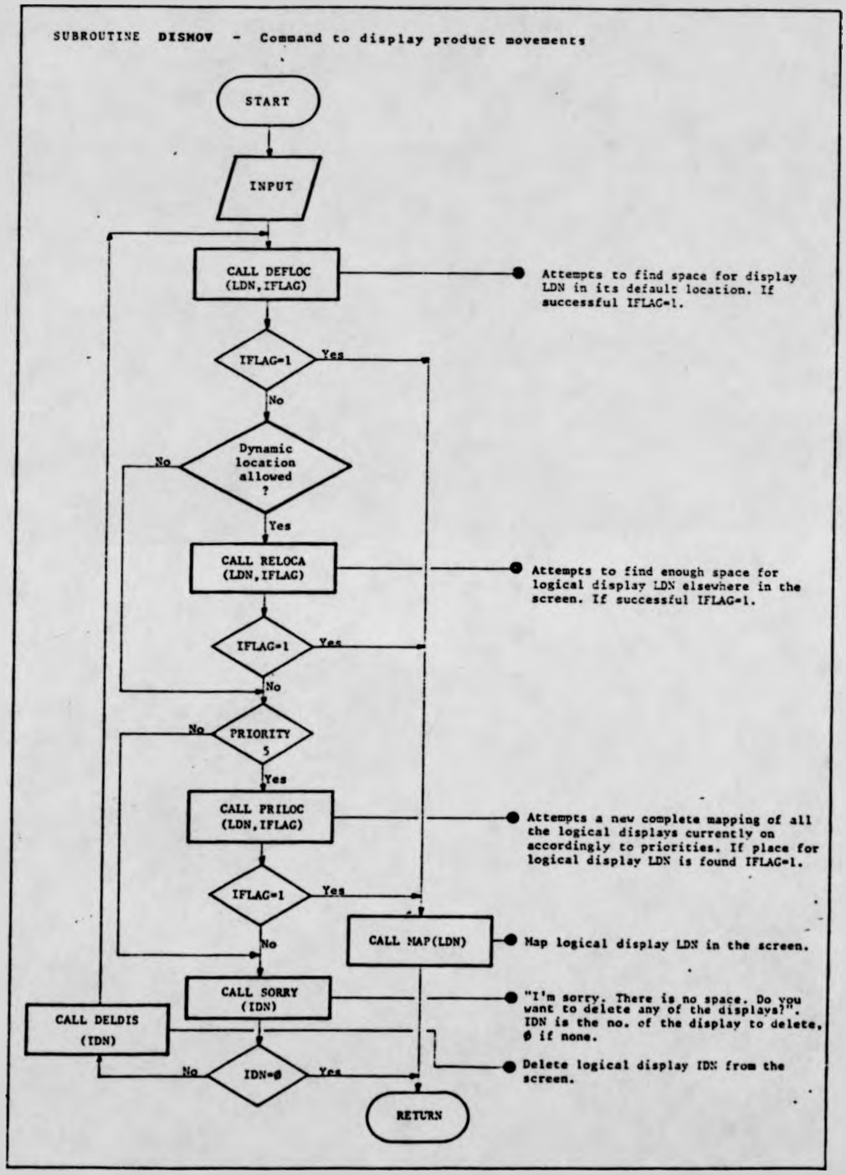
The display management system is formed by data structures (logical displays) whose contents are represented in the table of page 238, and by a number of subroutines that enable the analyst to build the problem dependant displays.

The generation of a display can be automatic, via the use of global variables, or through the dialogue structure to which appropriate interactions are hooked. The flowchart for a typical interaction is depicted in page 239. The analyst has to provide such a subroutine where he uses the facilities existant in the system and he also has to write the subroutine that maps the display in the screen and hook it in the table of subroutine MAP (See flowchart).

User attributes and list area in the logical displays

No.	NAME	Possible values and validity notes
1	Dynamic key	1 - If dynamic location is allowed Ø - Otherwise
2	Compatibility key	Ø - Totally incompatible 99- Totally compatible = number of compatible sets allowed (1-2)
3	Type key	Ø - Fixed size display 1 - Variable size display
4	Priority	Values from 1 to 5. (1 is the highest)
5	Resolution	Ø - Alphanumeric 1 - Graphs
6	IXMIN	Window definition
7	IYMIN	
8	IXMAX	
9	IYMAX	
10	IXREF	Default coordinates for window reference point
11	IYREF	
12	IDXREF	Dynamic coordinates for window reference point. Values of -1 if attribute 1 is 1.
13	IDYREF	
14	LD11	Numbers of the compatible logical displays. LDij : i is the set number j the order of the compatible display
15	LD12	
16	LD13	
17	LD21	
18	LD22	
19	LD23	
20	ICOL1	Colour codes
21	ICOL2	
22	ICOL3	
23	ICOL4	
24	ICOL5	
25	NBLOCK	No. of blocks currently displayed (if attribute3=1)
26	NLINES	No. of lines in each block
	LIST OF NBLOCK POINTERS TO THE DATA BASE	

Flowchart for a typical display command



APPENDIX 3 - LIST OF BASIC MODELS

1. Amend the opening stock of a product
2. Create a manufacturing campaign
3. Delete a manufacturing campaign
4. Move a manufacturing campaign
5. Amend a manufacturing campaign (includes extending or shortening and/or moving)
6. Amend the number of batches of a manufacturing campaign
7. Amend the testing time of a manufacturing campaign
8. Amend the availability rules of a manufacturing campaign
9. Amend the batch size of a manufacturing campaign
10. Create a movement of material (import or export)
11. Delete a movement of material
12. Move a movement of material
13. Amend the quantity of a movement of material

APPENDIX 4 - AN EXAMPLE OF A BASIC MODEL

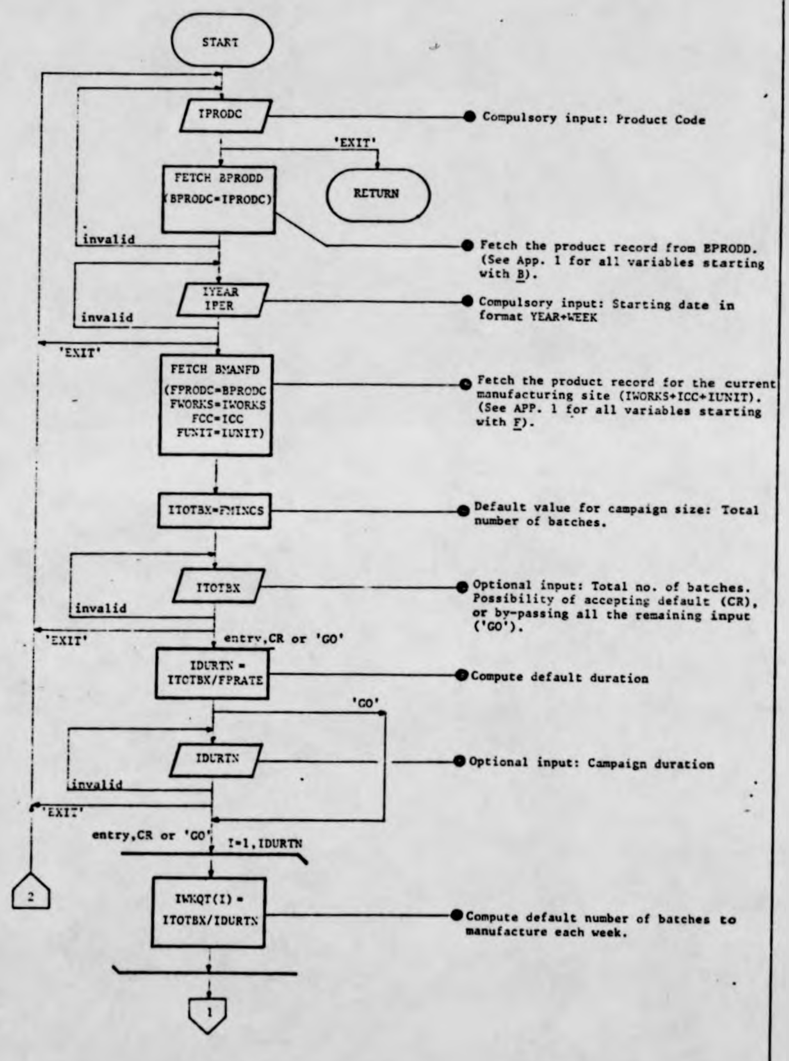
In this Appendix the basic model that creates a manufacturing campaign is presented in detail. As referred to in Chapter 7 it is advisable that the implementation of each basic model should be achieved with two main subroutines: One for the input of data and the other for the execution of the model's relationships.

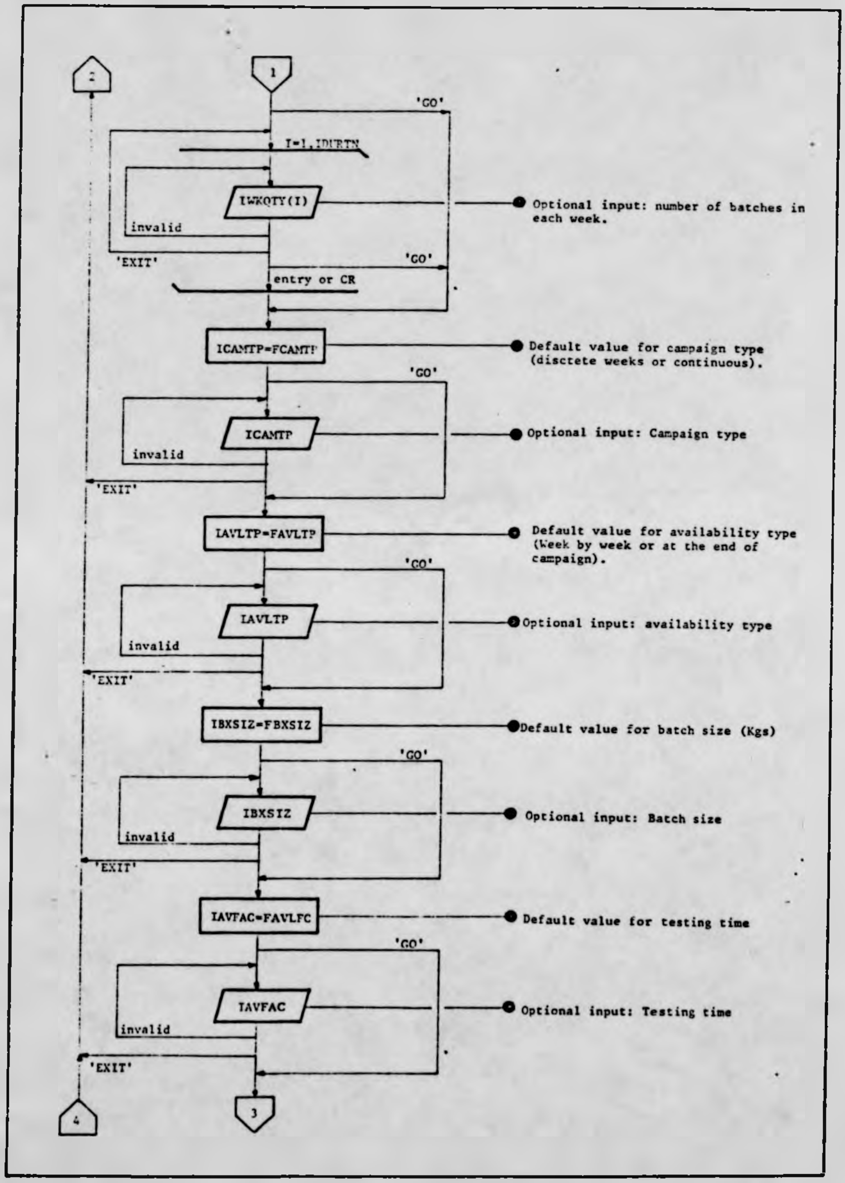
In the present case the data input is made in subroutine PLCUCR for which a flowchart is presented in pages 243 to 245.It is worth noting the multiple entry possibilities that enable the user to exit at any stage and, once all the compulsory data is input, to accept default values bypassing the remaining queries. Moreover it is important that the compulsory data should be taken as much as possible from the context as it is the case with the codes for the Works, Cost Centre and Manufacturing Unit in the present example.

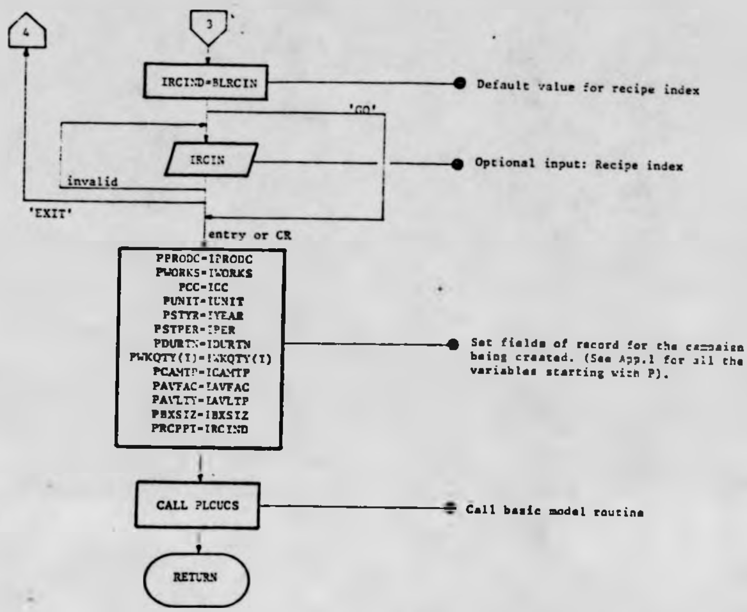
The second subroutine - PLCUCS - (pages 246 to 252) evaluates the policy defined in the previous subroutine by updating and inserting the relevant records in the data base logical files.

The flowcharts presented in this Appendix do not intend to be a full representation of the computer programs but only to enhance their main points.

SUBROUTINE PLCCCR - Data input for the basic model that creates a campaign

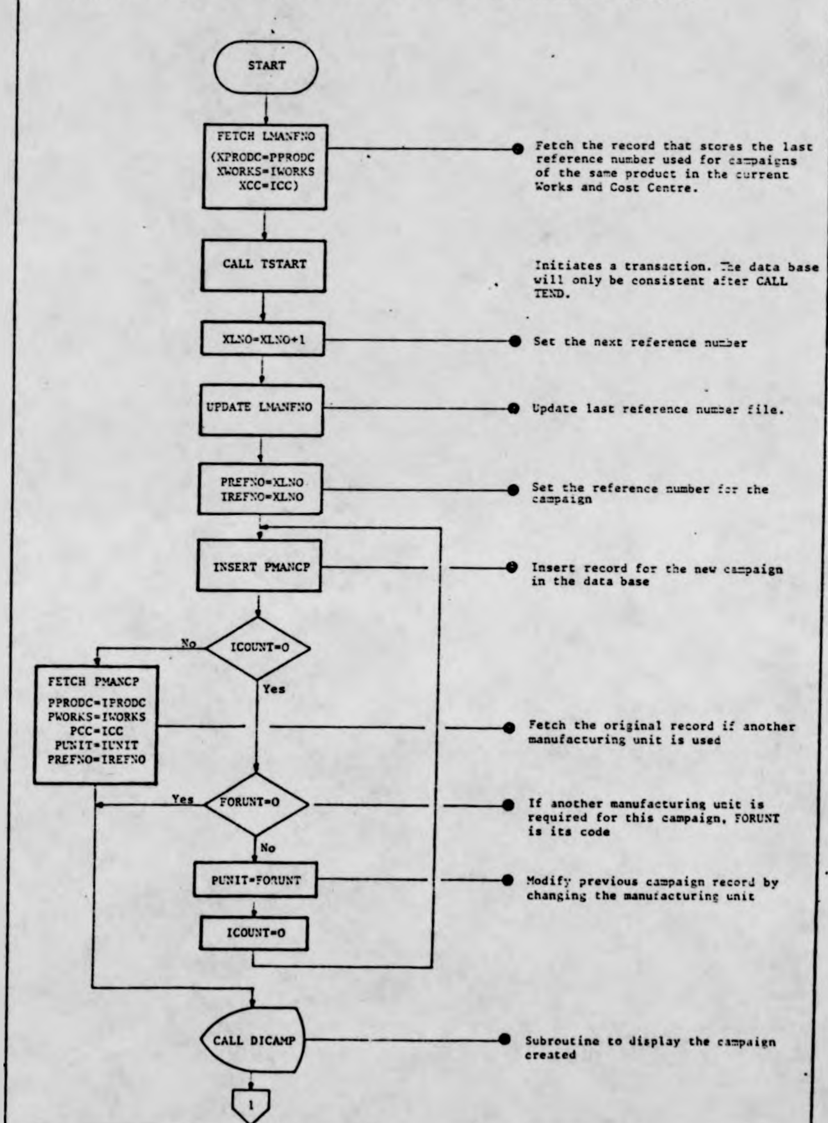


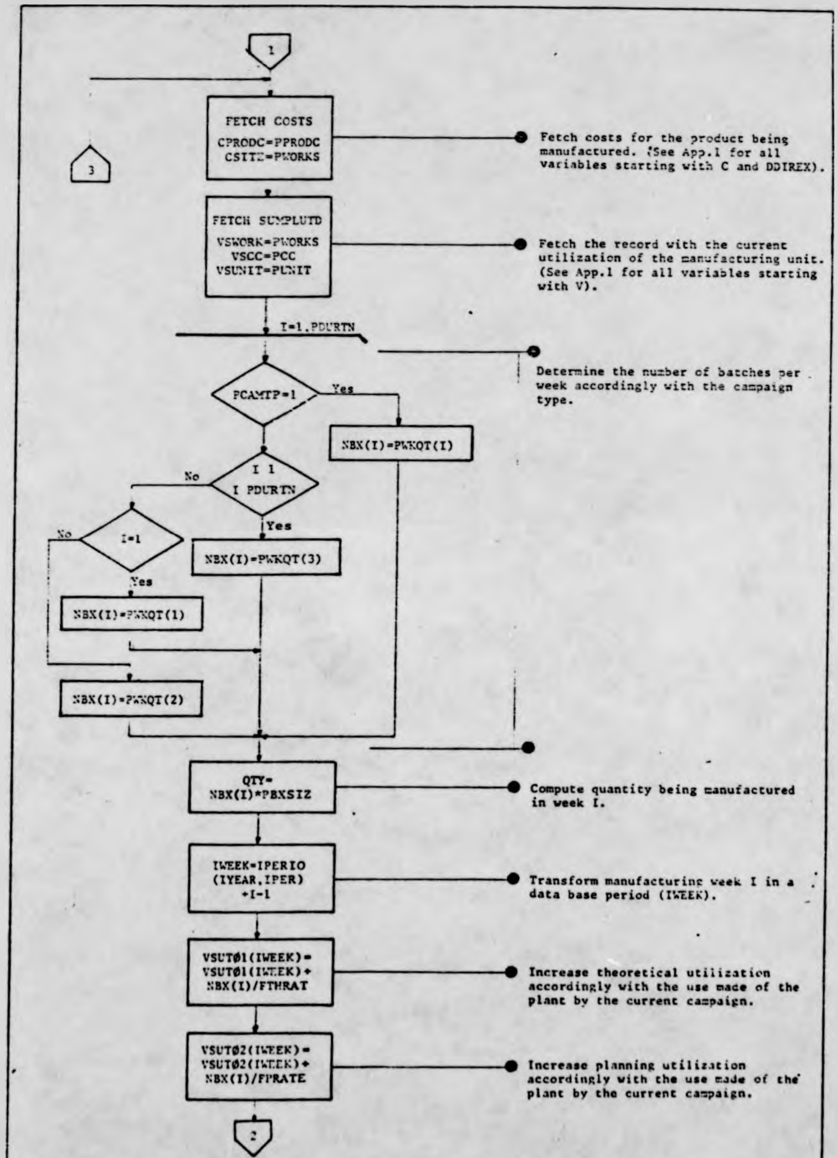

2
1
'GO'
IWKQTY(I)
invalid
'EXIT'
'GO'
entry or CR
Optional input: number of batches in each week.
ICAMTP=FCAMTP
Default value for campaign type (disctete weeks or continuous).
'GO'
ICAMTP
Optional input: Campaign type
invalid
'EXIT'
IAVLTP=FAVLTP
Default value for availability type (Week by week or at the end of campaign).
'GO'
IAVLTP
Optional input: availability type
invalid
'EXIT'
IBXSIZ=FBXSIZ
Default value for batch size (Kgs)
'GO'
IBXSIZ
Optional input: Batch size
invalid
'EXIT'
IAVFAC=FAVLFC
Default value for testing time
'GO'
IAVFAC
Optional input: Testing time
invalid
'EXIT'
4
3

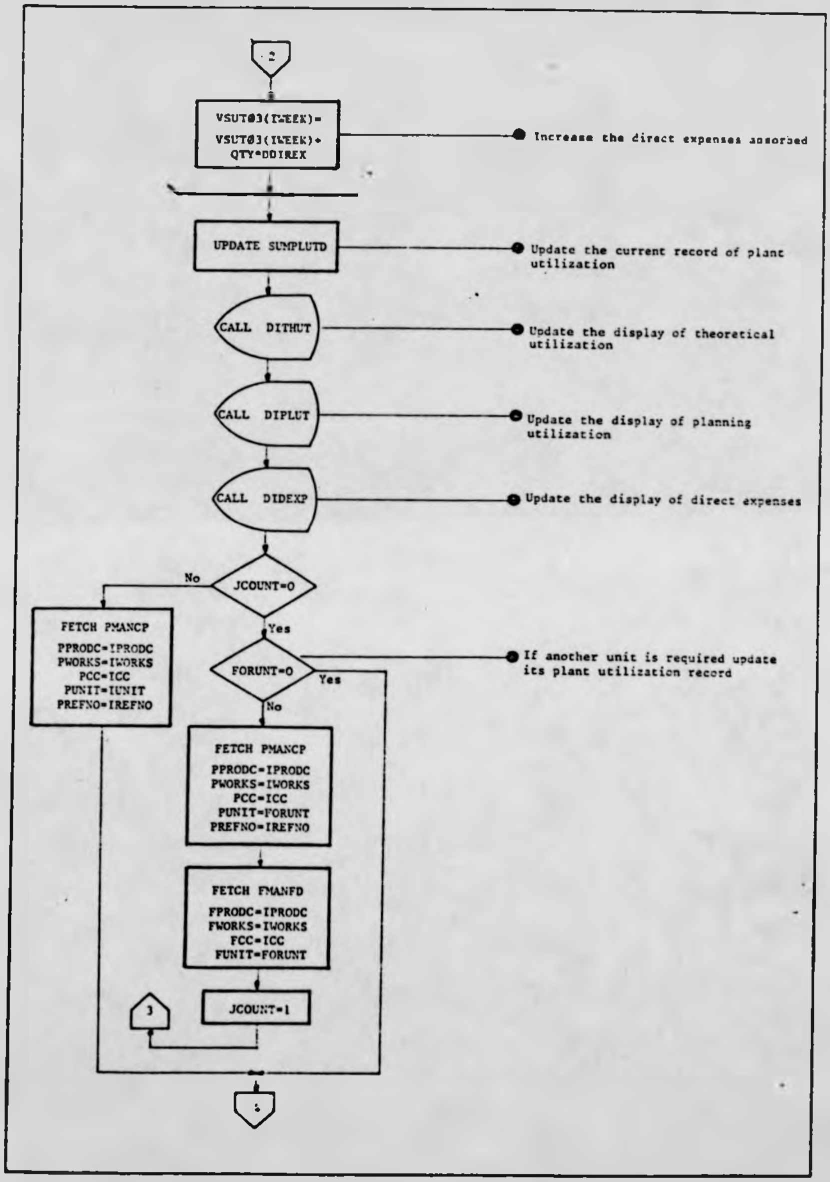


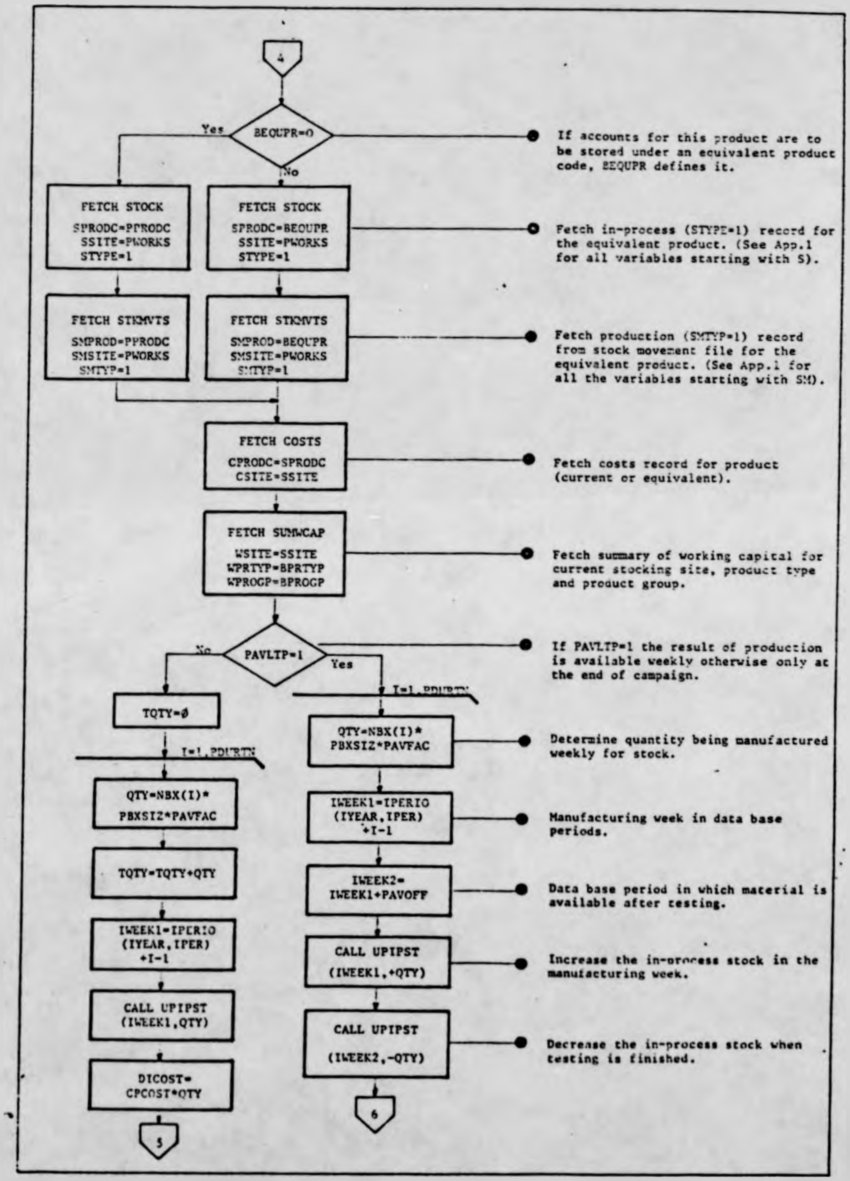
NOTE: All variables starting with I are local except IWORKS, ICC, IUNIT which define the current manufacturing site.

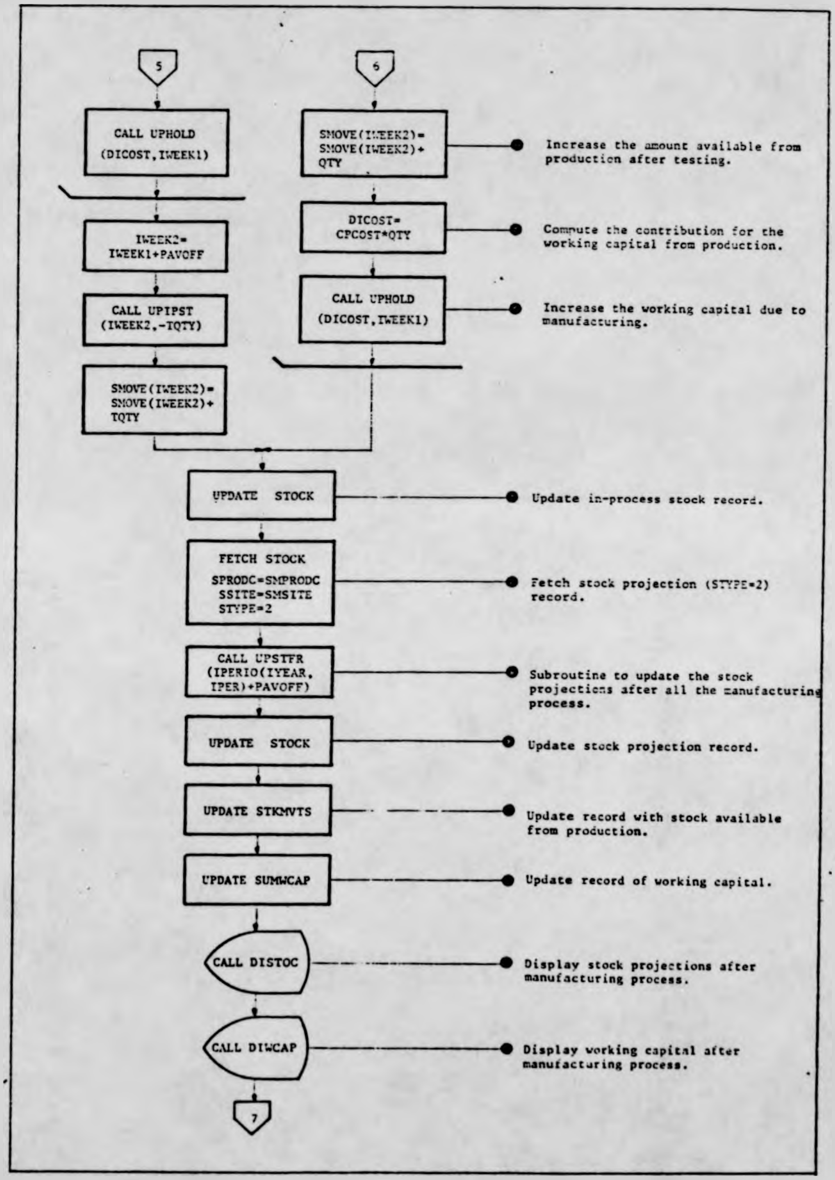
SUBROUTINE PLCUCS - Executes the basic model that creates a campaign

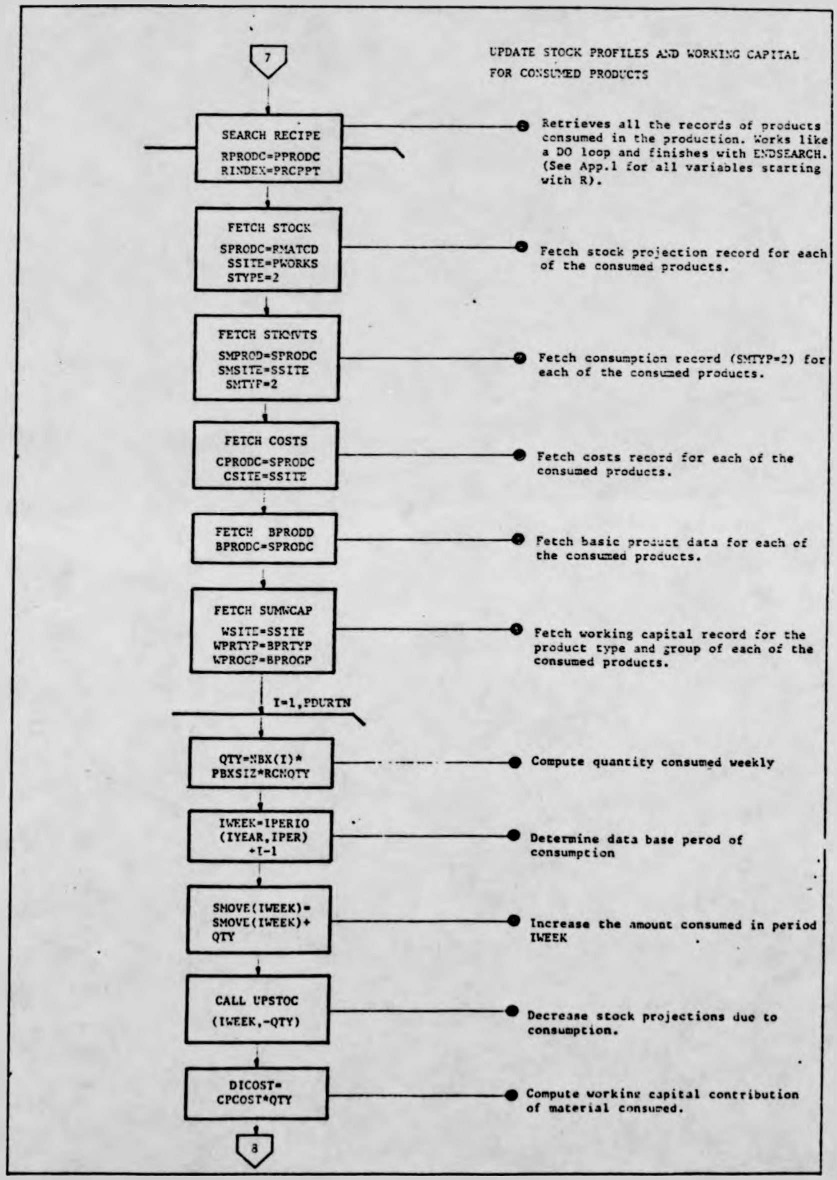


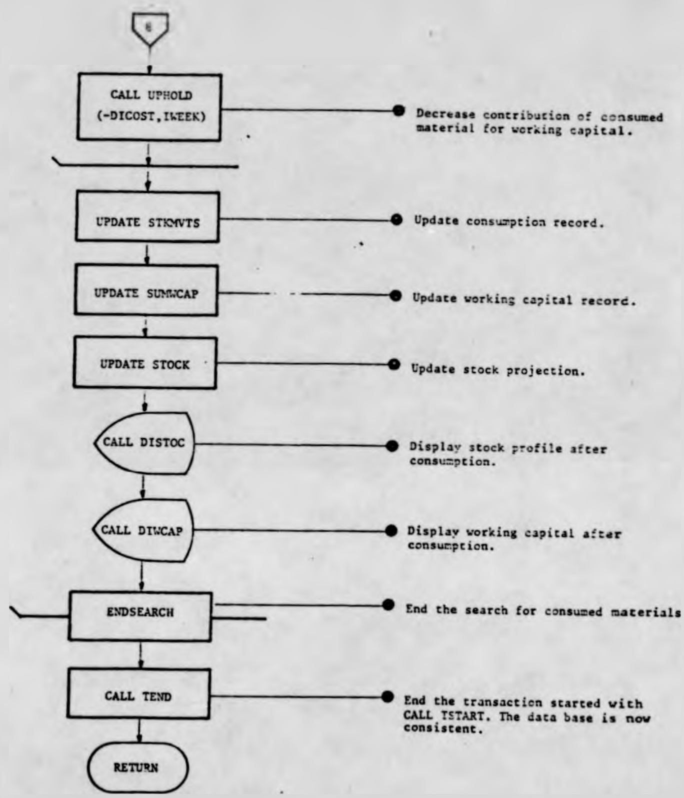

1
FETCH COSTS
CPRODC=PPRODC
CSITE=PWORKS
3
Fetch costs for the product being manufactured. (See App.1 for all variables starting with C and DDIREX).
FETCH SUMPLUTD
VSWORK=PWORKS
VSCC=PCC
VSUNIT=PUNIT
Fetch the record with the current utilization of the manufacturing unit. (See App.1 for all variables starting with V).
I=1,PDURTN
Determine the number of batches per week accordingly with the campaign type.
PCAMTP=1
Yes
NBX(I)=PWKQT(I)
I 1
I PDURTN
No
Yes
NBX(I)=PWKQT(3)
No
I=1
Yes
NBX(I)=PWKQT(1)
NBX(I)=PWKQT(2)
QTY=
NBX(I)*PBXSIZ
Compute quantity being manufactured in week I.
IWEEK=IPERIO
(IYEAR,IPER)
+I-1
Transform manufacturing week I in a data base period (IWEEK).
VSUTØ1(IWEEK)=
VSUTØ1(IWEEK)+
NBX(I)/FTHRAT
Increase theoretical utilization accordingly with the use made of the plant by the current campaign.
VSUTØ2(IWEEK)=
VSUTØ2(IWEEK)+
NBX(I)/FPRATE
Increase planning utilization accordingly with the use made of the plant by the current campaign.
2


2
VSUTØ3(IWEEK)=
VSUTØ3(IWEEK)+
QTY*DDIREX
Increase the direct expenses absorbed
UPDATE SUMPLUTD
Update the current record of plant utilization
CALL DITHUT
Update the display of theoretical utilization
CALL DIPLUT
Update the display of planning utilization
CALL DIDEXP
Update the display of direct expenses
JCOUNT=0
No
Yes
FETCH PMANCP
PPRODC=IPRODC
PWORKS=IWORKS
PCC=ICC
PUNIT=IUNIT
PREFNO=IREFNO
FORUNT=0
If another unit is required update its plant utilization record
Yes
No
FETCH PMANCP
PPRODC=IPRODC
PWORKS=IWORKS
PCC=ICC
PUNIT=FORUNT
PREFNO=IREFNO
FETCH FMANFD
FPRODC=IPRODC
FWORKS=IWORKS
FCC=ICC
FUNIT=FORUNT
3
JCOUNT=1


4
BEQUPR=0
Yes
No
If accounts for this product are to be stored under an equivalent product code, BEQUPR defines it.
FETCH STOCK
SPRODC=PPRODC
SSITE=PWORKS
STYPE=1
FETCH STOCK
SPRODC=BEQUPR
SSITE=PWORKS
STYPE=1
Fetch in-process (STYPE=1) record for the equivalent product. (See App.1 for all variables starting with S).
FETCH STKMVTS
SMPROD=PPRODC
SMSITE=PWORKS
SMTYP=1
FETCH STKMVTS
SMPROD=BEQUPR
SMSITE=PWORKS
SMTYP=1
Fetch production (SMTYP=1) record from stock movement file for the equivalent product. (See App.1 for all the variables starting with SM).
FETCH COSTS
CPRODC=SPRODC
CSITE=SSITE
Fetch costs record for product (current or equivalent).
FETCH SUMWCAP
WSITE=SSITE
WPRTYP=BPRTYP
WPROGP=BPROGP
Fetch summary of working capital for current stocking site, product type and product group.
PAVLTP=1
No
Yes
If PAVLTP=1 the result of production is available weekly otherwise only at the end of campaign.
TQTY=Ø
I=1,PDURTN
I=1,PDURTN
QTY=NBX(I)*
PBXSIZ*PAVFAC
Determine quantity being manufactured weekly for stock.
QTY=NBX(I)*
PBXSIZ*PAVFAC
IWEEK1=IPERIO
(IYEAR,IPER)
+I-1
Manufacturing week in data base periods.
TQTY=TQTY+QTY
IWEEK2=
IWEEK1+PAVOFF
Data base period in which material is available after testing.
IWEEK1=IPERIO
(IYEAR,IPER)
+I-1
CALL UPIPST
(IWEEK1,+QTY)
Increase the in-process stock in the manufacturing week.
CALL UPIPST
(IWEEK1,QTY)
CALL UPIPST
(IWEEK2,-QTY)
Decrease the in-process stock when testing is finished.
DICOST=
CPCOST*QTY
6
5


5
6
CALL UPHOLD (DICOST,IWEEK1)
SMOVE(IWEEK2)= SMOVE(IWEEK2)+ QTY
Increase the amount available from production after testing.
IWEEK2= IWEEK1+PAVOFF
DICOST= CPCOST*QTY
Compute the contribution for the working capital from production.
CALL UPIPST (IWEEK2,-TQTY)
CALL UPHOLD (DICOST,IWEEK1)
Increase the working capital due to manufacturing.
SMOVE(IWEEK2)= SMOVE(IWEEK2)+ TQTY
UPDATE STOCK
Update in-process stock record.
FETCH STOCK
SPRODC=SMPRODC
SSITE=SMSITE
STYPE=2
Fetch stock projection (STYPE=2) record.
CALL UPSTFR (IPERIO(IYEAR, IPER)+PAVOFF)
Subroutine to update the stock projections after all the manufacturing process.
UPDATE STOCK
Update stock projection record.
UPDATE STKMVTS
Update record with stock available from production.
UPDATE SUMWCAP
Update record of working capital.
CALL DISTOC
Display stock projections after manufacturing process.
CALL DIWCAP
Display working capital after manufacturing process.
7


UPDATE STOCK PROFILES AND WORKING CAPITAL FOR CONSUMED PRODUCTS
7
SEARCH RECIPE
RPRODC=PPRODC
RINDEX=PRCPPT
Retrieves all the records of products consumed in the production. Works like a DO loop and finishes with ENDSEARCH. (See App.1 for all variables starting with R).
FETCH STOCK
SPRODC=RMATCD
SSITE=PWORKS
STYPE=2
Fetch stock projection record for each of the consumed products.
FETCH STKMVTS
SMPROD=SPRODC
SMSITE=SSITE
SMTYP=2
Fetch consumption record (SMTYP=2) for each of the consumed products.
FETCH COSTS
CPRODC=SPRODC
CSITE=SSITE
Fetch costs record for each of the consumed products.
FETCH BPRODD
BPRODC=SPRODC
Fetch basic product data for each of the consumed products.
FETCH SUMWCAP
WSITE=SSITE
WPRTYP=BPRTYP
WPROGP=BPROGP
Fetch working capital record for the product type and group of each of the consumed products.
I=1,PDURTN
QTY=NBX(I)*
PBXSIZ*RCNQTY
Compute quantity consumed weekly
IWEEK=IPERIO
(IYEAR,IPER)
+I-1
Determine data base perod of consumption
SMOVE(IWEEK)=
SMOVE(IWEEK)+
QTY
Increase the amount consumed in period IWEEK
CALL UPSTOC
(IWEEK,-QTY)
Decrease stock projections due to consumption.
DICOST=
CPCOST*QTY
Compute working capital contribution of material consumed.
8


CALL UPHOLD (-DICOST,IWEEK)
Decrease contribution of consumed material for working capital.
UPDATE STKMVTS
Update consumption record.
UPDATE SUMWCAP
Update working capital record.
UPDATE STOCK
Update stock projection.
CALL DISTOC
Display stock profile after consumption.
CALL DIWCAP
Display working capital after consumption.
ENDSEARCH
End the search for consumed materials
CALL TEND
End the transaction started with CALL TSTART. The data base is now consistent.
RETURN

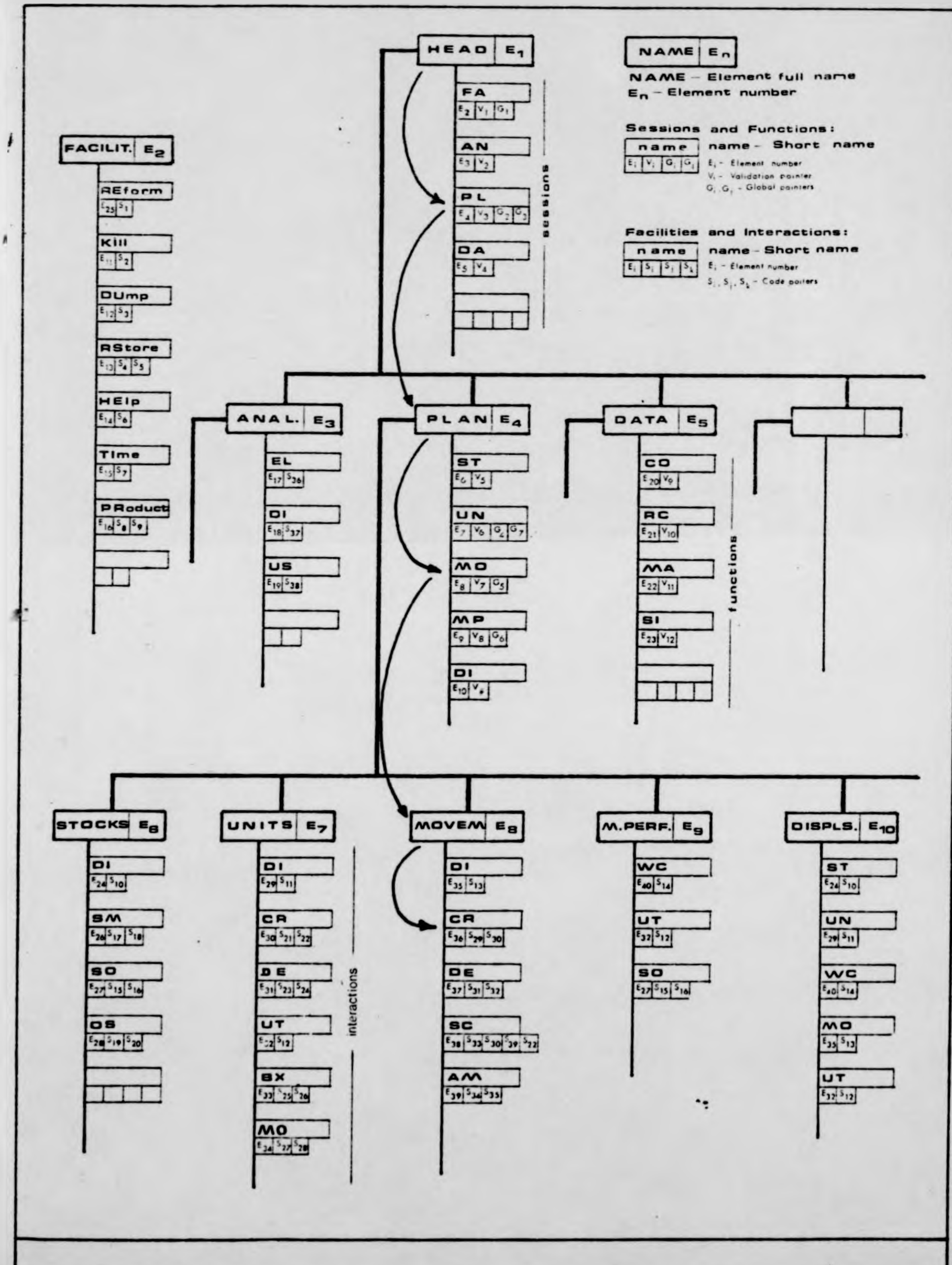
APPENDIX 5 - AN EXAMPLE OF THE USE OF THE TREE STRUCTURE

Let us assume that a planner is to start a planning session. After entering his usercode and password the system will let him choose one entry from the menu stored under the element HEAD. In the figure of page 254 the options are: FA (for facilities), AN (for analyst), PL (for planning) and DA (for data amendment).

If he chooses PL, either by keying in those characters or by pressing the appropriate function key, the system will execute three routines which are called via the use of pointers V3, G2 and G3.

V3 is a pointer to a software table that gives access to a validation subroutine. This subroutine checks in the data base whether this planner is entitled to plan, and returns a value that will abort the command or pass the control to the next pointer.

If the previous check is successful then G2 will imply the execution of a subroutine called from the software table with global routines. In this case the subroutine prompts the planner for the simulated time he is interested in, makes sure that the answer is valid and, if that is the case, stores the appropriate value as a global variable.


HEAD E_1
NAME E_n
NAME – Element full name
E_n – Element number
Sessions and Functions:
name – Short name
Facilities and Interactions:
name – Short name
sessions
functions
interactions
FA
AN
PL
DA
FACILIT. E_2
REform
Kill
DUmp
RStore
HElp
TIme
PRoduct
ANAL. E_3
EL
DI
US
PLAN E_4
ST
UN
MO
MP
DI
DATA E_5
CO
RC
MA
SI
STOCKS E_6
DI
SM
SO
OS
UNITS E_7
DI
CR
DE
UT
BX
MO
MOVEM E_8
DI
CR
DE
SC
AM
M.PERF. E_9
WC
UT
SO
DISPLS. E_{10}
ST
UN
WC
MO
UT

This means that at any time thereafter the simulated time will be the same until the planner changes it via the TIme facility (left of the figure of page 254).

The final pointer - G3 - is used in a similar way to enquire from the planner what is the code of the Works he wants to plan.

Once these three subroutines have been successfully executed the system enables the user to go down a level in the tree.This is made possible via the first pointer - E4 - which identifies the element PLAN and transfer the control to this element. This now gives the planner the possibility of choosing one of the available options: ST (for stocks), UN (for manufacturing unit), MO (for material movements), MP (for measures of performance) and DI (for displays).

If the planner chooses MO then the system will transfer the control to the validation software table that initiates the execution of subroutine V7 which makes sure that the current user is an authorized planner of movements in the current Works.

If that check is successful the control is then passed to the global software table for the execution of subroutine G5 that prompts the user for the code of the product whose movements he is interested to plan. After validating it the relevant value is stored as another global variable and the control on the tree is passed to the element MOVEM via the pointer E8.

This new element enables the user to actually start his planning activity by displaying (DI), creating (CR), deleting (DE), or amending (AM) materials movements and scheduling movements and production (SC).

If the planner chooses CR (create) the system will execute subroutines S29 and S30 from the software table where models are stored. As explained in chapter 7 S29 is the data input subroutine for the model and S30 is the routine that executes the model itself.