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Formal Problem Formulation in the Development of Decision Support Systems

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Problem formulation, the critical first stage of problem solving, affects the success of problem solving. Although the mission of Decision Support Systems (DSS) is to provide support for all phases of problem solving, in practice, DSS provides little support for problem formulation. Several studies illustrate that systems failure and negative impacts result from inadequate problem formulation. This paper aims to provide an understanding of the nature of problem formulation and the techniques for supporting problem formulation, and to establish a groundwork for further problem formulation research. The paper concludes with an argument that the use of formal problem formulation techniques early in the DSS development process may lead to the development of significantly better DSS.

1 Introduction

Problem formulation is the critical first stage of the problem solving process. It is the process of understanding a problem before generating solutions to it. The process involves specifying relevant variables and their cause-effect relationships in a problem domain (Ang *et al.* 1994). Figure 1 shows a model of problem formulation within problem solving (incomplete regarding post-formulation stages). As problem formulation is the front-end of problem solving, it affects the success of the subsequent phases of problem solving. Problem solving begins with the recognition of a problem's existence. This leads to the recursive and iterative phase of problem formulation. In the diagnosis stage, one attempts to understand a problem by gathering information and specifying relevant variables. A problem model is derived in the problem definition stage, where the problem is often stated in terms of a graphical model or textual representation.

This paper aims to provide a basis for extensive research on the use of formal problem formulation techniques early in the DSS development process. The paper discusses the importance of problem formulation to practitioners and researchers concerned with improving problem solving, and to the development of effective DSS. It also presents a discussion of the status of support for problem formulation in DSS development.

2 Importance of Problem Formulation

Problem formulation is important to both researchers and practitioners concerned with understanding and improving managerial problem solving (Mintzberg *et al.* 1976). The importance of problem formulation stems from its pervasiveness and centrality in the context of strategic problem solving, and its role in determining Type III error. Type III error is the "probability of having solved the wrong problem when one should have solved the right problem". It results in "correct" solutions, but to an incorrectly formulated problem (Raiffa 1968:12). An optimal answer to the wrong problem is likely to be worse than a sub-optimal answer to the real problem (Adams *et al.* 1987). Tversky and Kahneman (1981) demonstrate the crucial importance of designing meaningful decision frames and problem formulations in the context of applied decision analysis.

Problem formulation failure results in not only not solving the problem, but also causes significant time, money and energy to be wasted on implementing inappropriate solutions, and it may also cause serious adverse consequences, as histories of organizational disasters demonstrate (Miser 1993, Lyles 1987). The success and perhaps even survival of some organizations will depend on the managers' ability to perceive adverse business situations, formulate and solve the problem.

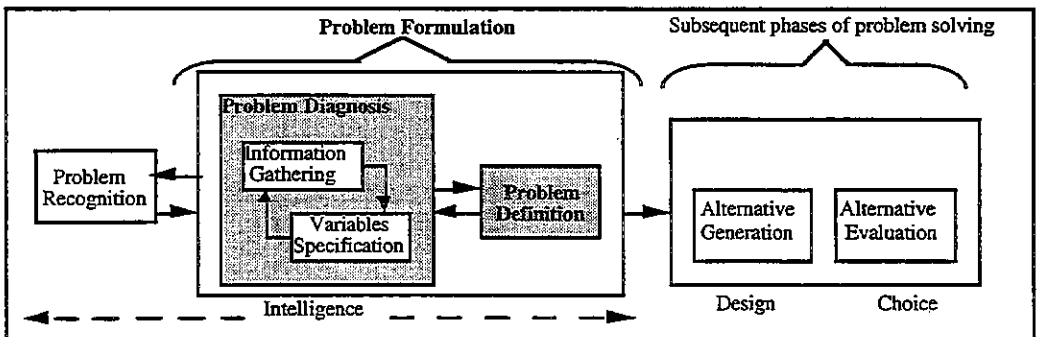

Figure 1. A Model of Problem Formulation within Problem Solving

Problem formulation research is also particularly important to developers of computerised and non-computerised problem solving aids, for these aids risk committing Type III error when an incorrectly formulated problem is taken as working input. Consultants (including DSS analysts) are often contacted during later stages to solve problem already "defined" by the client, which may actually be ill-defined or not defined. In situation where the client has not only "defined" the problem but also determined what the solution is, the consultants are brought in to help implement the solution. The later the consultant enters into the consulting process, the more likely the organization will commit a Type III error (Miser 1993).

Although the important need for problem formulation research has long been recognised, problem formulation research has only increased in recent years (Lyles 1987, Mintzberg *et al.* 1976). Problem formulation is largely an unaided process due to a lack of aids developed to support it. In the current state of research and practice in DSS and MS, virtually no computerised aid is available for supporting problem formulation. A more in depth discussion of the status of DSS support for problem formulation can be found in Ang *et al.* (1995).

While various general non-computerised techniques and concepts from cognitive psychology, organizational behaviour and MS are suggested to be applicable to problem formulation, very few aids have been developed specifically to support problem formulation. Table 1 shows a summary of most of these problem solving and problem formulation techniques, which may be used in the DSS development process for supporting problem formulation (a comprehensive discussion on several of these techniques can be found in Ang *et al.* 1995).

(Stabell 1987, Hirschheim *et al.* 1991, Stabell 1987). One can only expect a system to offer effective problem solving support if the problem the system is built to support is diagnosed and understood first. In two insightful independent surveys of DSS development and use, Meador *et al.* (1984) and Adams *et al.* (1987) found that users rated problem diagnosis as the most important but the least supported decision-making steps in DSS development. There are two ways by which the problem can be formulated. One is by developing DSS that have the capability to support problem formulation. The other option calls for a DSS development process that explicitly and formally performs problem formulation by the application of some decision aids, to arrive at a proper problem understanding before building a DSS to support the problem solving phases of alternative generation and choice. However, rarely any example of either option is observed in DSS research and practice (Ang *et al.* 1995).

DSS that do not support problem formulation implicitly assume that the decision problem has been correctly diagnosed. Hence, the tools of DSS for supporting evaluation and choice may be incorrectly applied or even applied to the wrong problem (Adams *et al.* 1987). This may lead to poor decision performance, not because incorrect solutions are derived, but because solutions to the wrong problem are sought. As such DSS, in supporting the solving of an incorrectly formulated problem, fails in its mission to support managers to be effective in their problem solving. Despite the importance of problem formulation, in both research and practice, DSS provides little support for problem formulation. Some experimental studies conducted to investigate support for problem formulation show that DSS offer little assistance for

Structured Methods	*Heuristic-based Methods*	*Thinking Heuristics*
1. Kepnor-Tregoe model	1. Problem expansion heuristic	1. Reverse thinking
2. Soft Systems Methodology	2. Problem reduction heuristic	2. Forward thinking
3. Strategic Options Development and Analysis	3. Divergent heuristic	3. Analogies
4. Robustness Analysis	4. Convergent heurictic	4. Deferment of judgement
5. Metagame Analysis	5. Reformulation	5. Assumptions
6. Hypergame Analysis	6. Decomposition	6. Divergent thinking
7. AIDA	7. Value-focused thinking	7. Convergent thinking
8. Nominal Group Technique	8. Use of objectives	8. Satisficing
9. Purpose Expansion	*Modelling Methods*	9. Intuition
10. Program Planning Model	1. Cognitive map	10. Creativity
11. Decision Analysis	2. Influence diagram	11. Objectivity
12. Strategic Assumptions Surfacing and Testing	3. Structural Modelling	*Conflict-based Methods*
Cognitive-based Aids	*Idea Generation Methods*	1. Devil's Advocacy
1. Reformulation	1. Brainstorming	2. Dialectical Inquiry
2. Decomposition	2. Synectics	*Expert Approach*
3. Taxonomy	3. Morphological Analysis	
4. Means-end Analysis	3. Delphi	
	4. Scenario Construction	

Table 1: Problem Solving Techniques and Concepts

3 DSS, DSS Development and Problem Formulation

It is well-recognised that problem formulation is important to the development of successful systems problem formulation (for a brief outline of the systems developed see Courtney and Paradice 1993).

A dominant trend in DSS research which may reduce the attention on problem formulation is the emphasis on the development of techniques and technology (Ang *et al.* 1994). Many DSS development methodologies subscribe to

an implementation orientation where rapid systems implementation is the focus, and overlooks the importance of systems analysis. The analyst repeatedly modifies the systems according to the manager's changing problem understanding. In this situation, the analyst may become an agent for user directed "incorrect change" as the analyst implements the changes required by the manager without questioning their validity and correctness. The end point of these methodologies is seen as the capture of the clients' requirements and the delivery of systems to match the client's requirements, whether or not the client's problems are solved. There is no clear idea of the content and direction of changes to be achieved, which can result in a "usability trap", which is the development of systems that are usable and used, but not very useful (Stabell 1987).

Although the implementation-oriented development approaches are espoused widely, there is little research on what is necessary to accomplish this radical change to the way conventional analysis is performed. There is also little emphasis on the process used to accomplish analysis or planning mechanisms to allow the system to evolve over time, and about the direction or content of changes to be achieved by the users, and there are also few guidelines about how to define and identify the content of changes. For example, how do the users pick the starting point to build the initial system from their perspective (Valusek 1988). Tversky and Kahneman (1981) have shown that, with relation to decision making, adjustment from a starting position is usually insufficient. The initial specification of the problem biases all future development.

4 Conclusion

While the mission of DSS is to provide support to all phases of problem solving to improve the effectiveness of managerial problem solving, DSS has not been very successful in supporting problem formulation. Many DSS development methodologies do not involve a formal and explicit problem formulation phase, as the emphasis is on systems implementation. As requirements specifications are derived from, and constantly evolve with problem understanding, wrong problem understanding may lead to the specification of wrong requirements. The possibility exists that the users could be engaged in a vicious cycle of problem misunderstanding and wrong requirement specification resulting from lack of problem formulation, which may render the evolutionary process ineffective or a waste of resources. Greater attention on the use of formal problem formulation techniques early in the life of a DSS may lead to the development of significantly better systems. This area is a priority in DSS research.

References

Ang, T.S.L., Arnott, D.R. and O'Donnell, P.A. "Problem Formulation and Decision Support Systems Development," *Proceedings in Australian Conference on Information Systems* (1), Monash University, Melbourne, 1994, pp. 719-739.

Ang, T.S.L., Arnott, D.R. and O'Donnell, P.A. "A Problem Formulation Method for Joint Problem Formulation Approach to Decision Support Systems Development," Paper accepted by *International Society for Decision Support Systems - Third International Conference*, Hong Kong, 22-23rd June, 1995.

Adams, D., Courtney, J.F. and Kasper, G.M. "Evaluation of DSS Modelling Software: A Methodology and some Results," *Proceedings of the Twentieth Hawaii International Conference on Systems Sciences*, Western Periodicals, North Hollywood, 1987.

Arinze, B. "Developing Decision Support Systems from a Model of the DSS/User Interface," in Doukidis, G.I, Land, F. and Miller, G. (eds). *Knowledge Based Management Support Systems*, Ellis Horwood, 1989.

Courtney, J.F. and Paradice, D.B. "Studies in Managerial Problem Formulation Systems," *Decision Support Systems* (9), 1993, pp. 413-423.

Hirschheim, R., Klein, H.K. and Newman, N. "Information Systems Development as a Social Action: Theoretical Perspective and Practice," *OMEGA* (19:6), 1991, pp. 587-608.

Lyles, M.A. "Defining Strategic Problems: Subjective Criteria of Executives," *Organization Studies* (8:3), 1987, pp. 263-280.

Meador, C.L., Guyote, M.J. and Keen, P.G.W. "Setting Priorities for DSS Development," *MIS Quarterly* (18:2), 1984, pp. 117-129.

Mintzberg, H., Raisinghani, D. and Theoret, A. "The Structure of 'Unstructured' Decision Processes," *Administrative Science Quarterly* (21:6), June 1976.

Miser, H.J. "The Easy Chair: Avoiding the Corrupting Lie of a Poorly Stated Problem," *Interfaces* (13:9), November-December 1993, pp. 114-119.

Raiffa, H. *Decision Analysis*. Mass: Addison-Wesley, California, 1968.

Stabell, C.B. "Decision Support Systems: Alternative Perspectives and Schools," *Decision Support Systems* (3), 1987, pp 243-251.

Tversky, A. and Kahneman, D. "The Framing of Decisions and the Psychology of Choice," *Sciences* (211), 1981, pp. 453-458.

Valusek, J.R. "Adaptive Design of DSSs: A User Perspective," *DSS-88 Transactions*, 1988.