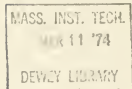


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ALFRED P. SLOAN SCHOOL OF MANAGEMENT

A DESCRIPTIVE MODEL  
OF DETAILED PROBLEM-FINDING BEHAVIOR

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January 1974

695-74

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This paper is greatly improved as a result of discussions with P.G.W. Keen. It is a pleasure to acknowledge his help and guidance.

This work was supported by Honeywell Information Systems Inc., 200 Smith Street, Waltham, Mass., 02154

This paper was produced with the assistance of the PDP-10 computer acquired by Project MAC, M.I.T. with a grant from the Advanced Research Projects Agency of the Department of Defence.

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## INTRODUCTION

Management science views the manager as a decision-maker and attempts to improve his performance by assisting the decision-making process. It is handicapped in this, however, by a lack of adequate models of decision-making. This paper presents a new model of detailed problem-finding, the isolation of specific problems from gross symptoms, based on a "frame-oriented" theory of human thought. Detailed problem-finding can be considered to be one component of the decision-making process but the model shows it to be inextricably linked with another component; the search for solutions.

Consider, for example, the manager who discovers that profits for the last quarter were lower than expected. Starting from such a problem, which may be recognized by any of the means described by Pounds (1), he will usually want to dig deeper and find problems at a more detailed level.

Detailed problem-finding involves a particular kind of thinking. It is concerned with problems that are generally familiar but are neither routine nor monumental. Typically, the manager's level of aspiration is not very important. These characteristics are, however, common to a wide range of problem situations and we hope that the model will provide insight into a large subset of managerial activity. Further, the model, after



development and validation, will provide guidelines for the design of knowledge-based and other decision-support-systems. The model will also verify that managers do not think in terms of equations but rather in terms of loose "frames" and that managerial models are useful because they assist in the creation and selection of more appropriate frames. This could have implications for the presentation of management science results and the interaction between managers and management scientists.

This paper describes a "frame-oriented" theory of human thinking and a model of detailed problem-finding based upon it. It also analyzes the problem-finding behavior of two subjects in an experimental setting in terms of this model. The final section of the paper outlines a proposed experimental study to extend the work documented here.

#### NEED FOR DETAILED PROBLEM-FINDING

More specifically, the detailed problem-finding process can be characterized as the analysis of a problem known to be soluble and for which the solution criteria are well known. Innovation is rarely required. Further, the detailed problem-finding process is hierarchical, i.e. if low profits are analyzed to result from high overheads then high overheads can be analyzed further for even more detailed causes. (There is considerable evidence of problem decomposition and hierarchical processes in problem-finding/problem-solving. See, for instance, Newell and



Simon (2).) Thus, starting from the gross symptoms the process creates a tree of problems. Each node of the tree is a problem and gives rise to secondary nodes that represent the set of sub-problems that contribute to it. Since the objective is to decide upon courses of action to alleviate the gross symptoms, the process stops with the isolation of problems that can be influenced directly by decision variables. Thus, the search for detailed problems is influenced by available solutions. Simon's (3) "intelligence" and "design" phases are, therefore, seen to be combined into a single process and the search for problems is intermixed with the search for solutions. The culmination of the process leaves the manager with not only a better understanding of the situation but also with a plan of action geared towards its resolution. Thus, problem-finding and problem-solving are seen to be closely related and, in fact, to form a single syndrome.

A problem branch may also terminate due to the inability of the manager to find more detailed problems or obtain the required information. In general, the exact set of detailed problems at which a tree will terminate will depend not only on the situation but on the manager's perception of it, the mental models and data he possesses to analyze it and the decision variables available to him. These factors will be explored in later sections of the paper.



## THE STRUCTURE OF MENTAL MODELS

Following Minsky (4), we postulate that people use frames to analyze situations and build mental representations of them. "When one encounters a new situation (or makes a substantial change in his view of a present problem) one selects from memory a substantial structure called a "Frame". This is an elaborate stereotype or "scenario" -- a remembered framework to be adapted to fit reality by changing details as necessary. The top levels of a Frame describe features and relations believed to be most important for the proposed scenario, while lower levels are to be filled in with the particular details of the present reality."

A frame is a structured format for representing a known situation -- like having an accident, being at a children's birthday party or a decline in sales volume. Attached to the structure are several kinds of information. Some of this information is about how to use (or fill) the frame. Some of it is about what can be expected next and some of it is about what to do if these expectations are not confirmed.

Each frame has a number of terminals for attaching specific information. These can be thought of as slots that can be filled by specific instances or by data. Each terminal has conditions which must be obeyed by the data or the instance that is to fill it. Thus the process of filling a frame consists of assigning data values or instances to each of its terminals. The act of filling terminals may, however, invoke frames for the terminal





situations and require further assignment of terminal values. Let us consider an example. Minsky quotes a fragment of a children's story:

There once was a Wolf who saw a Lamb drinking at the river and wanted an excuse to eat it. For that purpose, even though he himself was upstream, he accused the Lamb of stirring up the water and keeping him from drinking. (etc.)

If I were to relate the processes by which I form a mental representation of this story, I would say that reading the first sentence invokes the situation "Wolf wants to eat Lamb". In my mind, there are two frames associated with this situation. One is the real-life frame in which the Wolf catches, kills and eats the Lamb directly. The other is the story-book frame in which some ruse or stratagem is required to trick or trap the Lamb. The next sentence invalidates the real-life frame and confirms the story-book frame. Now, I try and fill the terminal of this frame which asks for the ruse or stratagem employed. To do this I invoke a ruse/stratagem frame, perhaps a very simple one since I realize this is a children's story, and try and fill its terminals with the specifics of the ruse.

Ultimately, I will have analyzed the story into a set of frames and terminal values (some of which may be filled by default) and created a mental model. This model is my "understanding" of the story and I can use it to answer questions about the story. In fact, the frames and terminals of this model will fit into a more general structure of frames and terminals in



my mind -- my model of the world -- and I will be able to use it to answer questions about the story that go beyond the facts contained in it. Such a question may be "Was the Wolf salivating?" and it will receive an affirmative answer because a default terminal value of the desire-to-eat frame is salivation.

An interesting confirmation of frame-oriented thinking comes from an experiment described by Mosher and Hornsby (5) in which children were asked to play a variation of "twenty questions" and determine the cause of an accident -- "A man is driving down the road in his car, the car goes off the road and hits a tree." Asked to describe his "system" for getting the answers an eleven-year-old responded:

Well, to eliminate big things quickly -- like was there anything wrong with the road -- was there anything wrong with the weather -- was there anything wrong with the car -- was there anything wrong with the person -- if there's something wrong with the person, you start from the bottom and go to the top.

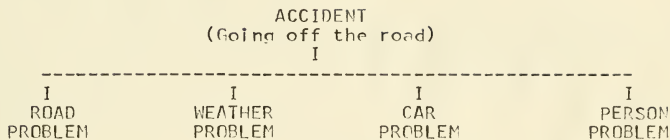
I group like all the things with weather, breaking (sic), then I group them smaller and smaller till I get to the point.

It seems clear that the description of the accident causes him to invoke an analysis frame that contains four potential causes -- the road, the weather, the car and the person. He intends to explore each of these until he finds the applicable one. Then, he plans to investigate it further.

The top level of his analysis frame may, therefore, be diagrammed as below. It is reasonable to postulate that he also has frames for each of the terminal causes which allow him to



carry the analysis further.



Thus, the potential causes in the frame are used to form the branches of the problem tree. The next level of the problem tree is built up by invoking and filling frames for the applicable problems.

#### PROCESSES IN SITUATION ANALYSIS AND COMPREHENSION

The above examples demonstrate the following processes in situation comprehension:

1. Invocation of frames from named concepts.
2. Selection between competing frames and frame validation.
3. Assignment of terminals.

A more complete model of situation comprehension can be described in terms of these processes as follows:

- A. Invoke frames.
- B. Select between competing frames and validate the selected frame.
- C. Attempt to fill each terminal of selected frame.

This may require the invocation and filling of frames



i.e. steps A. to F. This makes the process recursive.

D. Are all terminals filled?

If so, proceed to E.

If not, use characteristics of unfilled terminals to A.

E. Have all important facts been considered?

If so, proceed to F.

If not, use unaccounted facts to A.

F. Fit frames together to create an internal representation of the problem.

The above model implies the capability of invoking new frames that differ from given frames according to specified terminal characteristics. This is used in a feedback mechanism that matches the given situation against a structure built from the manager's mental frames. In certain cases, appropriate frames may not exist in the manager's mind and, within certain limitations, new frames may be created. Often, these are created incrementally from old frames or hierarachically from more powerful, general frames.

Frames are one type of mental construct that may arise from a concept such as "profit". There are frames that analyze the reasons for low and high profit and probably others for more specific situations. In addition, there are cause-effect relations that say "Profit increases if revenues increase." and "Profit decreases if costs increase." etc. Basically, frames are





used for situation comprehension; a complex form of what Bruner (6) calls "categorizing". Once this is accomplished and an internal representation created, it dictates the implications and the cause-effect relations to be used in drawing conclusions and the search for action alternatives.

The master "profit" concept that contains the relationship "Profit = Revenue - Cost" exists in the background and seems difficult to work with directly. Its utility lies in the creation of new frames and cause-effect relations. Some frames, such as low-profit, have loose evaluative judgements, such as "bad", associated with them.

#### PROCESSES IN DETAILED PROBLEM-FINDING

From the general model described above we can specialize the processes that will be used in detailed problem-finding. In general situation comprehension frames can take on a variety of structures e.g. a description frame for a person may contain his job, his hobbies, his age and his net worth as terminals. In detailed problem-finding the analysis frames consist of a list of sub-problem terminals each of which may or may not exist in the given situation.

- A. The manager will check whether a decision frame exists for the problem (sub-problem) i.e. if it can be solved directly. If so, he will attempt to assign terminals to it. These may be inputs to a decision rule.



- If this is successful the problem branch will terminate.
- B. If a decision frame does not exist or cannot be filled adequately he will invoke one or more analysis frames for the problem (sub-problem).
  - C. Validating questions will be asked to eliminate some of the analysis frames. Typically, these are yes/no questions.
  - D. Each analysis frame will contain potential sub-problems as terminals. The manager will attempt to fill these terminals i.e. test each sub-problem to see if it exists. Each sub-problem that exists will be analyzed further starting at A. Competing analysis frames may also be eliminated at this stage.
  - E. In rare cases alternative branches of the problem tree will be created and alternative analysis frames pursued further and eliminated on the basis of information obtained at a lower level.

Thus, each problem is either attacked directly by a decision frame or analyzed into sub-problems using its analysis frame. In practice, there is another important method of dealing with problem branches -- they may be held in abeyance. This may be done to gather more information or to consult someone who may have special knowledge i.e. bring his, more refined, frames to bear on the problem. Sub-problems may also be (temporarily) abandoned in favor of more promising branches. Thus, branches of the problem tree may end in a "wait" state. Finally, because of



cognitive limitations, the manager may forget or ignore certain sub-problems and/or terminals.

We have discussed how this model does not accord with Simon's (3). In fact, it is closer to the heuristic model advocated by Gore (7). Gore's model has a much broader scope but the early phases of frame invocation and validation in the above model seem to correspond to his "Development of the Orientation Set" and the later phases of hierarchical analysis of problems and the selection of decisions to the development of the "Evaluation Set".

The remainder of the paper will analyze how well the above model fits actual experimental protocols of detailed problem-finding. These protocols were taken to get some idea of the questions a knowledge-based management information system should be able to answer. They also provide, however, a great deal of information on problem-finding processes and we hope that this can be used to improve the design of knowledge-based decision-support-systems. We must remember, however, that, unlike these protocols, real-life problem-finding is not a one-shot process. Typically, the manager will go through a preliminary session and then repeat the process again using more detailed frames some of which may have been created as a result of earlier analyses. This iterative nature of problem-finding is underplayed in the experiment.



## VALIDATION OF THE MODEL

Appendix 1 presents the scenario of a problem setting. Managers were asked to arrive at a recommended course of action for this problem situation with the (simulated) assistance of a computer system that would answer their questions. The following pages present and analyze two protocols of problem-finding sessions. Figures 1. and 2. present the frame structures of the subjects as evidenced by the protocols.

Subject 1

Subject 1 has an M.B.A. from a prestigious school and about five years of management experience. He starts off with a clear idea of how to analyze the situation, but runs into some trouble when he finds that the system does not have the data he needs to fill the first terminal. He then proceeds to modify his frame to use the data available. Once this is done, he is able to fill terminals and analyze the problem quite rapidly.

Q. 1: I'd like to know the break-even quantity for each unit and are we manufacturing sufficiently in excess of it?

A. 1: We have direct cost for each unit, overheads for plants and head office. How would you like me to calculate break-even quantities?

The subject seems to plunge right into his low-profit frame and





since there is no way to attack low-profit directly, i.e. there is no decision frame for it, he asks a generalized question to determine if the sub-problem that makes up the first terminal of the analysis frame exists. The answer he receives makes him suspect that the frame may be inappropriate and so he asks a question to validate it.

Q. 2: Is each product made on a continuous or a batch process?

A. 2: Continuous process.

The answer convinces him that his general frame is correct but the production-below-break-even-volume terminal which he was attempting to test in question 1. is inappropriate. He has, therefore, to use more general concepts on cost and production to obtain a suitable replacement and check if production is large enough. He finds this in a low-profit-margin terminal for which he proceeds to validate and fill a frame immediately and a high-overhead-cost terminal which he tackles later.

Q. 3: Can you give me a plot of fixed cost vs. variable cost for each product?

A. 3: All fixed costs are in plant overhead. All variable costs are attributed to products.

Q. 4: Do you have margin of profit vs. product for most recent history?

A. 4: Yes, for the last five years.

Q. 5: How is profit margin calculated?



A. 5: Contribution margin is calculated as list price less direct cost if the plant is specified. List price less average cost if plant is not specified.

Q. 6: Can you compute profit margin vs. quantity for each product?

A. 6: Contribution margins are constant with quantity. (Explanation of contribution margin and overhead costing.)

Q. 7: Can you tell me actual margin with quoted prices for each product?

A. 7: Yes, do you want average quotation prices?

Questions 3,4,5,6,and 7 are concerned with creating and validating the low-profit-margin frame.

Q. 8: What is the distribution of sales vs. size of order?

A. 8: Do you mean vs. quotation quantity?

Q. 9: Yes

A. 9: (A pareto distribution is presented with a few customers being responsible for most of the sales.)

Question 8 is a validating question . Note that the answer he receives is in fact the answer to another question -- "What is the distribution of sales by customer?" -- but since the shape of the distribution is as expected he validates his frame and goes ahead!



Q. 10: What is the margin using the price of quotations for the largest five customers?

A. 10: Unit	101	102	103	104	105
Margin	\$5.20	4.80	3.75	10.50	6.38

Q. 11: What is the contribution margin for each product using list prices?

A. 11: Unit	101	102	103	104	105
Margin	\$6.00	5.50	4.00	12.00	7.00

Questions 10 and 11 attack another terminal of the low-profit frame i.e. "Are quotation prices too low?". Satisfied that this problem is not serious the subject proceeds to the testing of another sub-problem terminal in question 12.

Q. 12: Do you have cost data on actual cost vs. budget cost?

A. 12: Yes.

Question 13 is a generalized question, similar to question 1, designed to eliminate a sub-problem. Unfortunately, the system cannot answer it.

Q. 13: Have the margins been maintained?

A. 13: I don't know what you mean by "maintained".

Questions 14 and 15 are specific questions designed to test the high-manufacturing-cost and low-profit-margin sub-problems. The answers indicate that these sub-problems are not operative.

Q. 14: Can you calculate the difference between actual



and budgeted cost for each product?

A. 14:	Unit	101	102	103	104	105
	Actual	\$31.00	28.15	43.45	24.00	47.25
	Budget	\$30.00	27.00	41.00	23.00	47.00

Q. 15: What is the percentage deviation of budgeted to actual margin?

A. 15:	Unit	101	102	103	104	105
	Deviation	3%	4%	3%	4%	0.5%

Question 16 attacks another sub-problem -- high-overhead-cost.

The answer indicates that this is a problem and the subject holds it temporarily in abeyance.

Q. 16: Can you provide data on actual plant overheads and deviations from budget?

A. 16:	Plant	H.O.	1	2	3	4
	Actual					
	Deviation	23%	30%	27%	15%	19.8%

The percentage deviations were provided before the actual overheads and the subject proceeded to the next question before the latter were completed!

Question 17 eliminates a sub-problem that is a terminal of the high-manufacturing-cost frame. Since high-manufacturing-cost has been eliminated as a problem by the answer to question 14 there was no need to ask this question. In fact, it seems to have just





occured to the subject that the cost of lead must be a significant factor in the profitability of the company and he asks the question without placing the sub-problem in its proper frame. Looked at another way, the late realization of this problem seems to have elevated it to the highest operative frame.

Q. 17: How have my lead costs fluctuated over the year?

A. 17: Month    jan   feb   mar   apr   may   jun   jul   aug   sep   oct   nov   dec  
           \$/Ton    .16 .17 .17 .18 .20 .19 .19 .20 .19 .18 .17 .18

Questions 18 and 19 investigate sub-problem terminals of the high-overhead-cost frame.

Q. 18: How many days inventory do we have on hand?

A. 18: 33 days.

Q. 19: Who pays transportation cost for lead and for batteries?

A. 19: We do.

After question 19 has been answered, the subject says he knows enough about the situation but immediately realizes that he has missed a terminal of the low-profit frame. He asks a final question and eliminates it.

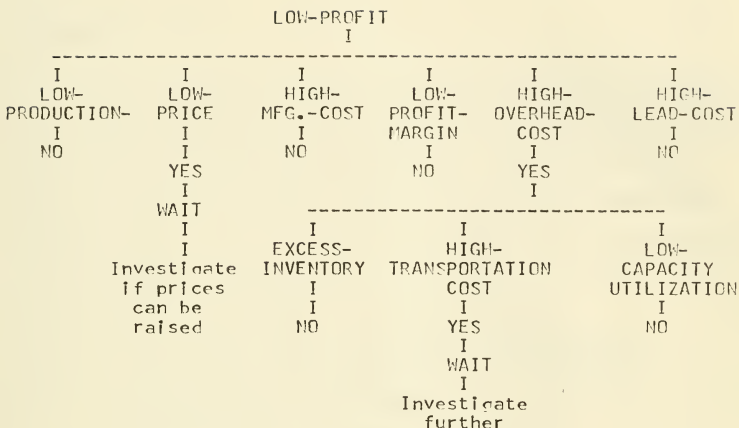
Q. 20: What percentage of plant capacity is being utilized?

A. 20: Plant	1	2	3	4
Utilization	90%	95%	98%	89%



The suggested action plan follows directly, without apparent thought. He feels quotation prices may be low and wants to investigate whether they could be raised. He feels incompetent to fill the low-quotation-price frame and decides to seek expert help. He wants to investigate this further. He muses about the high-management-salaries terminal of high-overhead-cost. He did not investigate this terminal. Perhaps he felt he knew the answer or perhaps it did not occur to him earlier.





## COMMENTS

1. HIGH-LEAD-COST should be a terminal of HIGH-MANUFACTURING-COST as discussed in the text.
2. LOW-CAPACITY-UTILIZATION occurs twice under different guises: once as LOW-PRODUCTION and once under its own name. The higher terminal may be a vestige of the BELOW-BREAK-EVEN terminal that was replaced due to data not being available.

FIGURE 1. FRAME STRUCTURE FOR SUBJECT 1



Subject 2

Subject 2 was also has an M.B.A. and two years of management experience. He asked two general, validating questions to start with. Then he got down to business and attacked the first terminal of the low-profit frame -- insufficient production planning time. This is tested and eliminated in questions 3 to 7 as not being significant.

Q. 1: What are the five basic battery types?

A. 1: They are different products with differences in performance and reliability.

Q. 2: Who is our major customer in the U.S.?

A. 2: Sears.

Q. 3: How long in advance do customers place their orders with us?

A. 3: I don't understand what you mean by "advance".

Q. 4: How long is the interval between the placing of a quotation and delivery to the customer?

A. 4: Would you like the average time between quotation and first delivery?

Q. 5: Yes.

A. 5: One month.

Q. 6: How long is this interval for our largest customer?

A. 6: Three months.

Q. 7: Is this the average interval over the last five years?





A. 7: Yes, it is.

Question 8 disposes of another sub-problem terminal. Answers to questions 9 to 11 indicate that high-transportation-cost may be a problem. The subject seems to feel that the problem can be attacked directly through a decision frame and does not invoke an analysis frame.

Q. 8: How often do branches order from a plant not closest to it?

A. 8: 2% of orders go to a plant not tied to a branch.

Q. 9: What percentage of product cost is allocated to transportation?

A. 9: 21%

Q. 10: Do you have budgeted transportation cost?

A. 10: Yes, we do.

Q. 11: What is the variance of between budgeted and actual transportation cost?

A. 11: 30% over budget for 1973

Questions 12 to 14 investigate the relationship between inventories, sales and production and their answers seem to indicate that this is not a problem.

Q. 12: Do you have a formula for inventory and production cycle rules?

A. 12: We do not have that data.



Q. 13: What has been our customer service level during the past year?

A. 13: Sorry, I don't know what you mean by "customer service level".

Q. 14: What percentage of customer orders have been shipped from stock?

A. 14: 65%

Question 15 investigates another sub-problem terminal and its answer indicates that overhead costs are a problem. The five questions that follow investigate the high-overhead-cost analysis frame and assign terminals.

Q. 15: By how much did overhead expenses increase over 1972?

A. 15: 35%

Q. 16: What percentage of sales comprised overhead expenses?

A. 16: Sorry, I don't understand the question.

Q. 17: What was our contribution margin in 1973?

A. 17: For which products would you like the contribution margin?

Q. 18: For the whole line.

A. 18: Unit	101	102	103	104	105
Budgeted Margin	\$6.00	5.50	4.00	12.00	7.00

Q. 19: What were the overhead expenses for each product?

A. 19: I have overheads by plant and head office.

Q. 20: What were these expenses by plant?



A. 20:	Plant	11.0.	1	2	3	4
	Overhead	\$				

The subject did not wait for question 20 to be answered but proceeded to questions 21 and 22 to investigate whether some products have too low a turnover and may profitably be dropped. This investigation proved abortive.

Q. 21: What was the percentage of each product as a percentage of total sales?

A. 21:	Unit	101	102	103	104	105
	Sales	10%	50%	20%	10%	10%

Q. 22: For 1972?

A. 22:	Unit	101	102	103	104	105
	Sales	15%	35%	10%	25%	25%

The following four questions, similarly, investigate whether inventories are too high. This too proves not to be the case.

Q. 23: Do you have any information on the balance sheet?

A. 23: No, I don't have the balance sheet.

Q. 24: What percentage of my assets are inventory?

A. 24: 30%

Q. 25: Can you break this up by product?

A. 25:	Unit	101	102	103	104	105
	Assets	1%	5%	10%	8%	6%



The subject says he's finished, but goes on to ask a final question that seems to fill the last sub-problem terminal of the low-profit frame.

Q. 26: What was the turnover by product?

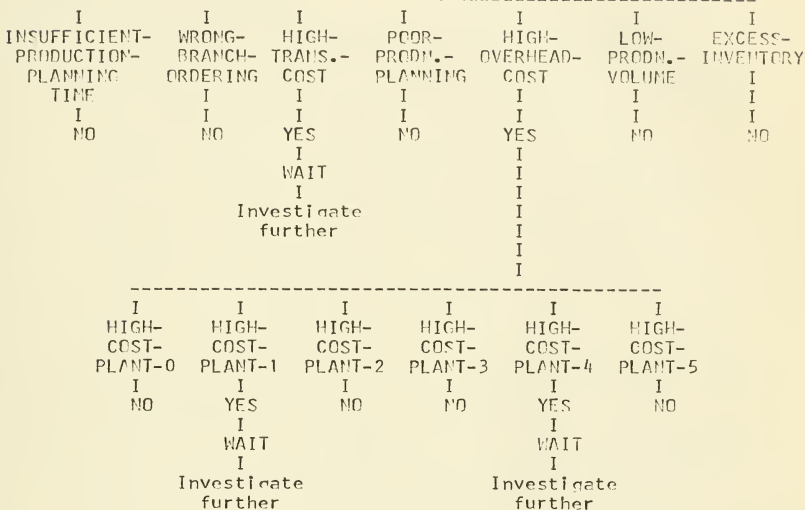
A. 26: Unit	101	102	103	104	105
Turnover	10.3	12.7	9.3	8.4	5.2

The subject concludes, having run out of frames and terminals. Again, his policy recommendations follow instantaneously -- he would like to control transportation costs and overhead, perhaps also change the product mix and control inventories. The problem analysis is based upon sub-problems selected from among those supplied by the analysis frames which are perceived to exist in this particular situation and for whom decision frames exist and can be filled.





LOW-PROFIT  
I



## COMMENTS

1. The EXCESS-INVENTORY terminal is attached to the LOW-PROFIT frame for Subject 2 and to the HIGH-OVERHEAD-COST frame for Subject 1.

FIGURE 2. FRAME STRUCTURE FOR SUBJECT 2



## COMMENTS ON THE PROTOCOLS

1. The structure of the frames seem to be very different for the two subjects. This is strikingly true of the low-profit frame. Subject 2 has a much wider frame with specific terminals. Subject 1 has fewer, more general terminals. Note, in particular, the position of the excess-inventory terminal. Subject 1 analyzes excess-inventories as a contribution to high-overhead-cost while Subject feels it contributes directly to low-profit. (He may be an inventory control expert !) This illustrates a fundamental difference in their underlying conceptual structures.
2. Certain terminal values seem to be filled by default and subjects do not seem to bother to ask questions to assign them. For example, they know that management salaries go up every year.
3. As the subjects were asked to assume they were asking questions of a computer system they may have tended to ask more specific questions than they would a human being. Also, some of their general questions could not be answered so they were forced to ask specific questions instead.
4. The protocols indicate that managers ask general questions (using words like "sufficient" and "maintained") to try and eliminate a sub-problem. If it cannot be eliminated they ask more specific questions to assign terminal values.



5. Most of the questions that attempt to eliminate a sub-problem terminal ask for a piece of data in relation to a norm, plan, standard or history. Often the relationship is a loose one (expressed by words like "sufficient" and "maintained") such as whether the two numbers are of about the same magnitude or whether one is greater or lesser than the other. This corresponds to the fact that the terminals are named "low-profit", "high-inventories", etc. In fact, subject 1 disregarded part of the answer to question 16 and subject 2 disregarded the answer to question 20 since these were expected to provide absolute numbers. The few single numbers that seem to be significant, such as sales, invoke a magnitude frame, such as "small-company".
6. We notice that the processes of validation, frame creation and terminal assignment do not take place in "logical" sequence. In fact, terminals are left hanging as higher level terminals are filled, frames created, etc. This suggests that all elements of a frame are not retrieved at the same time, but seem to occur in some order of importance. Further, the subjects seem to have special processes that bring in the next terminal and check if all terminals have been filled and if all the given facts are accounted for.
7. Since this was the first pass at the problem a number of branches tended to be left in the "wait" state due to



insufficient information or because the subject felt them to be less important relative to other branches. We expect that this will be found to be typical of early problem-finding attempts.

#### CONCLUSIONS AND OTHER OBSERVATIONS

Thus, we find that the model of detailed problem-finding described above fits the protocols quite well. This is only a preliminary test however and the model must await further development and testing before it can be useful in the design of decision-support systems.

Validating Questions One conclusion does emerge, however. Most yes/no questions are asked to validate frames. If answered in the affirmative they are followed by a question asking for data to eliminate a sub-problem or assign terminals in an analysis frame. Thus, whenever a yes/no question has to be answered in the affirmative, the support system should attempt to supply some of the information that may be relevant to the analysis frame that will be invoked. In some cases this can be done quite easily. For example, the question "Do you have profit margin by product?" should be answered by a listing of the margins for all products during the last year rather than by a mere "Yes, we do".

Generality of the Model We maintain that the process of detailed problem-finding is very similar from person to person.





Differences in problem-finding/problem-solving style and effectiveness can be attributed to differences in the number and structure of frames for the situation at hand. Structural differences will determine the importance of various factors in the analysis and the order in which they will be considered. See comment 1. above. Further, individual cognitive capacities dictate how many frames and terminals will be "overlooked"

An expert may have 1000 detailed frames for every aspect of a situation. Someone with less experience may have only fifteen or twenty. The orientation process for naive users may, therefore, involve a considerable amount of frame creation while an expert may require only validation and would, therefore, be much quicker. This may account for the expert's ability to "get right to the heart of the matter". Thus, the performance of the novice will always be worse; he may be unable to analyze the problem due to inadequate frames and if he tries to develop them he may strain his cognitive capacity and degrade his performance in other tasks.

Yes-No Questions and Scanning Strategies Yes-no questions seem to be associated with what Bruner (6) called scanning strategies i.e., the testing of hypotheses that the subject has in mind. The converse, focussing, would seem to correspond to the building up of frames from observed properties. Bruner recognizes that "the task of search imposed upon the user of ... focussing may become rather severe" and this is even more true in



situation analysis than in Bruner's concept attainment tasks. Thus, frames provide us with alternate hypotheses to be scanned and we seem to create frames only when absolutely necessary.

Problem-Finding Style On the simplest level, a manager may decide to fill all the terminals of a problem frame before investigating the next lower level or he may investigate each sub-problem as it arises. He may decide to leave some branches in the "wait" state while he investigates more promising branches. Some of these decisions will be taken according to his a priori evaluation of the importance of various sub-problems while others may be functions of personality variables. Bruner (6) found that the different concept attainment strategies employed by his subjects were consistent features of their personality. This may also be true of problem-finding/problem-solving strategies.

#### FURTHER EXPERIMENTAL INVESTIGATION

An experimental study is being planned to further validate the model and investigate some properties of the frame-structures and the problem-finding styles of different managers. A number of subjects will be asked to analyze a problem scenario similar to the one presented in the Appendix under similar circumstances. In addition, each subject may be asked to take some psychological tests, such as Kelly's Role Repertory Test (8), and answer some personal questions.



The protocols would then be analyzed to determine the frame-structures and some indicators of problem-finding style for each subject. Validation of the model will underscore the utility of knowledge-based systems that answer questions or in other ways support the processes of frame-validation and terminal-filling. The function of decision-support-systems in problem analysis could then be defined as the providing of information to support the component processes of the model described in this paper as well as the relief of strain on cognitive capacity and short-term memory.

The study may also lead to the elaboration of the model. Better understanding of the problem-solving/problem-finding process would, of course, lead to improved guidelines for the design of knowledge-based decision-support-systems.

Studies of a large number of frame-structures may show that managers have only a few frames for common problems like "low-profit". If this is true, the frame-structures can be incorporated into the knowledge-based system and, after a few exploratory questions, the system will be able to anticipate the manager's problem-finding process and thereby be of much greater assistance. It will, for example, not allow him to overlook any frames or terminals. In addition, by anticipating requests the system may be able to increase its own efficiency.

The experimental data may also show that frame-structures and problem-finding styles are correlated with personality



determinants: be they conceptual constructs or educational background. This would allow decision-support-systems to be tailored to individual styles and to different types of managers.





## APPENDIX 1

## A PROBLEM SCENARIO FOR TESTING THE PROPOSED MODEL

Globe Union is an established manufacturer of lead batteries with head offices located in the mid-west. It has four plants where the actual manufacturing is carried out. These are spread out over the continental United States.

Globe Union manufactures fifteen variations of five basic battery types for various purposes. Each distinct variety of battery is identified by a unit number.

Globe Union sells mainly in bulk to twenty major customers located all over the United States. Customers place long range "quotations" with Globe Union for specified quantities of a certain unit number. Globe Union supplies against these quotations on the receipt of orders from customer branches. Each branch is expected to order from a certain plant, usually the one closest to it. In general, a given plant supplies customer branches in a set of states surrounding it.

Each plant manufactures all the types of units it supplies. The product is heavy and transportation can make up a large proportion of product cost. Only in rare cases of shortages and lack of facilities to manufacture a specialized unit will batteries be supplied from other than the closest plant.

Plants manufacture according to certain inventory and



production cycle rules. They are expected to meet budgets on direct costs and overheads. Performance against budget as well as customer service are the main criteria for plant manager evaluation. Plants are not run as profit centers because prices on quotations are negotiated by the head office even though standard price lists exist.

It is February 1974 and as President of Globe Union you are a little concerned at the results for 1973 that you have just received. Despite a 20% increase in sales over 1972, profits decreased by 1%.

You feel that the decrease in profit could be due to a combination of three causes: increase in overhead expenses, decrease in contribution margins, (difference between selling price and direct cost) or a change in product mix toward less profitable units. You would like to investigate the cause of the decreased profit using the Globe Union Information System. Depending on what you find, you will take a decision to enforce strict control on the pricing of quotations, review and reset list prices which are supposed to serve as guidelines for quotation pricing, or introduce a cost control program. The purpose of this exercise is to determine which decisions are appropriate under the circumstances.

As sales growth has been very healthy, you are inclined to disregard competitive actions in your analysis. You also assume that the cost and other data contained in the system is accurate.



The following two pages contain a description of the Globe Union Information System.



The following two pages contain a description of the Globe Union Information System.





APPENDIX 1 (Continued)  
GLOBE UNION INFORMATION SYSTEM

The Globe Union Information System contains data on sales, costs, prices and other indicators of Globe Union's operations during the last five years. It is capable of answering questions posed to it in simple English about the contents of the database and functions of these contents such as "profit" or "average price for unit 103". In addition, the system is capable of answering questions about itself, i.e. it can enumerate the data items it contains, explain the procedures embedded in the functions, etc.

The system can be queried much as one would use an assistant to answer questions, prepare reports, etc. It will provide appropriate responses to requests it does not understand or cannot reply to. A typical dialog with the system may be:

Q: What data do you have regarding unit costs?

A: I have actual and budgeted costs for each unit at each plant.

Q: What was the cost of unit 103 in plant 4?

A: \$78.23



Q: What was the list price for unit 103?

A: \$81.00

Q: Do you have a model for contribution margin?

A: Yes.

Q: How does it work?

A: It computes the list (standard) price minus actual cost for the given unit.

Q: What was the contribution for unit 113 at plant 2?

A: \$9.20

Q: What was the contribution for unit 81?

A: \$0.30

Q: What was the avreage cost of unit 81?

A: Sorry, I don't know the word "avreage".

Q: What was the average cost for unit 81?

A: \$78.67

Q: What was the average budneted cost for unit 81?

A: \$76.00



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