Qualitative Analysis of Financial Models

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Abstract

Financial modeling is generally founded on the premise that financial managers and fiscal policy makers operate "by the numbers". Indeed, this assumption is so deeply ingrained as to shape much of spreadsheet software to conform with accounting practices. It is the thesis of this paper that there is a qualitative side to financial decision making which translates the mathematical expressions of accounting into the commonsense language of managers.

The research reported in this paper examines the relationships between conventional financial models and the linguistic representations given them by financial managers. The research takes the form of a STELLA model of corporate finance with a HYPERCARD interface. In the interface, the authors employ the propositions of fuzzy set theory to incorporate such linguistic hedges as "too high", "way out of line", and others found in common management speech. The resulting model assists financial managers in linking their qualitative judgments to the numerical parameters of a typical corporate financial model. As the model runs, it allows managers to adjust their financial policies on a quarterly time scale - while recording each person's decisions as related to model performance.

The authors report the decision making practices of a sample of corporate executives as a set of qualitative propositions. There take the form of statements like, "If market share is falling rapidly, and leverage is fairly high, product line expansion is required." Such propositions take on a dual role; they can be translated into average numerical values to control a STELLA simulation - or they can be simulated as a purely qualitative model.

The significance of the qualitative thesis lies in the new perspective it offers to those who study and practice financial management. The thesis offers a clear connection between the arcane world of the analyst or accountant and the complex environment of the working manager. It fosters a dialog across professional boundaries that may well result in more accurate models and more effective practitioners.

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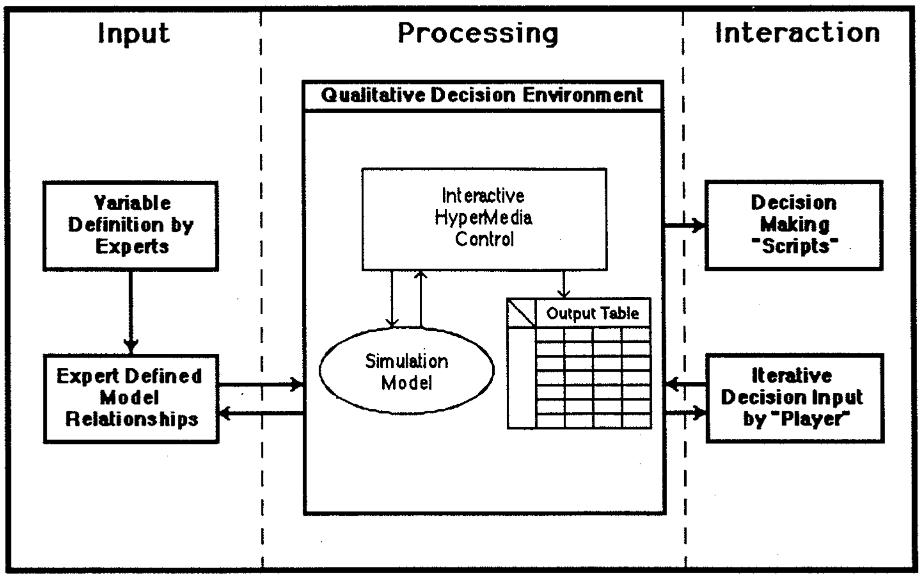
Introduction

Figure 1 provides an overview of the structure and operation of the qualitative decision-making model upon which this study is based. Three primary activities define the functioning of the model: input, processing and interaction. Accordingly, the results of this research are organized into three sections: Decision Model Parameters, Qualitative Decision Processing Environment, and Qualitative Decision Making.

Figure 1
Model Design Flow Diagram



Section one (input) details the definition, by experts, of the financial risk parameters. The primary "inputs" to the model are expert defined performance and decision control model variables. The second section (processing) presents the process by which the experts' judgments are translated into a financial simulation. Processing within the model entails quantitative-qualitative translations, funds flow simulation and data collection. The third and final section (interaction) provides the outcomes of the users' qualitative decision-making sessions. Users interact with the model by making decisions in qualitative terms in response to qualitatively translated results.

Decision Model Parameters

The first stage in the formulation of the decision making environment involves identification and definition of the primary model parameters. Parameters in this model were derived from the judgments of experts. In a two-step process, seven experts provided the baseline information used to "inform" the model. Step one involved personal interviews with each of the experts to identify financial performance indicators and decision control variables. In the second step experts defined qualitative levels for the selected performance indicators and translated the impact of decision control variables into qualitative terms.

Expert Determination of Primary Performance Indicators

A series of open-ended interview questions were asked of experts to determine the indicators of financial performance that the experts judged to be the most useful. Specifically, each expert was asked to identify the five "best" indicators of the performance of a firm. Experts were asked to explain the importance of each indicator mentioned and, if possible, how each should be measured. All but one of the indicators mentioned were expressed in measurable terms utilizing readily available financial statement information. The sole exception was "Quality of Management". When asked how quality of management should/could be measured, the expert said that "it was something inferred from a variety of other indicators", but "did not really know how to measure it directly."

Expert Determination of Primary Financial Decision Control Variables

In addition to being the source of the performance indicators, experts were questioned in order to define decision control variables for the model. Experts were asked to identify those variables that a manager could "manipulate to effect an individual firm's performance." As before, experts were asked to explain the importance of each of these potential "control" variables and how each should be measured. Most of the variables mentioned by the experts were more general in nature than their performance indicator responses. Follow-up questions intended to determine more explicit responses yielded somewhat vague answers, such as, "it depends . . .", "I'm not sure . . .", etc. This lack of certainty may, in part, reflect a higher degree of complexity when dealing with potential "causes".

As previously discussed, the decision control variables identified by the experts lacked the specificity necessary to be called variables. The three potential variables which emerged for the original list of ten suffer the same shortcoming. By piecing together the experts' comments somewhat clearer definitions were derived. Some vagueness, however, remained. Given their eventual qualitative use in the decision model, some "openness" is merited. The "final three" decision control variables are "Adjust Credit Policy", "Adjust Leverage Level", and "Adjust Product Mix."

The experts were asked to identify the factors that "contribute most to an individual firm's risk." As before, they were asked to explain the significance of each factor and how it should be measured. Similar to the decision control variable replies, all of the initial responses were general. To assess the value of these risk factors, it is important to remember that the primary use of this information was to characterize experts' understanding of firm risk and the manner in which it influences firm performance. The resulting information was used to "weight" the influence of the decision control variables on the performance indicators. Three categories of risk for the firm emerged: the direction and leadership of the firm's Management, the firm's effectiveness within its Market, and the firm's ability to meet fixed interest obligations (Leverage).

Expert Determination of Qualitative Levels and Variable Relationships

Once the performance indicators and decision control variables were identified and defined, qualitative levels needed to be determined. Two sets of on-screen HYPERCARD devices were developed to facilitate the definition of these qualitative levels. The first set of devices was used to translate each of the four performance indicators into three qualitative levels and to assign qualitative risk values to each of the levels. A second set of on-screen devices was used to define the qualitative impact of the three decision control variables upon each of the four performance indicators. Samples of the two types of on-screen devices along with the results of the qualitative assignments are provided below.

Figure 2 depicts one of the performance indicator translation screens used by the experts to define the qualitative levels for the performance indicators. Each of the seven experts was asked to define **T**arget, **H**igh and **L**ow qualitative levels for each of the four performance indicators by positioning the "sliding pointers".

This particular screen shows the actual positions for the firm's Current Ratio, selected by one of the experts. As can be seen from the diagram, this expert judged that a current ratio of 1.80 should be the **T**arget for this firm. Accordingly, **H**igh and **L**ow current ratios were judged to be about 2.50 and 0.80 respectively. The positions of the other pointers indicate that this expert believed that when the firm's Current Ratio is around 1.80 (**T**arget) the impact on the firm's risk

Figure 3 shows the experts' qualitative judgments of the firm's Current Ratio. The seven lighter pairs of lines exhibit each of the seven individual expert's opinions. The darker pair of lines represents an aggregation (median value) of all seven sets of judgments. The horizontal location of the point formed by top of each pair of lines indicates the value judged to be the **T**arget level for the firm's Current Ratio. The horizontal location of the bottoms of each of the line pairs indicates the values the **L**ow (on the left) and **H**igh (on the right) current ratio levels. The vertical scale provides the degree of membership (fuzzy scale from 0 to 1) for the **T**arget level. That is, at the location of the top point, the membership value for the target level is 1.0. As you move above or below this point horizontally, the degree of membership declines. The degree of membership for the target level is 0 at the bottoms of the line pairs. At the bottom left point the degree of membership for the **L**ow level is 1.0 and at the bottom right point the degree of membership for the **H**igh level is 1.0.

While the primary interest is in the underlying numbers, this diagram does provide some indication of the level of agreement in the experts' judgments. While agreement is by no means necessary, the higher the apparent level of agreement, the greater the face validity of the defined qualitative levels. Given the positions of the pairs of lines, there appears to be reasonable agreement between five of the seven experts. Review of the corresponding diagrams for the other three performance indicators yields similar results regarding the face validity of the experts' qualitative level definitions.

After the experts established the qualitative levels for each of the performance indicators, they were directed to qualitatively define the impact of the decision control variables. Using the second set of on-screen selection devices, like the one presented in figure 4, experts were instructed to position sliding pointers to indicate their judgments regarding the effect of a change in a particular control variable upon the performance indicators. One screen for each of the three decision variables was presented to the experts. Two changes for each of the decision control variables were defined, a marginal ("small incremental") **I**ncrease and a marginal ("small incremental") **D**ecrease. By adjusting the position of each of these pointers, the experts defined the qualitative impact of change on each performance indicator.

Figure 4
Qualitative Relationship Screen

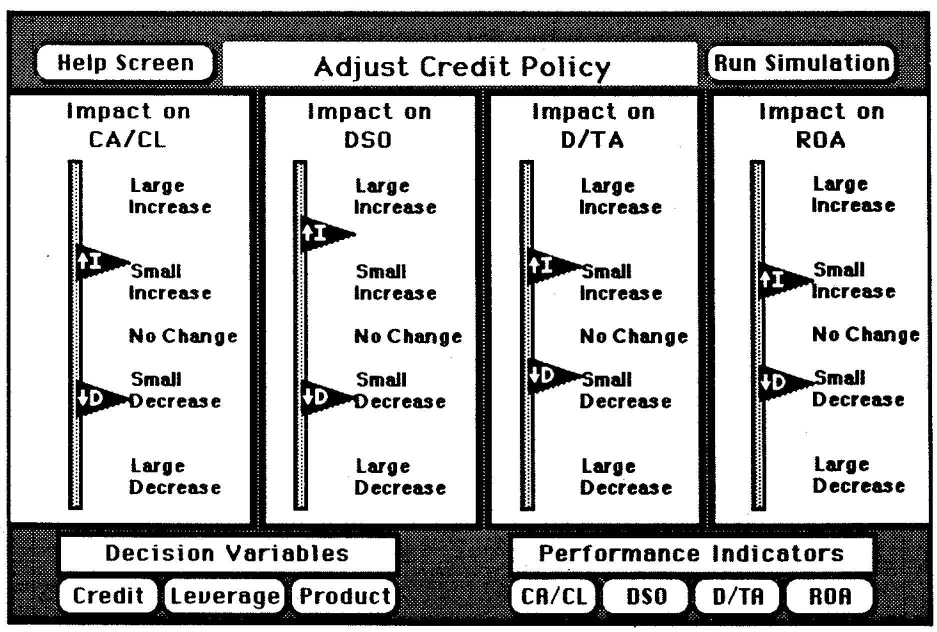


Figure 4 is a copy of the screen used by an expert to indicate judgments regarding the impact of **I**ncreases and **D**ecreases in Credit Policy on the four performance indicators. The positions of the sliding pointers indicate that this particular expert thought that a small **I**ncrease in credit policy would result in a slightly more than small increase in the current ratio, a slightly less than large increase in Days Sales Outstanding, a slightly more than small increase in debt to total assets and a small increase in return on total assets. A small **D**ecrease in credit policy would result in a small decrease in each of the four performance indicators.

As was the case for the performance indicator definition screens, the relative location of the pointers were translated into a numerical scale (0 to 1) and recorded in the database. Again, these numerical values provided the necessary coordinates to graph the experts' judgments (Figure 5). In this particular case, the seven experts' individual and median judgments regarding the impact of **I**ncreases (upper portion) and **D**ecreases (lower portion) in a firm's credit policy on the four performance indicators are plotted.

Qualitative Decision Processing Environment

The second stage in the development of the qualitative decision model was the design of the decision processing environment. This development was divided into three steps. Step one involved modifying the financial simulation model to include the variables defined by the experts. The second step focused on the derivation of membership functions for the qualitative levels defined by the experts. Step three involved developing procedures for translating qualitative inputs and outputs. The results of each of these steps are provided in the following three sections.

Financial Decision Simulation Model

Development of the financial behavior simulation algorithm was accomplished using the **STELLA** simulation software. The writers of this software include a variety of "generic process" templates. One of these templates is a simulation of a basic financial funds flow process. This particular template provided the basic architecture for the simulation model developed here. While the template saved having to design the simulation from "scratch", a variety of modifications were necessary to accommodate the particulars of this study. Specifically, the performance variables and decision control variables identified by the experts were built into the template. The manner in which a number of the variables already included in the template were related to one another also required modification. Finally, the specifics of the problem scenario had to built into the model.

The first modifications to the financial template involved adding a variety of variables. Two types of variables were added to the simulation. The first type was the performance indicator and decision control variables defined by the experts: **CA/CL, DSO, D/TA, ROA, Credit Adjust, Leverage Adjust** and **Mix Adjust**. To properly define the performance indicator and decision control variables a second type was needed. Those included: **Interest Expense, Change Current, Change Days, Change Debt** and **Change Return**. Beyond the addition of these new variables, a number of the existing simulation variables required some modification.

The three Decision Control Variables influence the model in two ways: primary (direct) impact and indirect influences. A decision variable's primary impact is relatively easy to visualize. Certain sets of stocks and flows constitute model areas which would be directly effected by changes in one or more of the Decision Variables.

The primary impact of a Decision Variable, however, is only the beginning of the story. In contrast to the reasonably straight forward identification of a Decision Variable's primary impact, the indirect influences are far more difficult to visualize. One of the greatest benefits of system dynamics is its capacity for capturing the richness of the interrelationships between model variables. A price, however, is paid for this benefit. Without a dynamic computer model, following the behavior of more than a few variables is virtually impossible.

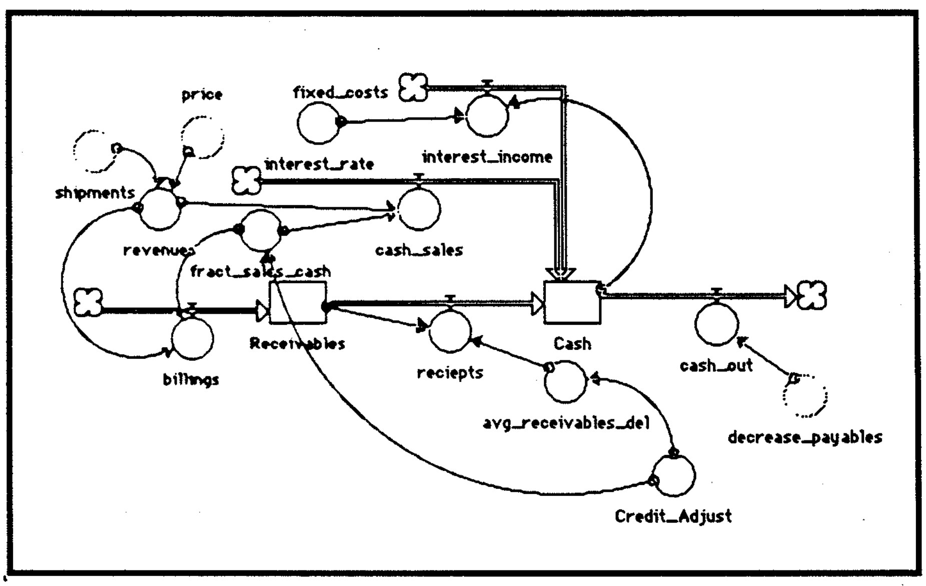
Fortunately, computer simulation affords the capability of keeping "track" of the complex interrelationships between the large number of variables of which this model is built. A graphic device called a "system map" provides a particularly effective way to "see" how the various model variables are linked together. The control variables have a direct impact on the funds flow simulation model in five distinct locations within the system map. In each of these locations, one or more of the control variables directly influenced model inflows and outflows and at least one stock variable. These stock and flow variables, in turn, are linked to at least one of the four performance indicators.

A sample portion of the system map which directly involves the decision control variables and the performance indicators is presented in Figures 5. By examining this diagram an improved understanding of how the variables were built into the model may be gained.

Credit policy effects the flow of funds through a firm in a variety of ways. The most significant impact is on a firm's levels of cash and accounts receivable. More specifically, a firm's use of credit influences its cash sales and receipts which, in turn, effect cash and receivables levels. Figure 5 provides a diagram of the manner in which the control variable **Credit Adjust** can have this influence on the firm. In this diagram, the boxes represent model stocks and circles represent flows and converters. The lines connecting one variable to another indicate a defined relationship between those variables.

Based on the judgments of experts, the firm's credit policy will influence whether or not their customers will make purchases with cash or by credit and ,if by credit, the length of time the credit obligation is outstanding. Depending on how favorably the credit terms are viewed, the percent of the firm's sales which are made for cash will be higher or lower. As the firm expands its credit terms and conditions, the length of time an account receivable is outstanding will increase.

Figure 5
Decision Control Variable Impact: Credit Policy



As shown in the diagram, **Credit Adjust** is linked directly to the fraction of sales for cash (fract_sales_cash) and the average receivables delay (avg_receivables_del). If the firm opts to expand its credit, the fraction of the firm's sales which are made for cash will decline which will reduce the firm's rate of cash sales. The rate of cash sales is an inflow to Cash, therefore, a decrease in this rate will cause a decrease in Cash. The expansion in credit will also cause the average receivables delay to increase which will slow down the firm's receipts. Since receipts is an outflow variable from Receivables and an inflow variable to Cash, the decline in receipts will result in an initial increase in Receivables and a further decrease in Cash. If the firm opts to reduce its available credit the effects on Cash and Receivables are reversed; Cash increases and Receivables decline.

Qualitative Membership Functions

The second step in the formulation of the decision processing environment was the determination of the qualitative ranges for each of the expert defined performance indicators. The individual judgments by the experts were aggregated by calculating the median value for each indicator. Each of these median values was then used to construct the "membership" function for the corresponding performance indicator.

Figure 6
Aggregate Expert Membership Function for Current Ratio

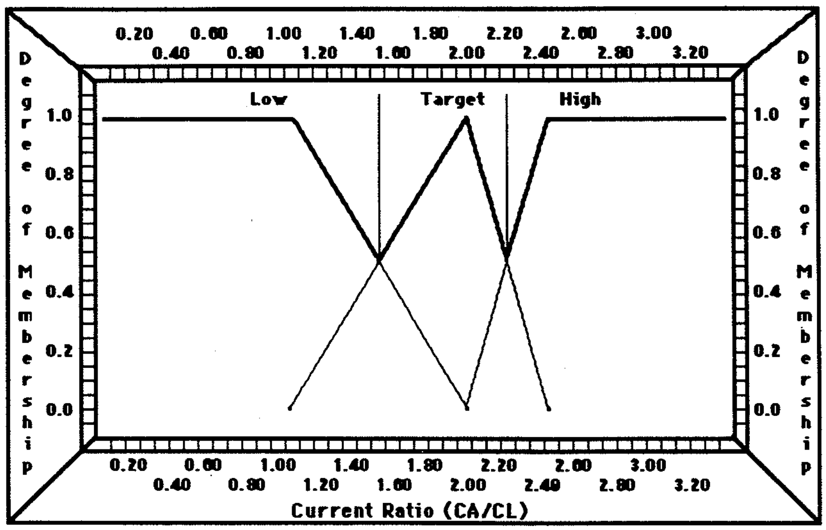


Figure 6 exhibits the membership function for the current ratio. By connecting the median Target, High and Low values for the current ratio, three sets of lines were drawn. These lines were then placed on the same graph. The point at which the qualitative level changes from Low to Target and from Target to High was defined by the point where the three sets of lines intersected one another. The portion of the line sets shown in bold show the qualitative levels which resulted and their corresponding degree of membership. Two vertical lines were placed on the graph to indicate the position on the horizontal scale where the change in qualitative levels occurs. In the case of the current ratio, a ratio value of about 1.5 or less was defined to be Low. Current ratio values between 1.5 and 2.2 were defined to be Target level. And, values of about 2.2 or more were defined to High.

Similar membership function diagrams were constructed for each of the performance indicators. From these membership functions the ranges that correspond with the three qualitative levels of the underlying ratios were derived.

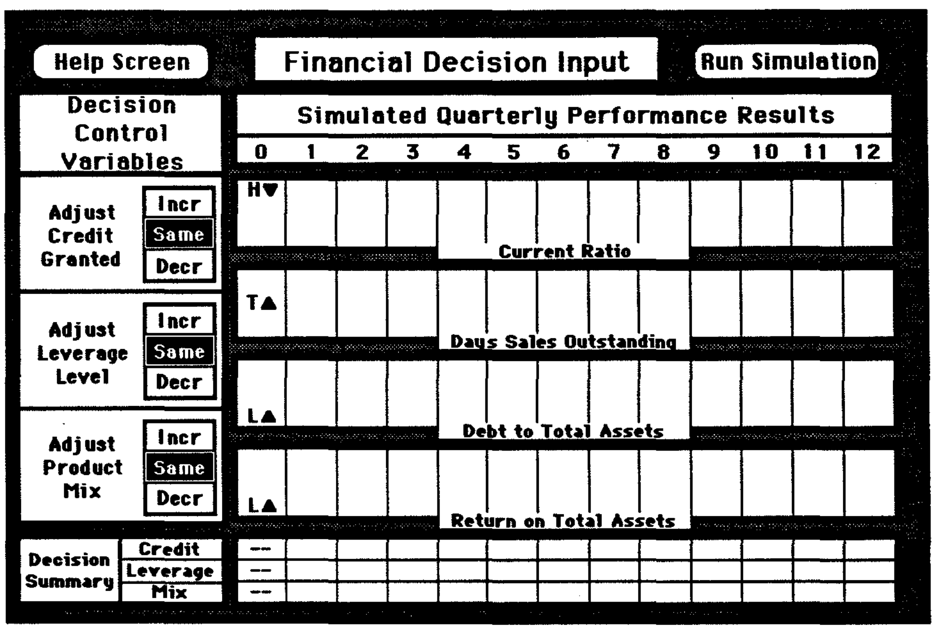
The simulation model which ran in the background of the decision making environment produced results in numerical form. Each iteration of the simulation generated quarterly values for the four performance indicator ratios. These ratio values required translation into the appropriate qualitative levels. The numerical values exhibited were used in the model to translate the ratio values coming from the simulation into the qualitative levels defined by the experts.

Incorporation of Qualitative Inputs and Outputs

The third and final step in the formulation of the decision processing environment was to link the qualitative inputs and outputs to the simulation model. An input/output control screen (Figure 7) was designed with which users entered their qualitative decisions and received qualitative performance results in return. Examination of this diagram reveals each of the qualitative input and output components.

All inputs to and outputs from the model were presented to the model "user" in qualitative terms. The decision control variables which the users were able to qualitatively manipulate appear on the left side of the screen. Users' decisions regarding these variables provided the input to the model. Users were faced with three choices for each of these decision control variables. Each variable had to be **I**ncreased, kept the **S**ame or **D**ecreased. Increases and decreases were defined qualitatively for the user as "small (incremental) changes."

Figure 7
Qualitative Input/Output Control Screen



To enter these "incremental" changes into the simulation model, incremental increases and decreases had to be translated into numerical values. This translation was accomplished with the aid of the information provided by the experts. The three qualitative levels of the decision control variables (**Credit Adjust, Leverage Adjust** and **Mix Adjust**) were assigned weights derived from the collective judgments of the experts.

When a user selected a particular level for a decision variable the weight corresponding to that level entered into the equations of the simulation model. For instance, if the user decided to decrease (Decr) credit, then the weight assigned to that level (0.90) entered the simulation wherever **Credit Adjust** appeared. Depending on how a particular equation is written, the effect will be to reduce or increase an inflow or outflow. Weights less than 1.00 will, generally speaking, tend to have a reducing influence. If the user decides to increase (Incr) credit, the corresponding weight (1.10) enters the simulation equations and the values of related variables change accordingly. Weights greater than 1.00 tend to have an expanding effect. In general, the farther the value is from 1.00, the greater the impact. If the user decided to not change the credit, a weight of 1.00 entered the equations. When the value is 1.00, the variable **Credit Adjust** had no effect on the model.

The remainder of the Input/Output Screen (Figure 7) provides a record of the decisions made each quarter by the user and the qualitative results for the performance indicators. The results for each of the four performance indicators were provided in terms of **(L)**ow, **(T)**arget or **(H)**igh. These qualitative results were translated from the output of the simulation model. After selecting the levels for each of the decision control variables the user selected the "Run Simulation" button and the simulation for the next quarter was run. The output from the simulation (the four performance ratios) was provided by the model in numerical terms. These numerical values were, in turn, translated into the three qualitative levels using the ranges derived from the expert membership functions.

To provide additional information to the user, up and down arrows were placed next to the qualitative labels to indicate whether the level of the performance indicator was growing or declining. While the performance results were only reported at the end of each quarter, the simulation model was running multiple iterations. The iteration to iteration changes in each of the performance indicators were recorded. If the last change before the end of the quarter for a particular performance ratio was positive, then an "up" arrow appeared next to the qualitative label for that indicator. If the last change was negative, then a "down" arrow appeared. In the event that the last iteration to iteration change was very small (less then +/- .0000) only the qualitative label appeared.

The initial conditions (time 0) of the firm's four performance indicators were provided in the first column of the results portion of the Input/Output Screen (figure 13) in qualitative terms. Each user began his or her decision process with these same conditions: a Current Ratio that was **(H)**igh and falling, a Days Sales Outstanding that was on **(T)**arget and rising, a Debt to Total Assets that was **(L)**ow and rising, and a Return on Total Assets that was **(L)**ow and rising.

Qualitative Decision Making

The final stage in the development of the decision making environment involved user interaction with the model. This interaction provided a "test" of the environment. Insights into both the functioning of the decision making environment and the process of making decisions with qualitative information (inputs and outputs) were gained from this "test of concept".

The results of the user interactions are organized into three areas. The first involves the users' definitions of the qualitative levels of the model variables. The second area summarizes the results of the user simulation "runs". The last area presents "maps" of the users' qualitative decision making process.

User Definition of Qualitative Levels

For purposes of comparison to the judgments of the experts, a group of "users" were asked to make judgments regarding the definitions of the qualitative levels of the performance indicators and the decision control variables. Users, for this study, had to have some formal training in accounting and finance (two or more college/university level courses in each) with limited direct financial management experience. Seven such individuals were selected.

Using a set of HYPERCARD screens similar to those used by the experts, each of the seven users was instructed to define the qualitative levels for the performance indicators and the impact of the decision control variables upon each of the performance ratios. As with the experts, the users' individual and median judgments were positioned on graphs to form "membership functions". The resulting membership functions were then compared to the experts' membership functions.

Qualitative Decision Simulations

After each user had completed entering his or her qualitative judgments, they were provided with on-screen instructions about the interactive simulation. Then, using the simulation control screen (Figure 7) discussed in a previous section, each user ran the simulation. Starting at time zero with qualitative indicators of the current condition for the four performance ratios, each user entered his or her decisions regarding each of the three decision control variables. The first iteration of the simulation (one quarter) was then run and qualitative results appeared on the screen. The user again entered decisions for the control variables and ran the second iteration. This process continued for a total of twelve iterations (12 quarters or 36 months of performance).

Summary

The focus of this research was on the identification of the essential qualitative components of a financial decision making situation and the development of an interactive environment in which qualitative decision making can be explored. This qualitative decision making environment was fashioned out of linguistic variables which provided both the primary input to and output from the model. Once translated into their expert defined quantitative equivalents, the values of these variables were entered into a STELLA simulation, controlled by a computer based expert system which was used to examine financial risk management decision making.

This study was designed, primarily, as a test of the concepts involved in qualitative decision making. The major effort was the development and demonstration of a decision making environment based on qualitative inputs and outputs. The apparatus fashioned provides the tools for analyzing decision making behavior. Decision making "styles" (short vs. long-term perspective, fine-tuning vs. wait and see approach, etc.) can be identified in terms of the frequency of adjustments in decision variables, changes in direction of variable adjustment and changes in reported decision making objectives. The performance results, recorded and stored in a database within the HYPERCARD environment, of decision makers of differing "types" can be compared to assess differences in decision making effectiveness.

The learning behavior of a decision maker can also be studied. Decision makers are given the opportunity to run the financial decision making simulation multiple times or to "re-run" iterations of the simulation. In either case, the decision variable adjustments and model performance results for each running of the model can be recorded and compared.

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