A KNOWLEDGE-BASED SYSTEM FOR CASH MANAGEMENT WITH MANAGEMENT SCIENCE EXPERTISE

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Abstract

A PC based system called CASH MANAGER is presented. It is a knowledge-based decision support system designed for financial managers. The system contains financial manager knowledge and management science expertise. It is designed to support decisions made by financial managers, who are not management science experts, yet desire to employ the capabilities of management science tools. CASH MANAGER can formulate a cash management problem as an embedded network problem, solve the problem, ensure its feasibility, interpret the output of the solution and recommend alternative courses of action.

1. Introduction

A significant improvement in a company's return on investment can be obtained by efficient management of its short-run investment/financing portfolio. This involves the careful choice of short-term investments (e.g. treasury bills, commercial paper, market accounts and certificates of deposits). A financial manager often must make decisions on very short notice while fully considering all of the instruments involved with their differing interest rates, maturity, and structure. During times of high interest and inflation it is especially worthwhile to make the best decision when trying to solve the company's cash flow management problems.

Financial managers shy away from using management science (MS) techniques such as linear programming and its special subclass of network models [27]. When cash management problems have been cast as general linear programming problems they have been very cumbersome to use [14]. Many managers have a lack of understanding of LP and network techniques and do not have quick access to MS experts. There may be a large time lag between the managers recognition of the need to solve the problem and the time when the MS expert can help formulate, solve and interpret a solution.

In this paper we discuss a personal computer (PC) based system, called CASH MANAGER. The system, developed using Microsoft's Windows, provides a user friendly mouse-based environment for supporting cash management decision making. The system includes a knowledge of a set of financial instruments and uses an approach that is congruent with the approach that financial managers use to solve cash management problems, without the system. The MS expertise has been built into the system to allow the manager to very quickly formulate, solve, and interpret optimal cash flow solutions. The user only works with sets of financial instruments (portfolios) and cash inflows and outflows. The system helps the user develop a consistent portfolio which is converted to an embedded generalized network when the model is solved. As the model is solved the system determines those investment decisions which maximize the value of the investment portfolio at a future point in time, called the horizon, or minimizes the amount the portfolio is short. No traditional MS expertise is required by the user.

2. Decision support systems

CASH MANAGER differs from the computer-based query systems used to analyze general mathematical programs. Query systems such as Analyze [7] and Peruse [11] are designed for the analyst who is an expert in linear programming. These systems allow the user to retrieve data, test alternative solutions for a particular decision and eliminate redundant constraints among other things. Recently, knowledge-based expert systems have been suggested to interface databases and mathematical programming [8,20] by developing a general system to analyze the output of an arbitrary mathematical program. These systems support the intelligent and knowledgeable MS user.

Barbosa and Hirko [1] suggest that there are a number of advantages to including MS algorithms in decision support systems. Tomlin [28] argues that it may be a difficult task to provide a general mathematical programming analysis package. Tomlin suggests that such an approach may not be cost-beneficial. Tomlin also raises the question "When is it simpler (and perhaps safer) for the user to specify all the logical relationships in his program?" That is, it may be more efficient to include domain specific knowledge into the system.

Tomlin's questioning is congruent with the suggestion by builders of expert systems. McDermott [19] and others have indicated that expert systems should be developed for self-contained and specific problems. Systems are beginning to be designed with this in mind. O'Leary [21] designed a system for production scheduling that exploited specificity and application knowledge.

3. Approaches to cash management

The cash management problem was first modeled as a linear program by Robichek et al. [25]. That linear programming model was later generalized by Mao [15], Orgler [23], Pogue and Bussard [24] and O'Leary and O'Leary [22] to allow for the possibility of unequal time periods, additional deterministic constraints, chance constraints and multiple criterion. Maier and Vander Weide [14] developed a version of the linear programming model that was more "user oriented" than other versions. Their approach focused on making the system accessible to non-technical users by allowing easier input of data and output reports that the user can understand.

Although a framework for investigating the cash management problem was presented in Srinivasan and Kim [27], they did not implement such a system. Further, although there have been some efforts to integrate financial intelligence into computer programs (e.g., Lee [12,13]), there has been little developed to directly support cash management and other financial decision makers.

Network formulations of the cash management problem, also have been investigated. Srinivasan [26], used the transshipment model to solve the problem. Golden et al. [5], modeled cash flow problems using networks. Processing network models, which are a special class of network models with side constraints, also have been proposed [10,16].

Embedded generalized networks (generalized network models with side constraints) have found use in conceptualizing a broad range of applications. Crum et al. [4] designed a model for cash management of multinational companies. Crum et al. [3] designed a model for meeting working capital needs using a generalized network approach. Both of these models were aimed at making broad-based decisions, e.g., production and marketing expenditures. McBride [17] used embedded processing networks, a class of embedded generalized networks models, to formulate the cash management problem. Not only do generalized networks provide a conceptual framework for such problems but there are very efficient algorithms to solve generalized network problems [2] and embedded generalized network problems [18].

4. System insights and example problem

To illustrate the use of CASH MANAGER and show some system insights, consider the following example. Sam's Inc. has the following projected cash flows for the next two months.

Day	Cash flow
1	$40,000
16	($10,000)
31	($ 2,000)
61	0

The positive values represent a cash inflow for Sam's and the negative values represent cash outflows Sam's must make.

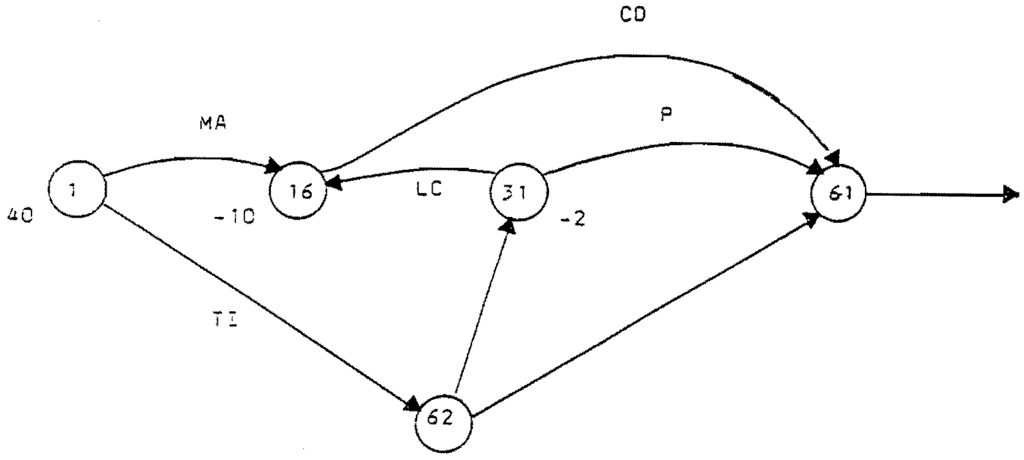

Fig. 1.

Sam's has a line of credit with an interest rate of 9% per annum at a local bank. Sam's can invest in CDs, money market accounts, and commercial paper. There is also a special investment available on day 1 called Tricities with returns on days 31 and 61 with a return of 10%. If \$31,482.61 is invested by Sam's on day 1 then Sam's will receive \$8,000 on day 31 and \$24,000 on day 61.

The investments can be summarized as follows:

Instrument	*Maturity annual yield*		*Yield for period invested*
Borrowing			
Line of Credit (LC)	15	9%	$i_1 = 0.0036975$
Investments			
Cert of Deposit (CD)	45	8%	$r_1 = 0.009859$
Paper (P)	30	8.5%	$r_2 = 0.006984$
Market Account (MA)	15	7.5%	$r_3 = 0.003081$
Tricities Investment (TCI)	30,60	10%	$r_4 = 0.016434$

Sam's desires to maximize their cash on hand at the beginning of day 61. The network for the complete problem is shown in fig. 1.

CASH MANAGER is menu driven. There are five dropdown menus in the menu bar as seen in fig. 2: File, Edit, Instruments, External Flows, and Solve Model. Under *File* the manager has the following options:

New – Start a new cash management problem.
Open – Read an existing file of instruments.
Append – Append an additional set of instruments to the working set of instruments.
Save – Save the working set of instruments.
Save as... – Save the working set of instruments in a different file.

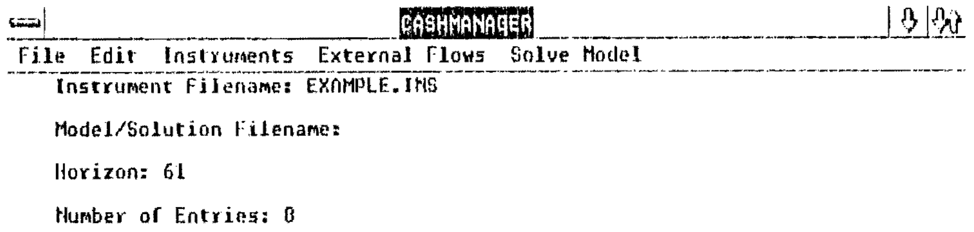

Fig. 2.

CASH MANAGER is configured to start a new cash management problem when first entered.

To start, we proceed to the *Instrument* menu and select it with the mouse by clicking on it (fig. 3). We select the *Simple Loan* option to build a Line of Credit Borrowing Instrument. After entering each piece of data we just hit the tab key to move to the next data entry field. The loan limit is entered in units of $1,000. The percentage rate paid for the duration of the loan is entered as the interest rate. After all data is entered (see fig. 4) the instrument is saved by clicking the 'OK' button.

The *General Investment* option in the *Instrument* menu is selected to build the Market Account instrument. Investments sold at a discount can be build using the *Discount Investment* option. Figure 5 shows the MA instrument. The rate of return is the percentage yield of the investment for the duration of the investment. The commercial paper and certificate of deposit instruments are build in a manner similar to the Market Account instrument.

With the "Tricities Investment" (fig. 6) the more general capability of this *General Instrument* template is illustrated. The payments on days 31 and 61 from the investment in proportions of 25% and 75% are accomplished by listing the payment days and corresponding percentages as shown. The number of entries in corresponding fields must agree and the percentages must add to 100%. The system reminds the user of such construction problems when the 'OK' button is clicked. The template is returned to the screen when problems exist.

The cash flows on days 1, 16, and 31 are entered by using the Cash Inflows/Cash Outflows options in the *External Flows* menu. The *Cash Inflows*

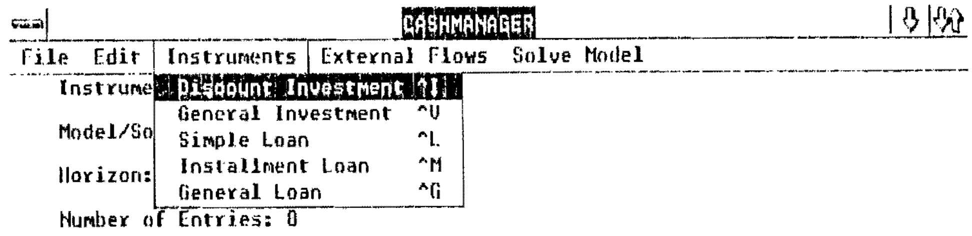

Fig. 3.

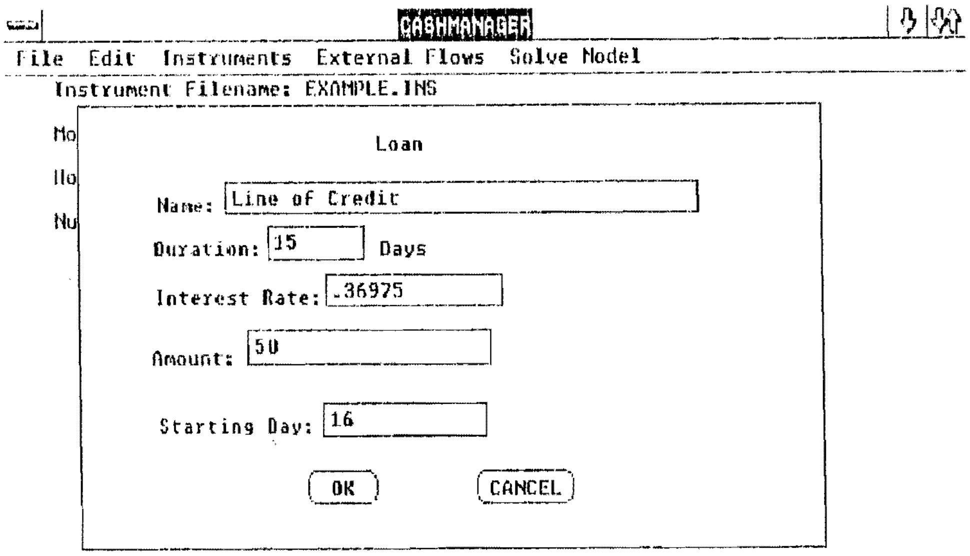

Fig. 4.

option is selected to enter the $40,000 cash inflow in day 1 (fig. 7). The remaining cash flows are entered in a similar manner.

Previously built instruments can be edited by clicking the *Edit* menu option in the menu bar. After building all of Sam's instruments and cash flows clicking this

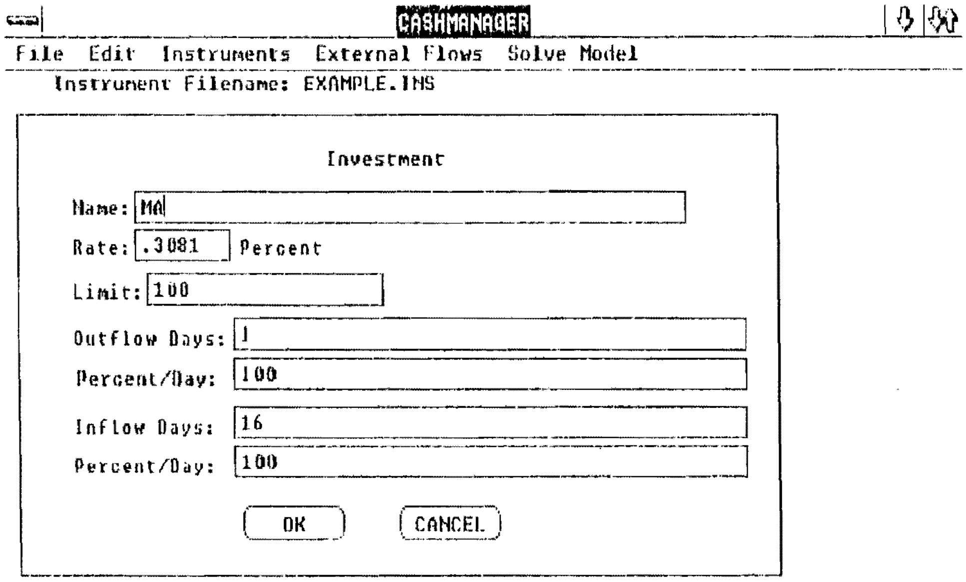

Fig. 5.

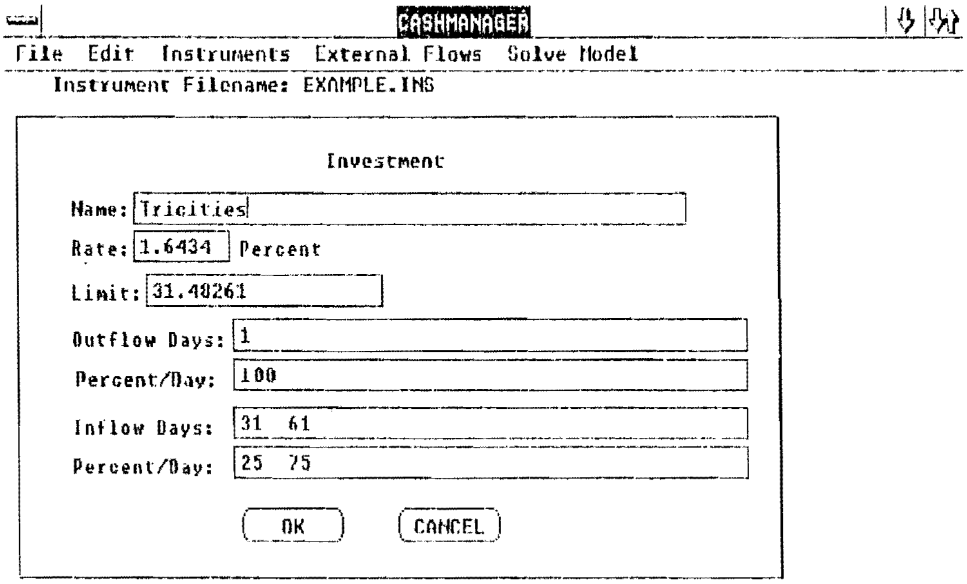

Fig. 6.

option yields the result shown in fig. 8. In this window any instrument can be selected by clicking in its row. The selection of Tricities is illustrated in fig. 8. By selecting one of the buttons at the bottom of the window, the manager can:

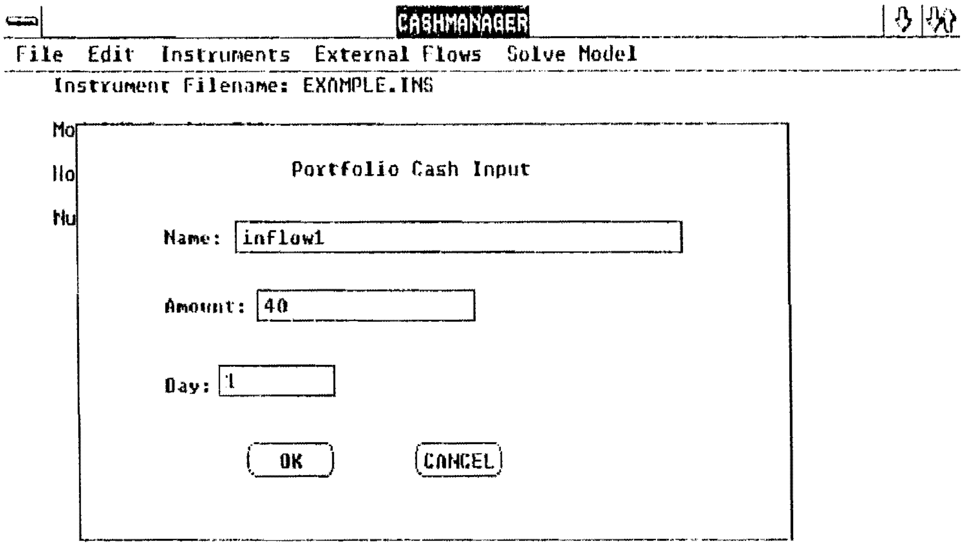

Fig. 7.

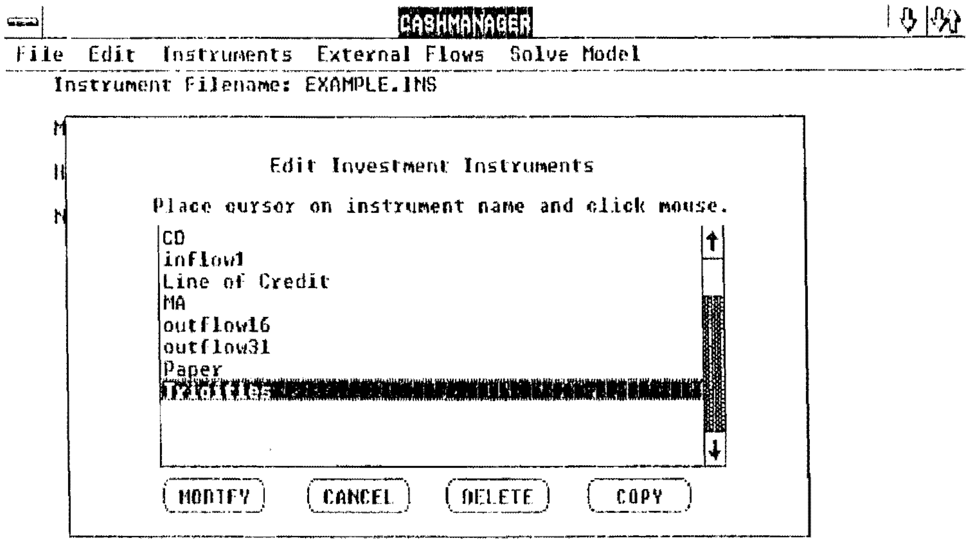

Fig. 8.

1. *MODIFY* the selected instrument or cash flow by bringing up the appropriate template with all of the data fields showing their current values, which can then be changed;
2. *CANCEL* or exit out of the exit mode;
3. *Delete* the selected instrument from the current working set;
4. *COPY* the selected instrument to create a new one have the same template and data values. In this option the name of the instrument is left blank but all other data fields have the data of the selected instrument.

Select the *Create and Solve Model* option in the *Solve Model* menu to solve the model. CASH MANAGER creates the cash flow model from the set of instruments and cash flows and checks for obvious infeasibilities. If no infeasibilities are encountered, as is our case, the solution will be projected onto the screen (see fig. 9) and written to a file for further reference (see fig. 10). A cash inflow/outflow sensitivity analysis (SA) is also provided with the solution. The SA shows the change in the optimal cash flow at the horizon for a unit change in the cash inflow/outflow.

CASH MANAGER allows the user to build instruments with maturities as short as 1 day. The time horizon is only restricted by the user's ability to estimate future interest and return rates. A user may set up a model with a time horizon of a month or more but only implement the solution for the first week. The next week the user could solve the model again taking the past weeks decisions as fixed and the current date as day 1 in the model. The interest/return rates can

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CASHMANAGER
File  Edit  Instruments  External Flows  Solve Model
   Instrument Filename: EXAMPLE.INS

   Model/Solution Filename: EXAMPLE.sol

   Horizon: 61

   Number of Entries: 8

   Optimal Cash Flow at Horizon = 28.5699

   Day 1
     Outflows                                        Amount
        MA                                           8.5174
        Tricities                                   31.4826
   Day 16
     Inflows                                         Amount
        MA                                           8.5436
        Line of Credit                               1.4564
   Day 31
     Outflows                                        Amount
        Line of Credit                               1.4618
        Paper                                        4.5382
   Day 31
     Inflows                                         Amount
        Tricities                                    8.0000
   Day 61
     Inflows                                         Amount
        Paper                                        4.5699
        Tricities                                   24.0000

   Inflow/Outflow Sensitivity Analysis
```

Fig. 9.

```
Optimal Casn Flow at Horizon = 28.5699

Day 1
  Outflows                                           Amount
     MA                                              8.5174
     Tricities                                      31.4826
Day 16
  Inflows                                            Amount
     MA                                              8.5436
     Line of Credit                                  1.4564
Day 31
  Outflows                                           Amount
     Line of Credit                                  1.4618
     Paper                                           4.5382
Day 31
  Inflows                                            Amount
     Tricities                                       8.0000
Day 61
  Inflows                                            Amount
     Paper                                           4.5699
     Tricities                                      24.0000

Inflow/Outflow Sensitivity Analysis
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Rate of change	Day	Lower Limit	Given	Upper Limit
1.0138	1	35.4924	40.0000	41.4519
1.0107	16	-14.5215	-10.0000	-8.5436
1.0070	31	-6.5382	-2.0000	0.0000

Fig. 10.

also be adjusted according to the user's improved knowledge. In this rolling schedule approach the user only acts on the current more accurate information. The user can reflect his knowledge of and confidence in the future by the length of the time horizon. Extending the time horizon beyond the decision making time period better approximates the real world.

5. Knowledge base of CASH MANAGER

CASH MANAGER employs two knowledge bases, one based on the financial manager and the other based on the management science expert. That knowledge takes two different formats: factual and process.

5.1. FINANCIAL MANAGER KNOWLEDGE BASE

CASH MANAGER is a knowledge-base decision support system designed to interact with financial management experts to support their decision making process. When using the system the financial manager works with a portfolio of financial instruments and cash inflows and outflows.

CASH MANAGER uses frames (templates) to capture each of the generic types of financial instruments in the system. The contents of the frame vary, depending on the type of instrument. The instrument frames define a means of storing information that can be used in generating its network representation. Knowledge is acquired by CASH MANAGER by defining instruments using the frames. For example, fig. 4 shows the frame for a simple loan instrument.

This version of the system is built upon a daily time reference. It requires the user to define all instruments so that their cash flows occurs on days numbered from the user selected day one. Alternatively time references such as weekly, could be employed in the instruments, depending on the user. The frames allow the user to create simple loan and discount investment instruments. The user also can create custom instruments by using other frames. These frames allow the user substantial flexibility in specifying the cash flows associated with the instrument. Investment instruments also can be customized by the user specifying the days outflows and inflows occur along with the percent of the flow for each of those days. There also exist frames for creating general loan instruments and installment loans.

Many different instruments can be created using the frames. Each unique instrument is identified by its name. Instruments can be modified, deleted, or copied for use in making new instruments. If an instrument is to be modified it is placed into its appropriate frame for editing. The financial manager always views the instruments through their associated frames. Associated with a set of financial instruments is a set of external cash flows. The financial manager can specify the days when cash becomes available to the portfolio (cash inflow) or when cash must be removed from the portfolio (cash outflow). Portfolio cash inflows and outflows are given using Cash Inflow and Cash Outflow frames.

5.2. MANAGEMENT SCIENCE KNOWLEDGE BASE

In the network formulation of the cash management problem discussed here, nodes represent days when cash can enter or leave investments, loans or the portfolio in general. Arcs represent the possible flow of cash from one time period or day to another.

When the user selects the solve option CASH MANAGER takes the set of instruments and external cash flows and creates the corresponding cash flow model. The built-in MS knowledge base is used to construct the appropriate network LP model from the set of instruments and external cash flows. Each instrument is built into the model using the data provided by the user in the frame associated with the instrument.

The formulation of a cash flow embedded network can sometimes inadvertently lead to infeasibilities. As a result, the system is designed to perform two sets of feasibility checks. The first set examines the feasibility of the network before the solution, during the formulation process. The second set occurs during the solution process. In each case, the error messages are presented to the user in a manner that is easily understood by the financial manager using terms of the financial manager knowledge base.

CASH MANAGER performs infeasibility checks on the network before is it solved. When any of the following conditions occur a solution is not attempted. Instead the user must adjust the instruments and/or external cash flows to mitigate the problem.

1. A node with supply or demand but with no incident arcs.
2. A node with only arcs entering but no demand (external cash outflow).
3. A node with only arcs leaving but no supply (external cash inflow).
4. A node with leaving arc capacity less than its supply.
5. A node with entering arc capacity less than its demand.
6. An arc with zero upper capacity.
7. An arc with a negative multiplier when not allowed.

These seven conditions are obvious modeling problems for a MS expert when the set of financial instruments and external cash flows are viewed as an embedded network LP. A financial manager should pick up these modeling inconsistencies but it may be difficult with a large number of instruments. Thus, when one of these seven conditions occur there is a sure infeasibility or an oversight on the part of the user. When one of these conditions are encountered a Message Box is displayed on the screen with messages indicating the day and the problem. Suppose that the node corresponding to day 31 has entering arcs but no demand or leaving arcs. In this case a Message Box would be displayed on the screen indicating that there is a problem with day 31 displaying the message 'This day has possible cash inflows but no cash outflow'. This message remains on the screen until the user clicks the OK button in the Message Box. The user may have forgotten to put an external cash outflow for the day or provided reinvestment opportunities.

Additional feasibility checks are performed when the user works with frames for general instruments like Figure 6. The user is not permitted to save instruments if there are inconsistencies. The percent/day data must add to 100 percent. The number of entries in the outflow days and the percent/day input fields must agree. The same applies for inflows.

The model may pass the above seven tests and yet be infeasible. In such a situation, it would not be acceptable for the linear programming code to just return with the message that the LP cash management problem is infeasible. If a user were to just get an infeasibility message no information would be provided to the user about the nature of the infeasibility.

The LP cash flow model created by CASH MANAGER can never be infeasible since feasibility analysis is integrated into the model itself. An outflowing singleton arc, with a zero profit is used to account for excess investable funds. These arcs are placed on all nodes with external cash inflows. An infeasible surplus flow will only occur on this arc if there is no other opportunity to disburse the funds. Alternatively, a inflowing singleton arc, with a large cost is used to account for cash outflows which cannot be met. An infeasibility deficit occurs when maturing instrument inflows cannot meet cash demands created by external cash outflows.

Analysis on the final linear programming tableau is used to determine how to reduce the infeasibility surplus or deficit. These infeasibilities can be reduced by increasing the capacity of selected instruments determined by the analysis. Thus, the system will make recommendations as to which instruments upper capacities should be increased. As a result, the feasibility process can be used to provide additional feedback to the user about the limitations of the current portfolio instruments. Of course, the user may wish to add additional instruments to resolve the infeasibility. This may be the case when the financial manager first tries to invest in only certain high grade instruments.

CASH MANAGER also does a sensitivity analysis of the network to provide further analysis of the output. Sensitivity analysis is done on the portfolio cash inflows and outflows which are supplies and demands at nodes. The dual variable is used to get the rate of change of the total return and sensitivity analysis is used to compute the upper and lower limits of the supply and demand values which apply to the current dual. This is information available to the MS expert in the LP tableau which is useful to the financial manager because of the possible uncertainty associated with cash inflows and outflows.

5.3. PROCESS EXPERTISE

The knowledge base of CASH MANAGER includes both factual and procedural knowledge. The former includes knowledge about the financial instruments and modeling errors. The later includes knowledge about assembling information about the individual instruments into a single portfolio, checking the model integrity and solving the problem. It is this second type of knowledge that is most interesting and complex.

The process of identifying possible financial instruments is aided by the list of generic instruments and the frame structure of the information required for a particular instance of the instrument. The user of the system can combine several instruments to achieve the effect of a new undefined type of borrowing or investment. Although this is true, in some cases the user may have to work with both a financial and a management science expert to add the new type to the list of generic instruments.

The process of solving the problem involves creating input to the linear program algorithm (solver) using the cash inputs and outputs (forecasts) and possible instruments, checking the model integrity, and solving the problem. Given the set of forecasts and financial instruments the system generates input for the solver. Since there is only one model possible using the given portfolio the system does not have to deal with uncertainty. The model integrity is checked using the infeasibility conditions analysis in the previous section. This is a first phase of a generate and test approach to problem solving. The second phase involves the generation of additional singleton arcs. This is submitted to the solver where the second phase of testing takes place. The first test provides model integrity but not necessarily solution feasibility.

The process of examining the answer includes displaying the optimal flows and a sensitivity analysis. If the specified problem does not have a feasible solution then an infeasibility analysis is presented. The system suggests that the bounds on what can be invested in various instruments or the amounts borrowed be raised. The criteria for choosing among the possible suggestions is based on LP sensitivity analysis. The system does not change the cash forecast in order to achieve feasibility although this can be an option the user can explore.

5.4. SYSTEM IMPLEMENTATION OF THE MULTIPLE KINDS OF EXPERTISE

The system was not implemented in the traditional expert systems manner that stores the process and factual knowledge in a separate knowledge base that is acted upon by an inference engine. This approach was not used because of the large amount of process knowledge incorporated into the system and because the system integrates an analytic tool (linear programming) into the decision process.

Instead, a more traditional programming approach was taken. However, the particular programming environment facilitates a modular approach to various

In general, many of these extensions conceptually can be accomplished in a straightforward manner because of the modular structure of the system. For example, rather than a linear programming module, an integer programming module could be used. This would allow the modeling of situations such as stairstep investment functions that restrict investments to multiples of $1,000. Further, any changes that relate to financial instruments can be implemented through the instrument modules.

7. Conclusion

CASH MANAGER is a user friendly, knowledge-based decision support system designed for use by a corporate financial manager. The system solicits minimal amounts of informations from the user and employs that information in the context of an embedded network, to help the user chose between alternative financial instruments.

The system employs MS expertise and cash management knowledge. Network modeling expertise is used to take information about portfolio financial instruments and develop an embedded network that represents the portfolio. Feasibility analysis is employed to ensure that the user inputs the parameters in an appropriate manner and to guide the user to develop a consistent model. Sensitivity analysis is used to help the user understand the implications of varying external cash flows.

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