CMS/1 - A CORPORATE MODELING SYSTEM

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Abstract

Past efforts in the area of corporate modeling have demonstrated the need for "problem-oriented" languages which would facilitate the construction of corporate models. CMS/1 is a discrete-state simulation system designed for use in corporate modeling. It is composed of three languages - a control language, a logic/data specification language, and a report format specification language. Among the features of CMS/1 are 1) the user specification of each variable's name and meaning, 2) the capability of "grouping" variables, 3) the ability to execute a logic module both as a deterministic model and as a stochastic model, and 4) the ability to transfer the values of variables from one model to another.

This paper describes some of the design concepts of the system and presents some examples which illustrate its capabilities.

Introduction

The initial efforts of most firms in building corporate models have followed the philosophy characterized by Dickson; Mauriel, and Anderson as the "fixed structure approach" to model building.[1] Under this approach the model is usually constructed with the aid of a general purpose language such as Fortran or Cobol. The models allow the user little flexibility, forcing him "to employ existing accounts, fixed output reports, and a limited set of options for attaching values to variables in the

model."[2]

The limitations of the fixed structure approach have been mitigated by the development of corporate modeling systems such as IBM's PSG,[3] Monsanto's APEX,[4] and Applied Computer Technology Corporation's Foresight.[5] This paper describes a new system, called CMS/1, which was created in an effort to further the development of corporate modeling systems. The logical organization of the system will first be presented and then general design characteristics of the system will be discussed. Third, CMS/1 is briefly compared to another modeling system, Foresight IV. Finally, examples of the use of the system will be given.

Logical Organization

A model is composed of three types of modules. They specify the logical and mathematical relationships for the model (i.e., the logic module), the data to be used in executing the model (i.e., the data module), and the formats of reports which are to be produced (i.e., the report modules).

When the modules are entered into CMS/1, they are translated into a more conveniently executed form and stored on a magnetic disk (see Figure 1). The user may then specify the logic, data, and report modules that are to be retrieved from the disk, merged into a complete model, and executed (see Figure 2).

The execution of a model is actually accomplished in six steps.

1. The first step is to create a matrix of variables composed of the variables referenced by the specified logic module and report modules.

2. Second, the specified data modules are retrieved in turn, and the values are assigned to the indicated variables.

3. The logic module is retrieved and the specified calculations are performed.

4. If the execution is a part of a sensitivity analysis or a Monte Carlo simulation, the second and third steps are repeated.

5. If requested, the values of selected variables are saved.

6. The requested reports are printed. If no report modules are specified, a default report is printed.

Design Characteristics

The basic design characteristics of CMS/1 may be categorized into three groups: those which promote the ease of use, those which promote flexibility of use, and lastly, technical characteristics.

The major contributant to the ease of use of the system is the utilization of "English-like" languages. The use of

new specially designed languages means that the modeler need have no previous programming experience. The use of "English-like" languages also make the languages less cryptic and more easily understood. However, the experienced modeler usually tires of using the complete forms of such "English-like" languages; so, short-forms are provided for the expert.

A second contributant to the ease of use of CMS/1 is the provision of default conditions. The more capabilities provided by a modeling system, the more difficult it is to use since the user must select those things he wishes to do from all the alternatives available to him. Relief from this circumstance is provided by the use of defaults. That is, if no selection is explicitly made where an option exists, a predefined alternative is assumed by the modeling system.

CMS/1 also has extensive error-checking routines which check each statement as it is entered. When an error is detected, a concise though clearly worded error message is produced. Where applicable, the message identifies the character, word, or storage file which generated the error.

The modeler is also assisted in the specification of relationships among variables through the capability of "grouping" variables. For example, the statement

```
GROUP LABOR,MATERIALS,OVERHEAD
    UNDER MFG_EXPENSES
```

creates three variables which may be referenced collectively under the name "MFG_EXPENSES." The use of a group name will elicit different responses depending upon the context of its use.

Assuming that the variables SALES, LABOR, MATERIALS, and OVERHEAD have been previously assigned values, the following statement would cause the values of LABOR, MATERIALS, and OVERHEAD to be summed; the sum to be subtracted from the value of SALES; and the result to be associated with the variable OPERATING_INCOME.

```
OPERATING_INCOME EQUALS SALES
    MINUS MFG_EXPENSES
```

Another use of group names is exemplified by the following two statements.

```
GROUP LABOR, MATERIALS, OVERHEAD
    UNDER MFG_EXPENSES, STANDARDS

MFG_EXPENSES EQUAL SALES TIMES
    STANDARDS
```

The second statement above specifies that the values of the labor, materials, and overhead standards are each to be multiplied by the values of sales giving, respectively, the labor, material, and

overhead expenses.

The use of CMS/1 is further simplified by the segmentation of models into logic, data, and report modules. The modules are created separately and are combined into one complete model only when executed. A model may contain only one logic module, but any number of data and/or report modules may be used. Thus, a model can be easily altered simply by altering the "mix" of logic, data, and report modules.

This modularization of models also increases the flexibility of the modeling system in several ways. One way is by allowing logic modules to be created independently of the number of time periods over which they are to be executed. The time horizon of a model is limited by the interest of the manager or by the availability of data. When either of these factors change, the logic module may be executed over a longer horizon without altering the module itself. This also means, of course, that different types of logic modules (e.g., long-range planning and capital budgeting models) utilizing different time horizons may be created with CMS/1.

Another implication of the modularization of models is that a logic module may be created independently of its use as a simple deterministic model, its use in sensitivity analysis, and its use in Monte Carlo simulations. A logical relationship may be expressed so that it is invariant over these three situations. It is the data and the procedure used in executing the model which must change.

The segmentation of models is complemented by the facility of referencing all variables by user-supplied names (32 characters per name maximum). The modeler simply references the same variable by the same name in all modules. Then, when the modules are combined for execution, the modeling system links all like names to the same values. This frees the modeler from the burden of maintaining positional equivalency among variables over all modules.

Finally, the flexibility of CMS/1 is greatly enhanced by the facilities for including arithmetic calculations in data modules and for the superceding of selected values calculated in a logic module by values contained in a data module. These two facilities are useful in temporarily altering the logical structure of a model without actually altering the logic module. The alterations are accomplished simply by adding to the "mix" of modules a data module incorporating the desired changes.

There are two technical considera-

tions which have greatly influenced the design of CMS/1. The first is the consideration of the capacity of the system in terms of the number of variables, time periods, etc. which may be accommodated by the system. In some cases no limits are required. There is no direct limit, for example, on the number of data and/or report modules which may be included in a model. In other cases the items must be counted so that the capacity is limited by the maximum value which the counters can obtain. In these instances the capacity of the counters have been set so that the modeler is more likely to be restricted by the physical capacity of his computer than by the capacity of CMS/1. This is exemplified by the capacity of the matrix which is used to store the values of variables. The matrix is dynamically allocated with a maximum capacity of 32,767 variables defined over a maximum of 32,767 time periods. Thus, CMS/1 can accommodate over one billion values.

The second technical consideration deals with the procedure used in executing a model over several time periods. Since CMS/1 is an interpreter rather than a compiler, the most efficient procedure for executing a model would be to execute each operation within a statement over all time periods before proceding to the next operation. Thus, in executing the statement

```
INTEREST_EXPENSE EQUALS DEBT TIMES
    INTEREST_RATE
```

over five time periods, the multiplication would be carried out five times; and then the five products would be assigned to the variable "INTEREST_EXPENSE."

This procedure, though efficient, yields undesirable results in three cases: 1) when a variable is lagged on itself, 2) when a variable is a function of another lagged variable whose defining equation follows the equation being evaluated, and 3) when a conditional branch occurs. All three of these problems can be avoided by the slower process of interpreting the complete model once for each time period.

When one or more of these three cases arises, the slower procedure is automatically used by CMS/1. In all other cases the more efficient procedure is used by executing, in turn, each operator within an equation over all time periods.

Comparison of CMS/1 and Foresight IV

CMS/1 was originated as an experimental language - one which would offer advanced facilities (e.g., Monte Carlo simulations) for corporate modeling but still be easily used by a novice in computer programming. The resulting design

of CMS/1 differs fundamentally from the structure of Foresight. In the Foresight system, a model is basically a single unit containing data, logic, and report formats with the report formats dictating the structure of the model. That is, the data and logic statements are basically algebraic representations of the lines in a report.

In CMS/1 a model is composed of three types of related but separable segments (i.e., data, logic, and reports). The modeler constructs each segment individually. The system then merges the individual segments into a complete model. This segmentation allows the sequence of computations to be independent of the sequence in which the variables appear in a report. Also, one segment can be altered or restructured without necessarily requiring that the other segments be changed.

In addition to the fundamental difference in the approaches of CMS/1 and Foresight to the construction of models, there are also a number of structural differences. CMS/1 has more liberal capacity constraints on items such as the maximum number of variables and periods which may be used, the lengths of statements, or the number of operations in an arithmetic statement. CMS/1 also offers more flexibility in specifying data values and in specifying the form of reports (column widths, etc.). Foresight, on the other hand, has more built-in functions, supports the specification of relationships among columns, and, unlike CMS/1, is available in a time-sharing environment. These and other differences along with some similarities between the two systems are summarized in Table 1.

Example Models

The use of CMS/1 in constructing models is demonstrated in this section through the presentation of models which culminate in the production of a corporate income statement for a hypothetical firm. The sole purpose of the model is to demonstrate the use of CMS/1. They are not intended to reflect the circumstance in any particular firm.

The hypothetical firm is assumed to be composed of two divisions each producing two products. The corporate income statement is therefore developed from the divisions' income statements which in turn depend on the performance of the product lines.

The model for each division is composed of common logic and report modules (see Figure 3) which are combined with different data modules for each division (see Figure 4). The divisional models combine cost and revenue information

concerning the product lines (such information is contained in the data modules named "PRODUCT_11", etc.) with information concerning the expenses incurred at the divisional level in order to derive the net contribution of each division. The calculated values are then saved for later use in the corporate level model. (Note that the results from one model may be saved and used as data for another model.) The results of the execution of the two divisional models are depicted in Figures 5 and 6.

The information saved from the divisional models is combined with data on corporate expenses in order to derive a corporate income statement. A complete corporate level model including logic, data, and report modules is depicted in Figure 7. The corporate income statement developed by the model is presented in Figure 8.

Summary

CMS/1 is a corporate modeling system designed to assist in the construction and solution of discrete-state, case-study type models. The emphasis in its design is on the alleviation of the programming burden rather than on the efficient execution of a model.

Among the facilities of CMS/1 are data maintenance services, several special purpose functions such as present value and discounted rate of return computations, and capabilities for performing sensitivity analyses and Monte Carlo simulations. These and other facilities of CMS/1 are currently being extended and improved as a result of experience gained from the utilization of the system by several organizations.

The primary purpose of the development of CMS/1 was to further the development of corporate modeling systems which "will allow the modeler and planner to conceptualize the simulation model in the language it is to be programmed."[6]

Footnotes

1) G.W. Dickson, J. J. Mauriel, and J. C. Anderson, "Computer Assisted Planning Models, A Functional Analysis," Corporate Simulation Models, A. N. Schrieber (ed.), Graduate School of Business Administration, University of Washington, Seattle, Washington, 1970, pp. 43-70.

2) Ibid., p. 53.

3) "Planning Systems Generator User Guide," Program Information Department, International Business Machines Corporation, 1968.

4) Donald L. Buchman, "An Application-Oriented Computer Language for Financial/Economic Simulation," a

paper presented at the XIX International Meeting of the Institute of Management Science, Houston, Texas, April 5, 1972.

5) "Foresight III User Manual," Applied Computer Technology Corporation, Los Angeles, California, 1971.

6. James L. McKenney, "Guidelines For Simulation Model Development," Information Systems Science and Technology, 1967, pp. 169-173.

TABLE 1

Comparison of CMS/1 and Foresight IV

Characteristic	CMS/1	Foresight IV
Batch	Yes	Yes
Time-Sharing	No	Yes
Partition Size	140K +	105K
Computers Used	IBM 360-370 DOS and OS	IBM 360-370 DOS and OS
Sensitivity Analysis	Yes	Yes
Monte Carlo	Yes	No
Arithmetic by Columns	No	Yes
Report Format	Very flexible	Less flexible
Number of Reports	No limit	5
Number of Variables in Model	32,767	1,000
Number of Periods	32,767	21
Statement Length	32,767 characters	160 characters
Complexity of Arithmetic Statement	No limit	Simple with 6 variables and 5 operations maximum
Availability of Functions (present value, etc.)	Several available	More are available
Consolidation of Results from Models	Variables referenced by name	Variables referenced by position in model

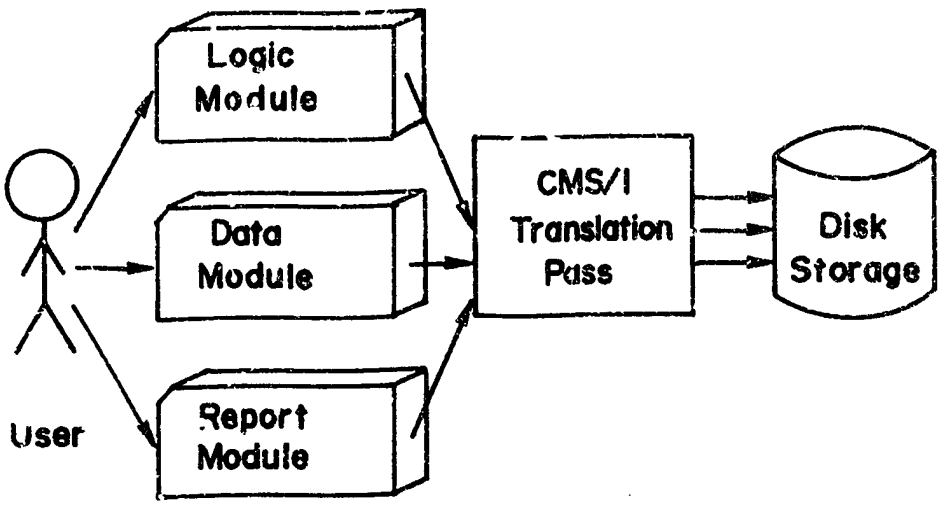

Figure 1. Logical organization of CMS/1 - translation pass.

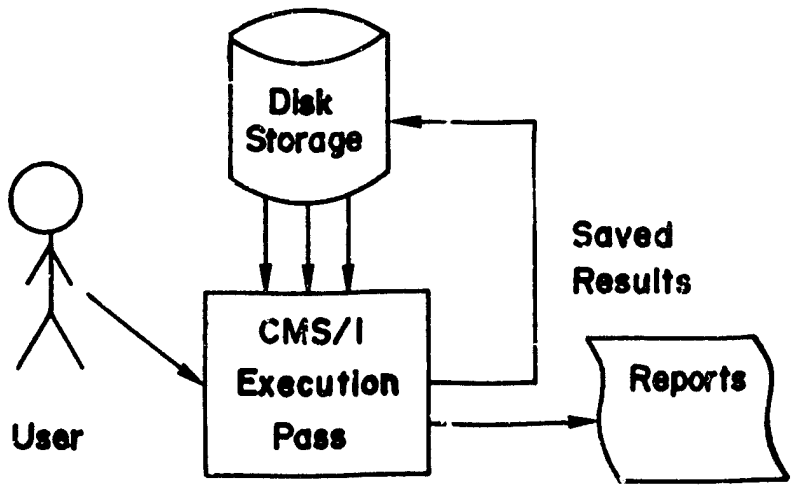

Figure 2. Logical organization of CMS/1 - execution pass.

```
*LOGIC  DIVISION
 GROUP  MFG_OVERHEAD, R_AND_D, SELLING_AND_ADVERTISING,
1       ADMINISTRATION  UNDER DIVISION_EXPENSES
 SALES EQUAL SALES1 PLUS SALES2
 MARGINAL_COST = MARGINAL_COST1 + MARGINAL_COST2
 FIXED_PRODUCT_EXPENSES = TOTAL_FIXED_EXPENSES1 PLUS
1                         TOTAL_FIXED_EXPENSES2
 TOTAL_PRODUCT_COSTS = MARGINAL_COST +
1          FIXED_PRODUCT_EXPENSES
 CONTRIBUTION_FROM_PRODUCTS = SALES - TOTAL_PRODUCT_COSTS
 TOTAL_DIVISION_EXPENSES = SUM OF DIVISION_EXPENSES
 CONTRIBUTION_FROM_DIVISION = CONTRIBUTION_FROM_PRODUCTS -
1          TOTAL_DIVISION_EXPENSES
 SAVE  SALES"DIVISION_NO, TOTAL_PRODUCT_COSTS"DIVISION_NO,
1      TOTAL_DIVISION_EXPENSES"DIVISION_NO,
1      CONTRIBUTION_FROM_DIVISION"DIVISION_NO
*REPORT  DIVISION
 TITLE                    DIVISIONAL QUARTERLY PLAN
 MARGIN 0
 LINE LENGTH 60
 COLUMN SIZES  26, 0, (8)
 BEGIN NEW PAGE
 SKIP 2 LINES
 COLUMN HEADINGS  "ACCOUNT", " FIRST", " SECOND",
1                 " THIRD", " FOURTH"
 COLUMN HEADINGS  "--------", " ------", " ------",
1                 " ------", " ------"
 ITEM SALES
 SKIP 1 LINE
 LINE  PRODUCT COSTS:
 ITEM MARGINAL_COST
 ITEM "FIXED COST", FIXED_PRODUCT_EXPENSES
 ITEM CONTRIBUTION_FROM_PRODUCTS
 SKIP 1 LINE
 LINE  DIVISIONAL COSTS:
 ITEM "FIXED MFG. OVERHEAD", DIVISION_EXPENSES:MFG_OVERHEAD
 ITEM "R & D EXPENSES", DIVISION_EXPENSES:R_AND_D
 ITEM DIVISION_EXPENSES:SELLING_AND_ADVERTISING
 ITEM DIVISION_EXPENSES:ADMINISTRATION
 ITEM TOTAL_DIVISION_EXPENSES
 SKIP 1 LINE
 ITEM CONTRIBUTION_FROM_DIVISION
```

Figure 3. Logic and report modules for divisional models.

```
*DATA  PERIODS 1 TO 4
 GROUP  MFG_OVERHEAD, R_AND_D, SELLING_AND_ADVERTISING,
1       ADMINISTRATION  UNDER DIVISION_EXPENSES
 DIVISION_NO IS 1
 DIVISION_EXPENSES:MFG_OVERHEAD = 200000
 DIVISION_EXPENSES:R_AND_D =  50000
 DIVISION_EXPENSES:SELLING_AND_ADVERTISING = 250000
 DIVISION_EXPENSES:ADMINISTRATION = 150000
*EXECUTE  LOGIC DIVISION, DATA PRODUCT_11 PRODUCT_12,
1         SAVE DIVISION_1
1         REPORT DIVISION, HEADING "DIVISION 1"
*DATA  PERIODS 1 TO 4
 GROUP  MFG_OVERHEAD, R_AND_D, SELLING_AND_ADVERTISING,
1       ADMINISTRATION  UNDER DIVISION_EXPENSES
 DIVISION_NO IS 2
 DIVISION_EXPENSES:MFG_OVERHEAD = 100000
 DIVISION_EXPENSES:R_AND_D =  50000
 DIVISION_EXPENSES:SELLING_AND_ADVERTISING = 200000
 DIVISION_EXPENSES:ADMINISTRATION = 150000
*EXECUTE  LOGIC DIVISION, DATA PRODUCT_21 PRODUCT_22,
1         SAVE DIVISION_2
1         REPORT DIVISION, HEADING "DIVISION 2"
```

Figure 4. Data modules and execute statements for divisional models.

DIVISION 1

DIVISIONAL QUARTERLY PLAN

ACCOUNT	FIRST	SECOND	THIRD	FOURTH
SALES	5100000	5100000	4320000	4860000
PRODUCT COSTS:				
MARGINAL COST	3210000	3194000	2704000	3058000
FIXED COST	800000	800000	800000	800000
CONTRIBUTION FROM PRODUCTS	1090000	1106000	816000	1002000
DIVISIONAL COSTS:				
FIXED MFG. OVERHEAD	200000	200000	200000	200000
R & D EXPENSES	50000	50000	50000	50000
SELLING AND ADVERTISING	250000	250000	250000	250000
ADMINISTRATION	150000	150000	150000	150000
TOTAL DIVISION EXPENSES	650000	650000	650000	650000
CONTRIBUTION FROM DIVISION	440000	456000	166000	352000

Figure 5. Results for first division.

DIVISION 2

DIVISIONAL QUARTERLY PLAN

ACCOUNT	FIRST	SECOND	THIRD	FOURTH
SALES	5550000	5120000	4680000	5060000
PRODUCT COSTS:				
MARGINAL COST	4035000	3632000	3324000	3674000
FIXED COST	675000	675000	675000	675000
CONTRIBUTION FROM PRODUCTS	840000	813000	681000	711000
DIVISIONAL COSTS:				
FIXED MFG. OVERHEAD	100000	100000	100000	100000
R & D EXPENSES	50000	50000	50000	50000
SELLING AND ADVERTISING	200000	200000	200000	200000
ADMINISTRATION	150000	150000	150000	150000
TOTAL DIVISION EXPENSES	500000	500000	500000	500000
CONTRIBUTION FROM DIVISION	340000	313000	181000	211000

Figure 6. Results for second division.

```
*LOGIC  CORPORATION
 GROUP  ADVERTISING, ADMINISTRATION, OTHER UNDER
1       CORPORATE_EXPENSES
 SALES = SALES1 + SALES2
 PRODUCT_COSTS = TOTAL_PRODUCT_COSTS1 PLUS
1                TOTAL_PRODUCT_COSTS2
 DIVISION_EXPENSES = TOTAL_DIVISION_EXPENSES1 PLUS
1                    TOTAL_DIVISION_EXPENSES2
 CONTRIBUTION_FROM_DIVISIONS = CONTRIBUTION_FROM_DIVISION1
1                              PLUS CONTRIBUTION_FROM_DIVISION2
 TOTAL_CORPORATE_EXPENSES = SUM OF CORPORATE_EXPENSES
 NET_INCOME_BEFORE_TAXES = CONTRIBUTION_FROM_DIVISIONS -
1        TOTAL_CORPORATE_EXPENSES
 IF NET_INCOME_BEFORE_TAXES < 0  THEN JUMP TO NO_TAX
 IF NET_INCOME_BEFORE_TAXES > 25000 THEN TAXES = .48 TIMES
1      NET_INCOME_BEFORE_TAXES - 6500
1                                  ELSE TAXES = .22 TIMES
1      NET_INCOME_BEFORE_TAXES
 JUMP TO AFTER_TAX
 NO_TAX) TAXES = 0
 AFTER_TAX)
 NET_INCOME_AFTER_TAXES = NET_INCOME_BEFORE_TAXES - TAXES
*REPORT  CORPORATION
 TITLE                      CORPORATE QUARTERLY PLAN
 MARGIN 0
 LINE LENGTH 60
 COLUMN SIZES  24, 0, (9)
 BEGIN NEW PAGE
 SKIP 2 LINES
 COLUMN HEADINGS  "ACCOUNT", " FIRST", " SECOND",
1                 " THIRD", "  FOURTH"
 COLUMN HEADINGS  "--------", " -----", " ------",
1                 " -----", "  ------"
 ITEM SALES
 SKIP 1 LINE
 ITEM PRODUCT_COSTS
 ITEM DIVISION_EXPENSES
 LINE  CONTRIBUTION FROM
 ITEM " DIVISIONS", CONTRIBUTION_FROM_DIVISIONS
 SKIP 1 LINE
 LINE  CORPORATE EXPENSES:
 ITEM CORPORATE_EXPENSES:ADVERTISING
 ITEM CORPORATE_EXPENSES:ADMINISTRATION
 ITEM CORPORATE_EXPENSES:OTHER
 ITEM TOTAL_CORPORATE_EXPENSES
 SKIP 1 LINE
 LINE  NET INCOME
 ITEM "  BEFORE TAXES", NET_INCOME_BEFORE_TAXES
 SKIP 1 LINE
 ITEM TAXES
 SKIP 1 LINE
 LINE  NET INCOME
 ITEM "  AFTER TAXES", NET_INCOME_AFTER_TAXES
*DATA  PERIODS 1 TO 4
 GROUP  ADVERTISING, ADMINISTRATION, OTHER UNDER
1       CORPORATE_EXPENSES
 CORPORATE_EXPENSES:ADVERTISING = 100000
 CORPORATE_EXPENSES:ADMINISTRATION = 150000
 CORPORATE_EXPENSES:OTHER =  50000
*EXECUTE  LOGIC CORPORATION, DATA DIVISION_1 DIVISION_2
1         REPORT CORPORATION
```

Figure 7. Complete corporate level model.

CORPORATE QUARTERLY PLAN

ACCOUNT	FIRST	SECOND	THIRD	FOURTH
SALES	10650000	10220000	9000000	9920000
PRODUCT COSTS	8720000	8301000	7503000	8207000
DIVISION EXPENSES	1150000	1150000	1150000	1150000
CONTRIBUTION FROM DIVISIONS	780000	769000	347000	563000
CORPORATE EXPENSES:				
ADVERTISING	100000	100000	100000	100000
ADMINISTRATION	150000	150000	150000	150000
OTHER	50000	50000	50000	50000
TOTAL CORPORATE EXPENSES	300000	300000	300000	300000
NET INCOME BEFORE TAXES	480000	469000	47000	263000
TAXES	223900	218620	16060	119740
NET INCOME AFTER TAXES	256100	250380	30940	143260

Figure 8. Results for corporate level model.