SIMULATION IN A DECENTRALIZED PLANNING ENVIRONMENT

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SUMMARY

The problem of integrating and controlling the planning process in a decentralized corporation—without stifling the individuality of its component units—is attacked through the use of simulation. A system of models, each representing a distinct organizational entity, permits simulation in detail to take place concurrently at several levels, using guidelines and criteria set by the central authority. The provision of a common planning data base, to which each of the models is linked, facilitates the monitoring of plans and permits the allocation of resources which best meets the objectives of the corporation as a whole.

I. Planning Background – The Environment

The large simulation system which this paper describes was designed in response to an important change in emphasis in Xerox' management policy. Prior to 1969 the field operations of the corporation's Business Products Group had been directed, by and large, from its Rochester, N. Y. headquarters. That year, however, saw the beginning of a movement away from this 'top down' approach and the adoption of a philosophy of decentralized regional movement.

Decentralization involved the setting up of five distinct regional organizations in the U. S.—each with its own marketing, financial, distribution and administrative staffs (Figure I-1).

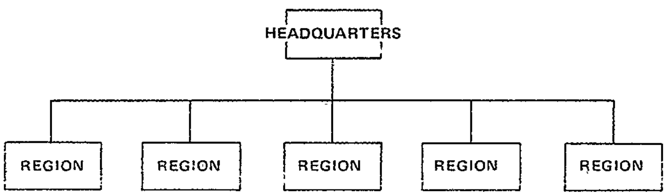

FIG. I-1 THE DECENTRALIZED ORGANIZATION

Among the functions which the new regions were called upon to perform was the development—within the policies and guidelines drawn up at the national level—of plans and targets for itself and for its component branches. The complexity of this segmented planning process was recognized at an early stage; with it came the realization that the introduction of a common and consistent methodology for each of the planning organizations was essential to the satisfactory execution of the planning cycle.

The problem then was to provide a means of supporting and guiding plan development in the regions, one which would allow for easy and immediate aggregation between branch and region and between region and headquarters, and one which would ensure that uniform and logical processes were employed by everyone involved. It was decided that this would be best accomplished through the use of a nationwide system of interlinked simulation models, and it was to meet the needs of this 'bottom up' philosophy that the present modeling system was devised.

The adoption of simulation models as a basis for the planning process did not represent a new departure for the Company: tried and proven modeling techniques for the development of forecasts and expenses had long been used at the national level[1,2] These techniques, however, had never before been implemented away from headquarters as part of a larger system nor had the technical and logistical implications which this raised received any thought prior to this time. The major problem, in short, was to arrange for the operation and interlinking of a whole series of simulation models, representing the revenue, expense and manpower activities of five distinct regions and over sixty separate branches at a number of computer installations across the country, and to provide at all times a means of consolidating and monitoring the results of these simulations at the national level.

Part II of this paper describes in more detail the simulation system; by way of introduction to the setting in which the various models are used it is useful at this point to give a brief overview of the nature of the business operation itself, and of some of the terminology employed.

The division of the corporation we are concerned with here is responsible for making, distributing, marketing and servicing the familiar copiers and duplicators. Its revenues are derived principally from rental and usage charges for these machines.

Not surprisingly, foremost among the objectives of the system is an accurate portrayal of the future revenues of the division: of equal importance is the estimation of allied expenses. Special prominence, therefore, is given to the sales and service functions within each region because these are the areas that directly impact the profit picture as the level of business activity changes; what is more, these are the areas that are under the immediate control of the regional organization. The manufacturing function, on the other hand, enters upon the scene only later in the planning cycle and tends to be regarded as an exogenous variable as far as the regional system is concerned.

As stated previously, rental and usage charges are the major revenue contributors and the dynamics of machine placement and utilization receives detailed consideration throughout the simulation process. Machines are installed at customer locations in response to orders taken by one of several categories of salesmen; these orders may represent new business or may involve the replacement (trade) of one product line by another. Likewise, removal of machines may be brought about either by outright loss of business or by the trading process just referred to. The trading mechanism, incidentally, is an involved affair: its accurate representation in model form is described in Section II of this paper and is a key feature of the simulation logic.

Machines may reach the customer through a number of routes (Figure I-2). They may have been supplied from branch inventory or from a nearby distribution center and they may consist of new, reconditioned or refurbished units (see below). The condition of a machine removed from the customer may be good enough for it to be put in working order (refurbished) at the branch itself; alternatively, a unit may be returned via the distribution network to the central manufacturing facility for complete reconditioning or, possibly, for conversion to another product line. Installed machines are serviced by technical representatives; the type of service performed may be scheduled (preventative) or prompted by a customer request (emergency). The same service work force, with the assistance of an outside contractor (rigger), is also responsible for the installation and removal of machines at the customer location.

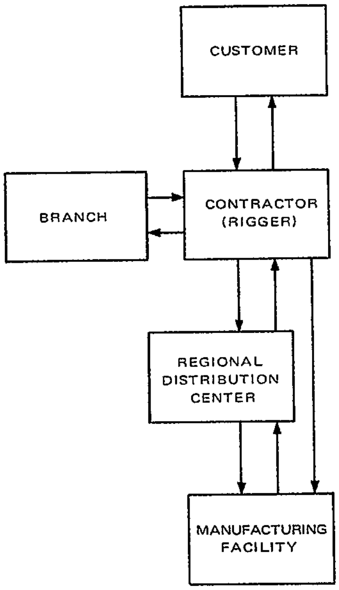

FIG. I-2 MACHINE FLOW

While the manufacturing operation itself is not explicitly modeled, the effects of its supply of machines to the system are. Thus, later in the simulation process, the repercussions of machine shortfall, the consequent impact upon order backlog, field inventory and so on, receive commensurate attention.

II. Modeling the Environment

The flow of data through the models closely parallels the flow of information in the operating environment. The main linkages of the models are shown in Figure II-1 in relation to the three major organizational units—Headquarters, Regions and Branches—which are involved in developing the regional operating plan.

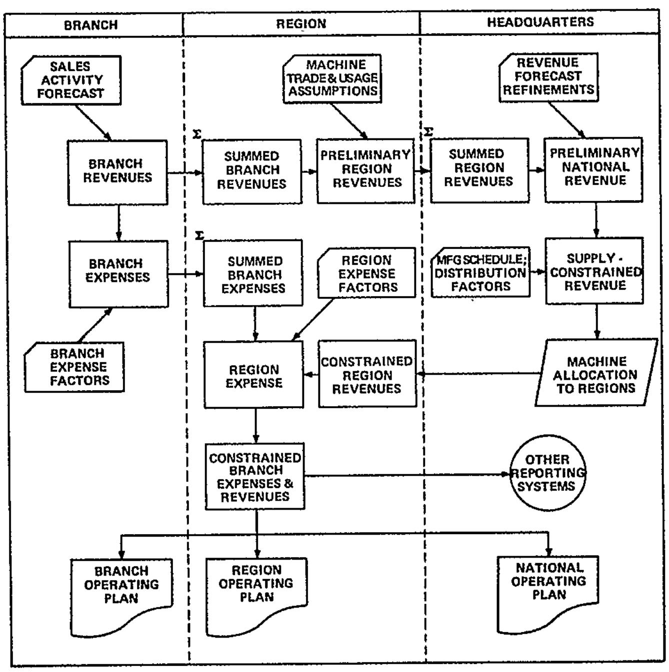

FIG. II-1 MODEL FLOW

It should be pointed out here that Figure II-1 is a gross simplification of the model systems network. The chart shows the main flow only; no attempt is made to show possible deviations, options, or cycling, all of which occur in the actual decentralized planning environment. A description of the modeling systems flow and the functions of each model in the system follows.

Model Flow

The **Branch Revenue** model is used by each branch manager to simulate the monthly revenue generated by his branch over a two-year planning horizon. The main inputs to the simulation model consist of initial machine populations and a sales activity forecast detailing expected new business orders, trade activity, order cancellations and installation cancellations. The model uses these inputs to simulate future machine populations. By applying revenue and copy volume input assumptions to the simulated machine populations, the model derives copy volume and associated revenue projections. The development of the sales activity forecast itself—admittedly a key factor in the simulation process—is performed outside the system and will not be discussed here. For the purpose of the model, sales activity is simply one of many input variables.

Branch Expenses fall into two major classes. On the one hand there are overhead items such as rental, utilities, supervisory salaries and the like which are largely discretionary and are not obviously related to branch activity: these items are input directly into the expense model. On the other hand there are expenses which bear definite relationships to order activity, machine movement and machine usage, and full recognition of these relationships is made within the model.

The variable expenses may be further subdivided into two categories, sales expense and service expense. Briefly, the development of sales expense rests upon the determination of the number of salesmen necessary to support the order forecast made by the branch manager.

Variable service expense contains both labor and parts components. Manpower requirements are derived from the determination of hours required for installations, removal and maintenance activities, while parts expense is expressed as a function of machine population and machine usage.

Aggregation of Branch Revenues and Expenses is performed by two essential summation routines, one for revenue, the other for expense. They perform the important task of aggregating the individual branch results into a total regional picture. As well as carrying out straightforward additions (eg., of numbers of orders, removals or branch managers), the routines also derive for the region weighted averages (eg., of salaries by manpower type) which are of immediate use as factors for the regional models.

The **Region Revenue** model initially resembles the branch model described above. As before, new business and trade orders—resulting in installations—and physical removals combine to modify the initial machine population.

In contrast to the former simplistic view of the population as a homogeneous mass, however, the concept of copy volume distribution is now introduced. Under this concept, the population is divided into a number of classes, each associated with a certain range of copy volumes, enabling class revenues—and hence total product revenue—to be developed according to the particular pricing plan in force at the time. The admission of distributions brings with it complications in the area of trade-outs, for now the population is no longer a uniform one. The problem is dealt with by classifying copy volumes into vulnerable ranges, each with a known propensity to trade.

Aggregation of Region Revenue is performed in a manner similar to the branch level summation. A necessary refinement is the weighting and summing of population distributions.

The **National Revenue** model follows the same logic as the Regional model. The more precise revenue forecast at the national level is derived solely from refinements of input assumptions.

The **National Constrained Revenue** model accepts as input the initial conditions and the customer demand from the unconstrained revenue model. It then recomputes machine populations along with their associated copy volumes and revenues based on machine availability as specified by the manufacturing build schedule, inventory factors, and in-transit requirements. In addition, the model simulates machine refurbish activity, in-process and finished goods inventory levels, order backlogs and lost orders.

The Regional Constrained Revenue model has as its input the manually allocated machine supply from the national constrained revenue model and the customer demand from the region unconstrained revenue model. The model functions in the same manner as its national counterpart.

The Region Expense model accepts as input the expense generating physical activities as well as the calculated revenues from the constrained model, aggregated branch expense factors from the branch summation routine, and specific expense variables peculiar to each region. The methodology employed in the development of regional expense closely parallels the way branch expenses are built up. The estimation of sales and service manpower requirements and the calculation of parts expense on a population/usage basis all follow the steps previously discussed as part of the branch subsystem.

The Allocation Subsystem performs four essential operations in the closing steps of developing an operating plan. Firstly, it examines all input for validity of budget center, product line and account codes; secondly, it allocates–if required–regional control totals to individual branches; thirdly, it produces region and branch revenues, expense, manpower and activity reports in full General Ledger detail; and fourthly, it provides direct linkages to other systems. Three of these functions are familiar and straight-forward operations, but the allocation process warrants additional comment. Allocation consists of redistributing to the branches all operating plan line items so as to match regional control totals. As Figure II-2 indicates, a proration technique is used to share the totals.

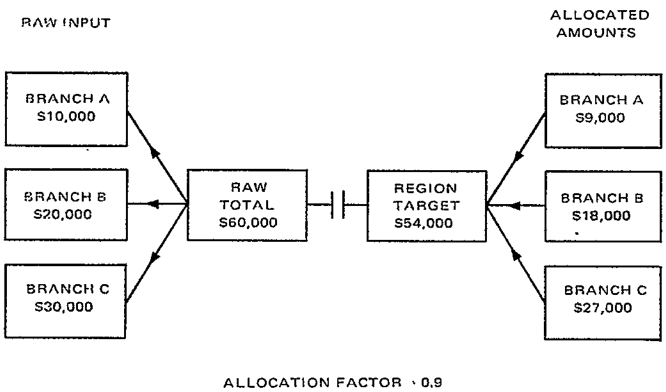

FIG. II-2 THE ALLOCATION PROCESS

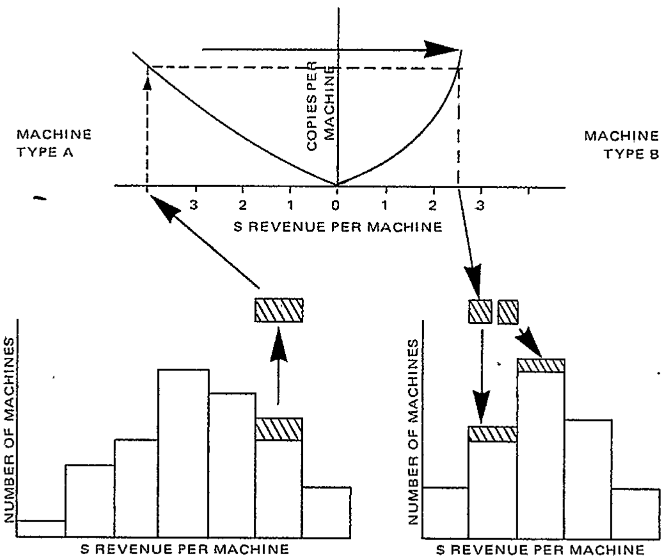

FIG. II-3 MACHINE TRADE LOGIC

Model Detail

A detailed discussion of the simulation logic in the models comprising the regional planning system is outside the scope of this paper. However, an indication of the level of detail at which the models operate and the extent to which the business environment is being simulated can be gained by examining one of the logic features contained in the Region/National Revenue Forecast model. With minor exceptions, the Company's machines are leased to customers whose monthly payments are based upon the volume and type of copies made. Due to a change in a customer's copying requirements, he may make arrangements to have his current machine replaced by one of the Company's other product lines. The propensity of a customer to trade is closely related to his copy volume or the revenue generated by the copy volume. The model accounts for machines on rental by population distributions which designate for each machine type the number of machines in each of fifty revenue categories. For any given machine type, up to twelve trade destination machine types may be specified. This is accomplished through a trade matrix which specifies the trade source and destination machine populations for all machines. Associated with each revenue range of a source machine population distribution are the trade propensities for all destination machine populations. The machine trade logic incorporated in the model is represented in Figure II-3. Each machine in a revenue category has a certain propensity to trade to some other machine population. Figure II-3 shows the machines trading from machine type A entering the price curve at their current monthly revenue level. The copies associated with this revenue level are determined via the price curve. This copy volume is then translated into resulting revenue according to the price curve for machine type B. The resulting revenue figure is then used to position the traded machines on the source population distribution so that their before and after trade copy volume will be equal.

The actual trade logic used by the model allows for some additional details and refinements such as instant copy volume growth and billed versus accrued revenue calculations. The reader can derive a fairly good indication of the level of detail at which the models operate by extending the same level of detail as presented in the above trade logic description to the remaining logic contained in the revenue forecasting model as well as the models making up the total regional planning system.

III. Use of the Models in Planning

The modeling system described above is capable of simulating as much as a ten-year planning horizon–the first three years by months, the last seven years by quarters. For the regional operating plan, it is found that a two- to three-year planning horizon is sufficient. At the branch and regional level a reliable projection beyond three years is difficult to obtain. This is brought about mainly by the small units with which a forecast at that level must deal and the drastic effect shifts in individual customer accounts can have at the branch and regional level.

At the national level the smoothing effect resulting from the accumulation of counteracting factors as well as a more precise set of forecast assumptions make a ten-year plan attainable.

The input to the models is derived from diverse sources. Sales and machine trade data are obtained from market research studies factored in relation to the local sales activity anticipated by branch sales managers. Expense and inventory factors are taken directly from operating reports, while the customer billing system is the source for the machine population distributions.

Revenue projections based on the models have been quite accurate. It is not unusual to expect less than one percent deviation between actual and forecasted revenues over a one-year planning horizon. Obviously, extrinsic market and economic factors as well as changes in company marketing strategy will cause the actual revenues generated to deviate from the forecast.

The projected revenues as well as the expenses developed at each organizational level are submitted to the next higher organizational level in the form of an operating plan. Each organizational unit is held accountable for deviations from this plan. All significant deviations are scrutinized by operating management through a monthly reporting system which compares actual to planned factors in addition to providing a second type of projection, an outlook. The outlook parallels the original forecast in format; however, it is adjusted each month to take into account the most recent developments impacting expected revenue, expense and activity at each organizational level.

The forecasts developed by the models are used in a wide spectrum of operating, planning and control functions either through direct feed to operating systems or indirect use of data in special studies. The models themselves find use outside the scope of the regional planning system in areas such as market and pricing strategy analysis, new product impact studies, manufacturing planning, and long-range profitability planning.

Management recognition of the models as a viable planning tool is evidenced by the degree and level of management involvement. Several organizational staffs have as their prime responsibility the operation of models and the analysis of results. This work constitutes an essential part of the planning function and includes the evaluation of alternative strategies.

IV. Technical Considerations

Throughout the design and implementation of the simulation system the constraints imposed by technical factors remained an important factor. The broad objectives which the system sought to meet were (properly) hardware and software independent while the system's structure and logic were of necessity greatly influenced by machine and language considerations. Some conflict was inevitable: the need at the branch level was for the simulation to be carried out as close as possible to the branch itself, at once promoting rapid turnaround and sustaining the interest of operating staff. At the regional and higher levels, in contrast, the time element was subordinate to the requirement for the more sophisticated approach described in earlier sections of the paper.

Branch simulations in the first year of operation of the system were performed at each region's data processing center, using equipment operating under DOS. To meet the core restrictions of this equipment, the model had to be of minimal sophistication. Moreover, since the experience of systems and data processing staff at the field installation was limited to business oriented languages, the decision was made to write the branch models in COBOL. This had the added advantage of expediting implementation and, to some extent, simplifying the maintenance process.

The requirement for a more comprehensive series of models at the regional and national levels called for a much larger computer, making the corporation's scientific computer at Rochester a natural choice.

FORTRAN was chosen as the programming language for several reasons: a staff of experienced FORTRAN programmers was available; a nucleus of operational models which enjoyed the confidence of planning management already existed; and a continuing high level of software support for the language was assured.

A year's experience with the total system has changed the picture to some degree. This is especially true in the case of the branch models where the need for improved compatibility in several areas soon became apparent. The differences in input requirements between the branch models and their regional counterparts complicated the preparation of input data. The intermittent demand pattern for machine time set up by the simulation models conflicted with that of regularly scheduled operating systems. The cumbersome interface between business and scientific computers discouraged cyclical iteration between branch and regional models. And, finally, the problems associated with the maintenance of modeling systems at several widely-separated field locations were found to have been greatly underestimated.

The development and implementation of branch models on the scientific computer in this second year of operation has solved these problems and shortcomings to a large degree. At the same time, the desire for decentralized operation of the models has been satisfied through the installation of a series of batch terminals linked directly to the central processor in Rochester.

V. Conclusion

The first year of experience of the simulation system revealed several areas where improvement was necessary, especially in the matter of compatibility between models at different levels in the system. With the introduction of communications linkages from the regions to the centralized processing facility, these problems have largely disappeared. At this point in time the value of the system has been essentially proven and it has achieved management recognition as a powerful planning and control device.

With the acceptance of the system, several extensions and enhancements of the planning mechanism are receiving consideration. One move is towards further simplification of model/user interaction; other areas which are being explored include the expansion of the system to other functional organizations. The introduction of more decision-making logic and the inclusion of optimization techniques at selected points within the system is also receiving close attention.

REFERENCES

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