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# OR PRACTICE IN PHILIPPINE BUSINESS: STATUS, PROBLEMS AND POTENTIALS*

by

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## Introduction

Operations Research (OR) invites a mixture of reactions from business managers — indifference, curiosity, awe, praise, and skepticism.

The simple-minded manager who pauses to examine the genesis of the term, readily concludes that OR is nothing more than research on the day-to-day operations of a company. Since he believes that no one knows more about the operations of his organization than him, he reacts with cold indifference. The manager who wants to keep abreast with new developments in business picks up a book on OR, or inquires about it from his friends in academia and in consulting. If his curiosity is superficial, he becomes content with knowing new buzz words that he can name-drop in a cocktal party. If he is learning how OR can be used to improve performance, he overcomes the awe that mathematical symbols threaten him with. The manager who understands the power and limitations of OR techniques appreciates their role in business decision-making. He praises their usefulness without building false expectations. The manager who does not understand the nature of OR, or who observes the drawbacks experienced in implementing OR projects, turns skeptical. He takes the attitude: "Show me first that it works in my company before I spend a single cent on it".

The paper attempts to shed light on what OR is about

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in the context of the Philippine business environment. It identifies areas of application of OR and describes actual applications under each area. It points out the potential for OR and the general problems that must be overcome to realize it.

A forthcoming paper will address the problems of how to successfully conduct an OR study.

## What Operations Research Is

Operations Research is the science of representing the structure of a real problem situation by a mathematical model in order to "optimize" performance. A basic OR model has four components: (1) a measure or a set of measures of the system's performance; (2) a set of controlled variables of the system; (3) a set of uncontrolled variables of the system; and (4) a set of relationships relating the controlled variables and uncontrolled variables to each other and to the measure(s) of performance.

A measure of performance indicates the extent to which resource inputs are utilized, or the degree to which output states of the system are attained. The measures may be expressed in physical units, in monetary amounts, in utility units, or in some indices of value. The improvement in performance that is sought may be stated in several ways: (1) minimize the use of inputs; (2) reduce inputs to specified cieling levels; (3) maximize outputs; (4) increase outputs to specified target levels; (5) seek a solution that gives a significantly better system performance than the present situation. It is essential that in seeking an improvement in performance, consideration be given to the cost of constructing the model, using it to find a solution, and implementing the results.

In cases when there is a multiplicity of objectives, the measures of performance must be combined to reflect the relative importance of the objectives.

The controlled variables are those factors in the system whose values can be set by management. On the other hand, uncontrolled variables are factors that are not under the control of management, within the context of the problem. Determining whether or not a variable is controlled is not always simple in model formulation. It sometimes happens that variables that management considered uncontrollable can in fact be brought under control, and that restrictions on variables considered controllable can be removed to make them uncontrollable.

The relationships among the variables describe the system. The functions may be linear or non-linear, deterministic or stochastic. The model parameters may be specified or estimated. The data sources for estimation may be accounting records, industry statistics or data generated by statistical sampling and estimation.

The functional relationships may be expanded to include constraints on possible values of the controlled variables. These may include resource limitations, legal restrictions, technical requirements, and policy constraints.

The form of the functional relationships, the number of variables and constraints (if any), and the specification of the objective function determine to a large extent the solution technique to be used. Of course, such considerations as the availability of a computer and computational software, the capability of the group of OR analysts, the cost of arriving at a solution, and the ability of the implementing group to use the results of the model play a significant role in choosing the solution procedure. Whatever approach is used, whether linear programming, Lagrange multipliers, goal programming, simulation, or a combination thereof, the solution consists of values of controllable variables determined from values of uncontrolled variables.

**What Is Not Operations Research**

Having discussed what OR is in so many words, it becomes a simple task to identify what is not OR.

Data processing is not OR. The creation, updating, and maintenance of data files for a management information system may provide the data source for estimating the parameters of an OR model, but do not constitute an OR process. There is a lack of accurate, relevant data at the level of detail appropriate for decision-oriented models. Gross simplifications and crude approximations are made. The OR practice is consequently hampered. Improvements in the generation and processing of data contribute to the advancement of the OR practice. However, OR modelling stands apart from data processing.

In the same vein, methods of statistical estimation and inference are useful in deriving the functional relationships of a model and in forecasting values of the uncontrolled variables. Multiple regression is the technique commonly used for such purposes. Estimated relationships and forecasts are components of an OR model. But since they are basically descriptive and do not seek to find improvement in system performance, they do not by themselves comprise an OR model.

Most of the classical industrial engineering methods, such as time and motion studies, work simplification techniques, and systems and procedures studies, do not belong to the OR arsenal. Indeed they have the same general objective as OR, namely to improve performance. Systems studies have the systems orientation that characterizes OR: that the activity of any part of a system has some effect on the activities of other parts of the system. But because the construct that these industrial engineering methods employ is not mathematical, they cannot be considered OR.

## The State of the Art

The OR practice in the Philippines started in the mid-sixties. As far as I knew, the first local OR group was in the Management Services Division of Sycip, Gorres, Velayo and Company (SGV). The OR technique that was making waves at that time was PERT/CPM.

OR practice in the Philippines began twenty years after the first industrial applications of OR in British nationalized industries (coal, electricity, railway), and fifteen years after the first conference on OR in U.S. industry was held at the Case Institute of Technology. Today, about five companies in the top 500 corporations in the Philippines have a group that regularly conduct OR studies. In the U.S., 44 percent of the top 500 corporations in 1970 had an OR department. The percentage can be conservatively projected to increase to 60 per cent in 1977. Many other U.S. companies use OR, but do not have an OR department. The Operations Research Society of America was formed in 1953| The Philippines does not yet have a professional society in OR.

The SGV OR group ceased to exist some four years after it was formed. An OR department in one of the largest Philippine companies was established with the assistance of a foreign consulting company in the early seventies. It still exists, and has the full support of top management. About five years ago, a large company put up a team of industrial engineers who did some OR work. This team became the forerunner of the OR group formed in early 1976. The other OR groups have been in existence for no more than three years.

## OR Applications

Appendix A gives a rundown of OR applications in Philippine business, both completed as well as those undergoing development. An attempt is made to cover a wide range of applications. The list is not exhaustive; rather, it is representative of OR modelling efforts in the Philippines.

The applications vary from simple to complex. Most of the applications require the use of a computer. Some of them use computer software packages like the PMS for project management, MPSX for mathematical programming, and FORESIGHT for financial planning. In many computerized applications, new systems are designed and new programs developed. A few of the applications are integrated systems consisting of a number of linked sub-systems. The development time for these applications take as long as five years. They also need frequent revisions and updating as old system parameters are redefined, or new ones are built in to the model.

The applications described in the appendix are classified as follows:

(1) Decision Analysis
(2) Project Management
(3) Inventory Control
(4) Production Planning
(5) Product Mix
(6) Physical Distribution
(7) Plant Site/Warehouse Location
(8) Financial Planning
(9) Other Applications

Decision analysis is a practical tool for generating and evaluating alternatives under uncertainty. It is finding its way into the tool kit of managers and their staff. Graduate schools of business, like the Asian Institute of Management, offer a course or two on decision theory and applications. An increasing number of Philippine cases on decision tree analysis are being developed. The applications in the Philippines are simple enough that recourse to computerization is deemed unnecessary. The structure it provides for generating alternatives and identifying uncertain events is considered to be its most useful facet.

Project management is useful to anyone involved in projects that have many activities and that utilize substantial amounts of resources. Companies involved in construction of buildings and infrastructure projects find PERT/CPM very handy. Some are using the computer to assist in monitoring the activities. Other are even going into computerized project cost accounting.

Inventory control and management is an area of concern common to many companies because substantial amounts of money are tied up in inventory, while at the same time, disruptions in operations and loss of customer goodwill result from inventory stockouts. Despite its recognized importance, only a handful of companies have operational inventory control systems. The main reason for this is the inadequacy of the inventory recording and accounting systems. The inventory records of many companies have inaccurate balances, negative balances even, and transactions are incorrectly processed. This in turn can be explained by deficiencies in the systems and procedures that affect the inventory system. To effectively apply OR modelling techniques for inventory control management, it is imperative that the systems and procedures that impinge on the inventory system be streamlined and the inventory data files be cleaned up.

Production planning models have great potential value in situations when the processes are fairly complex. However, the modelling effort required is often demanding, because many subsystems are involved. Production scheduling depends on soles forecasts and inventories of raw materials, work-in-process, and finished goods. Thus a production planning system tends to be integrative. Furthermore, frequent updating of the production schedules is usually necessary in order to effectively monitor the system. The memory requirements of computerized production planning systems are large. Simulation, and sometimes advanced mathematical programming techniques such as dynamic programming and mixed-integer programming, are the approaches used.

Product mix problems are more manageable than production scheduling problems. They can often be solved by linear programming. The determination of the optimum product mix can be modelled as part of a marketing strategy system. A variant of the product mix problem is the problem of determining the best ingredient mix of various types of feed.

Two related areas that have special significance in the Philippines because of its geography are in the realm of logistics: physical distribution and plant site/warehouse location. The many island groupings, the various modes of transportation, the restrictions arising from the inadequacy of pier and wharfing facilities, the variations in climatological conditions — they all contribute to the complexity of logistics operations and pose a challenge to innovative OR modelling.

Financial planning is a function common to all business. Money, or more precisely the sources and uses of money, is a common denominator among firms. A financial plan is needed when evaluating the financial implications of a capital investment, or of a strategic shift in policy, when making a project feasibility study, when applying for loans and tax exemptions or incentives, and when preparing the budget. The financial plan may be short-term, or long-term. It may be prepared for various levels in the organization — project, product, plant, department, division, company, and group of companies. Either because of the computational burden or the frequency of making the financial forecast, a computerized financial planning system is used.

Several alternatives are open: (1) use a generalized software package; (2) develop a model using a compiler (a user-oriented programming language) specifically designed for financial planning; (3) develop a model without the use of a software package nor of a special compiler. The only development time for (1) is the inputting of the data according to the format by the software package. Some packages can be bought from software companies at a very high price. Unless utilization is high, the purchase option is not cost-effective. An alternative is to contract the services of a consulting firm that has a package (the package may have been bought from software companies abroad, or developed by the consulting firm itself). The cost under this arrangement is relatively low. The drawback lies in the fact that the model that results is not tailor fit to the user's requirements.

For the second alternative, some development time is spent programming the model with the specialized programming language, like FORESIGHT. However, compared to the first alternative, the model is more application-oriented because most of the user specifications can be built into the program. There is more flexibility. The user has the option of buying the compiler for its own use, or of going to a service bureau that has the compiler and the technical people who can write programs with it.

Developing a financial planning system with no software nor compiler to start from is very costly. The cost may be justified not only by the computational burden that it relieves but also by its flexibility in meeting the user's own system specifications.

**Problems and Potential**

The value of an OR model lies in its usefulness, which has several dimensions — its capability to grasp the complex interrelationships, its comprehensiveness, the relevance for decision-making of the model outputs, the timeliness of the reports it generates, and the computational relief it provides. The potential for OR in the Philippines is high. After all, OR practice here is at least twenty years behind the U.S. For such a potential to be realized, managers in the Philippines must have a clear understanding of OR, must appreciate its value and must be convinced that the application is cost-beneficial. The cost of designing, developing, and implementing an OR model depends on many factors: (1) Technical expertise, which in the Philippines is hampered by the absence of a medium for exchanging ideas and concepts; (2) Problem orientation, which an OR practioner must have so that he would find problems in search of a solution, rather than techniques in search of a problem; (3) Data support, which is weak at the company level and sorely inadequate at the industry and national economy levels; and (4) Management skills in conducting the OR project from problem definition to implementation, which covers planning, organizing, interpersonal relations and communication. Cost over-runs and frictions among managers and OR specialists can be avoided if the conduct of the OR study is properly managed. As previously mentioned, a forthcoming paper will be devoted to the management dimension OR projects.

The potential for OR applications can be realized if the problems are overcome. To be sure, managers and their staff as well as the OR specialists themselves must go through an interactive learning process.

Appendix A

## OPERATIONS RESEARCH APPLICATIONS IN PHILIPPINE BUSINESS

### DECISION ANALYSIS:

* The service contract with a computer supplier was due to expire in three months. The suppliers announced that there would be a substantial increase in service fees, effective a month after, applicable to all new and renewed contracts. If a new contract was negotiated prior to the cut-off-date, the old lower rate would apply for the one-year duration of the renewed contract. The company was not very happy with the service of the supplier. On the other hand, it was impressed with the service rendered by a service bureau on an appliation done for the company. The problem the company president faced was whether to negotiate the contract with the supplier at the old rate, or to let it expire and go with the service bureau. The decision analysis focused on the generation of alternatives. Pertinent factors for consideration were: (a) whether or not the company could purchase the standard programs on accounting developed by the supplier, and for what price; (b) if the purchase option was out, or if the price was prohibitive, whether the service bureau could develop them in three months time without disrupting the operations of the company; (c) how much the service bureau would charge to develop new application programs needed in the near future. The EMV criterion was used in the formulation of the decision tree problem.

* A manufacturer of consumer products was confronted with a decision to immediately launch the distribution of a new product with limited test marketing experience, or to continue to conduct market tests. There was a high probability that its main competitor would distribute a similar product

on a nation-wide basis, but when that will be is uncertain. The first company that went nation-wide would eat into the market share of the other, but the negative effect could be tempered by aggressive advertising.

**PROJECT MANAGEMENT:**

* In the early sixties, a construction company involved in building a hotel hired a consultant to draw up a PERT network of the construction activities and determine the critical path. Because the network scheduling was manually done, updating was limited.

* Recently, a construction engineering company decided to computerize the PERT scheduling of all its projects, using the network processor of the Project Management System (PMS) package.

* A contractor involved in a multi-million project of the Government hired the services of a consulting outfit to design and develop a project management system that would monitor not only the activities but also the utilization of resources. The major component of this system would be a cost accounting system consisting of a labor distribution sub-system, a material usage sub-system, and an overhead accountability sub-system, that would keep track of costs by projects and consolidate tehm into the over-all accounting system.

**INVENTORY CONTROL:**

* A surplus inventory computational system was designed to assist management of a vehicle manufacturing company in maximizing the utilization of surplus inventory. The computational system determined the number of vehicles to be assembled per model that would minimize the total peso value of surplus inventory. A major constraint incorporated in this application was the predetermined total number of vehicles to be assembled. The computerized system allowed management to specify: (a) the number of vehicles to be assembled for some vehicles; (b) the number of models; (c) unlimited number of part items; (d) changes in basic input, such as unit price of the parts, usage, and desired total number of vehicles to be assembled.

* Economic Order Quantity (EOQ) and reorder Point (RP) levels were set for 300 items of equipment parts, accessories,

supplies and materials for a sugar refining company after an ABC analysis based on value and turnover was made. Usage data were compiled on a monthly basis for four years. Prior to implementation, a simulation of the proposed inventory system using historical data was done to validate the EOQ and RP parameters. It was found that substantial savings could have been realized if such a system had been existing then.. To implement the system, it was necessary to take a full physical count. Some items were missing; others accumulated rust and were scrapped. The inventory balances were then adjusted.

* A company decided to establish a computerized inventory control system for all items kept in stock for equipment maintenance purposes. The Monte Carlo simulation technique would be used to derive EOQ, RP, and Safety Stock (SS) levels for most of the time items in the inventory system. For item characterized by variable demands and variable lead times, samples were taken from historical records, frequency distributions were constructed, and the theoretical distribution that gave the best fit was determined. Sampling from these theoretical distributions of demand and lead time would be made to generate usage during lead time and its probability distribution. Using the generated data on usage during lead time, cost parameters, and annual forecasted demand rate (estimated by either Regression Analysis or Exponential Smoothing), the EOQ, RP, and SS levels would be computed.

## PRODUCTION PLANNING:

* A poultry production planning model was developed to determine how many grandparent hens should be maintained, and when, so that forecasted demand for broilers would be met. The mathematical model consisted of matrix difference equations that described the production process from grandparent hens to parent hens to broilers. Given an assumed number of grandparent hens, the number of broilers could be determined. A series of simulation trials were conducted until the number of grand-parent hens that produced a specified number of broilers was found.

* A model was designed to determine how much to produce at each of several bottling factories to be distributed to many warehouses. The objective was to minimize total production, inventory and transportation costs. The cost functions were

estimated from historical data. Sales forecast for the planning horizon and the cost functions were inputs of the model. The solution algorithm was based on partial differential equations and Lagrange multipliers.

* A combination of linear programming and simulation was used to derive the optimal production schedule that minimizes the total cost of producing and storing wires of different sizes and types, given constraint on machine capacity and demand.

* A system was developed for evaluating alternative operating flight schedules using traffic forecasts generated by time series forecasting techniques. All scheduled flights between any origin-destination combination were ranked on the basis of their weighted preference parameters, such as departure/arrival times, number of stops, aircraft types, etc. The traffic forecasts were allocated to the flight according to the ranking of the flights and other allocation criteria, such as average baggage per passenger, load factor per sector per aircraft type, fuel uplift/burnout per aircraft, etc. The traffic allocation computational program outputted the allocated traffic, unfilled flight sectors, and unallocated traffic. Different values of the allocation parameters were tried until the operating schedule that was deemed "best" was found. Then projected revenues and costs of the schedule was computed for evaluation.

**PRODUCT MIX:**

* A linear programming model was developed for a wood processing company to determine quantity of various product grades to be produced at each of seven processing subsystem: (a) logging operations, (b) veneer plant; (c) plywood plant; (d) sawmill; (e) plyboard plant; (f) log core sawmill; (g) dry kiln. The objective function to be maximized was total profit contribution. The constraints were on the available logs from the logging areas and from the log market, available volume of certain grades at certain logging areas, input-output relationships linking the processing sub-systems, capacities of the subsystems, sales potential, annual cut allowable by the government.

* A steel mill wanted to obtain the optimum product mix. The products varied in size, form, and type. Only the standard products were incorporated in the linear programming model

formulated to maximize contribution to profit and overhead. The model considered the processing time of each product at each production line it passed through, tonnage losses from one line to the next due to chemicals, trimmings and breakages, production line capacities, and shipout forecasts and restrictions. Complications in modelling from set-up times and costs that arose whenever there was a switch from one product to another were ignored. They would have to be reckoned with if the model were to be extended to production scheduling.

* A linear programming approach was used to derive the optimal ingredient formulation for different types of feed. Production costs were minimized. The constraints included the demand for different types of feed, the availability of ingredients, requirements of the different types of feed regarding protein content, malleability, and taste, and ingredient characteristics.

## PHYSICAL DISTRIBUTION

* A model was designed to produce weekly schedules of shipments from the plant to the many warehouses throughout the country that would meet expected demand at minimum cost. The cost function minimized was the sum of transportation costs, inventory holding costs, and stockout costs. The algorithm that was developed determined: (a) weekly sales forecast for each warehouse through an adaptive exponential smoothing technique; (b) the optimal shipping requirements based on the forecasts, on floor stock, and on computed safety stock; and schedules of shipments that take into account lead times and transport capacity of tractor-trailers, commercial shippin vessels and company-owned barges.

* Simulation was used to evaluate different alternative routing schedules for delivering known quantities of highly perishable products to various outlets. An optimization criterion was used to direct the simulation search for the best alternative, one that minimized transportation cost while satisfying the constraints on demand, truck capacity, and travelling time.

* An integrated petroleum distribution model was designed. It consisted of five sub-models: (a) tanker/barge fleet uti-

lization and schedule; (b) storage inventory control; (c) tank truck fleet utilization and schedule; (d) refinery production schedule; (e) demand forecasting. The schedule for the tanker voyages were based on many factors, among which were inventory levels at bulk plants, bulk plant characteristics, projected demand, refinery product availability and receiving, facilities, tanker characteristics and locations, and availability of barges. Tank trucks used to transport finished products from the bulk plants to the outlets were dispatched on the basis of volume sold, destination/customer location, tributary area, product compartmentation, tank truck ownership, and product availability. The development of this model was a long-drawn undertaking that is still in progress.

## PLANT SITE/WAREHOUSE LOCATION

* A model for warehouse expansion was developed. It determined how many warehouses to maintain, as well as when and where to locate them. The costs that were minimized were the inventory costs, trunking costs from factory to warehouse, and routing costs from warehouse to outlets or market areas. In the process of determining the warehouse decision variables, the optimal assignment of market areas to warehouses was also solved. Required model inputs were sales forecasts, distances from factories to warehouses and from warehouses to market areas, cost parameters, and candidate warehouse sites. A simulation iterative process was employed to find the best factory-warehouse-market area configuration.

* A simulation approach was used to determine the site for relocation of an operating center (the base of operations of linemen and other service personnel) that would service the southern part of Metro Manila and the cities and municipalities in the Southern Tagalog region. Relocation was deemed necessary because of the increasing difficulty in accomodating expansion in facilities and resources in the limited space of the existing operating center. Three schemes were considered: (a) a one-center scheme; (b) a two-center scheme with both centers located in a site other than the present one; and (c) a two-center scheme with one center remaining at the present site, and the other farther south. Twenty three sites were considered, and for each alternative an internal rate of return was computed. Savings were based on labor cost for travel, cost for the use of vehicle, fuel cost,

allowances, expenses for building repair and maintenance, salaries of additional personnel, and property tax. Investment consisted of cost of land, buildings, land improvements, and other facilities (additional tools, work equipment, communication, etc.). For each scheme, the alternative that yielded the highest IRR was found.

* The same problem on relocation of the operating center was formulated as a mixed-integer programming model, and solved by the branch-and-bound algorithm. The objective function minimized was the operational and service area of the service centers in the South Operating Zone. The annual travel cost from a center to a demand area was computed from allocated number of trips to the demand area and from the estimated travel cost per trip (taking distance, fuel cost, vehicle cost, and salaries). Yearly building costs were also calculated, and entered in the cost equation. The results did not differ much from the solution via simulation.

## FINANCIAL PLANNING:

* A model for project feasibility was developed in connection with applications for incentives granted by the Board of Investments (BOI). It was a tool for financially evaluating contemplated projects. Financial data were inputted and financial statements (balance sheet, and flow statement, income statement, and financial highlights) at the project level were generated. Different assumptions were tested, including the effects of BOI incentives.

* A long-term financial planning model was constructed for a large company to generate financial reports at the product, plant, division, and corporate levels. Basic financial data and assumptions were specified as input at the product level, and the model produced financial statements for the products were later consolidated at the higher levels. The model was capable of projecting up to 20 years. The computer program itself provided for sensitivity testing.

* A large conglomerate developed a financial corporate model consisting of three programs. The first program calculated volumes, sales, operating cost, cost detail items, and capital expenditures for 12 affiliates for a maximum of 24 years. Each affiliate could have up to ten functions, and ten products per function. Schedules of sales, cost of goods sold, and capital expenditures were generated. The second program

calculated the financial position of each company over the specified time, using a system of up to 40 simultaneous equations to solve some 160 variables. A option to consolidate any group of companies was provided. The third program was the report generator.

* A consulting outfit used a computer package (FORESIGHT) specifically designed for financial planning to write programs that were tailor-fit for its clients.

* A software package for financial projections was developed by a consulting firm over a four-year period. It was modular in design, incorporating different computational procedures as separate programs and methods of computation, and the corresponding programs in the package. The client was expected to specify its assumptions and methods of computation and the corresponding programs were retrieved from the computer library and linked together by the driving program. As new computational procedures were encountered, they were programmed and placed in the library. The package was oriented towards manufacturing firms. It did not have provisions for consolidation. Sensitivity analysis could be done only by re-running all the programs and printing routines whenever an assumption or input parameter was changed.

**OTHER APPLICATIONS:**

* A manufacturer of panties intent on pushing its new brand, Make-Love, wanted to know what media to use to maximize the reach-cost ratio over a three-month campaign given a budget of three hundred thousand pesos. The areas covered were Manila, Cebu, Bacolod and Davao. The reach-cost ratios of alternative media programs were computed and ranked. There were constraints that could not be incorporated in the computer program because they were either qualitative in nature, or were difficult to formulate mathematically. Nevertheless, they were used in sorting out some of the alternatives. For instance, it was believed that the effectiveness of advertising followed a curve with a saturation level. Consequently, it was not deemed prudent to have to flash the message more than once in a TV program, or to broadcast it too often whether in the same or in different stations. Thus, the ranked and screened alternative were manually picked out until the budget was exhausted.

* A linear programming decision model for multiple cropping

operations was designed to maximize net returns. It determined the optimal number of cropping periods into which a crop year could be divided and the optimum combination of crops to be planted in each cropping period.

The crops were four varieties of rice, corn, soybeans, sweet potatoes and onions. The model allowed for borrowing and transfers of capital resources from one month to another. Man labor and man-animal labor hiring activities were included. A choice between two types of land was provided: upland versus lowland paddies. The technical coefficients describing the input-output relationships were specified.

* An agricultural planning system to determine the optimal staggered multi-cropping scheme in a given planning horizon was in the process of model development. The question it addressed were: (a) what crop varieties should be planted at what time during the planning horizon? (b) how should the plantation area be apportioned to the various crops? (c) when should the different agricultural activities be conducted? (d) how much manpower and equipment support would be needed? The climatological forecasting system was first established. This was followed by a determination and evaluation of technical cropping schedules for each crop which would then be used in the formulation of the comprehensive system.

* In connection with the Tondo Off-Shore Development Project, a simulation model for integrated area development was developed. Local and foreign loan capital would be used to develop the area. Many decision variables were involved. The foremost question was: how many and what type of houses should be built so that the loans would be repaid from rentals in twenty-five years? A survey was first conducted to determine the number of families and their ability to pay. Different types of houses, single storey as well as multi-storey, were evaluated and their costs determined. Water systems, which were affected by the type of housing, were built into the model. The installation of utility equipment, the location of commercial centers, and the road network were also modelled. By a process of trial-and-error simulation, the best configuration was found.

* A comprehensive model for the integrated development of the Bicol River Basin was designed by the Asian Institute of technology, using the DYNAMO compiler. Some 16,000 variables were involved.