IMPROVEMENT IN THE BREWERY SYSTEM TO EXPAND THE BEER PRODUCTION CAPACITY: A DECISION SUPPORT MODEL

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ABSTRACT

This paper discusses a decision-support system model for the production capacity of Babeer. Babeer is a large corporation in Beerland which needs to control its beer operations. It is argued that this kind of decision support model helps managers of Babeer to analyse their corporate planning problems, especially in the making of decisions concerning all 21 of the beer factories.

Planning within Babeer must cover many fronts regarding the allocation of resources as well as the balancing of corporate activities. For example, the capital for capacity expansion will become increasingly more expensive, and capital requirements more difficult to predict: physical and political factors may limit the supply of raw materials; the relative costs of energy, transport, raw materials, labour and other factors will continue to change.

It is shown in this paper that managers can use decision support models to improve accuracy and efficiency in evaluating scenarios and answering hypothetical questions. For example, it is possible to plan production along a straightforward linear sequence; demand determines desired production, desired production determines expansion, and expansion determines investment.

Babeer is large enough to maintain a central OR group who are available to review this kind of model. Those who worked on the model have increased the number of variables and constraints included in the integer programme and they were satsfied that it would prove successful. However, the large amount of data that the model required as input made the chances of its success and survival very low.

Implementation and post-implementation evaluation is an important part of every OR model as these help managers to eliminate the risk and expense of actually implementing policies and then observe their possibly disastrous results. For example, in the study discussed in this paper, the model should have evoked adaptive quick responses that would enable the organisation to respond to changing environmental conditions. A more flexible model and proper methodologies and systems design would allow managers to concentrate their efforts on developing and testing all these different alternatives under changing conditions, rather than concentrating on a particular
model or technique.

KEY WORDS

Allocation Decision Analysis Decision Support Systems

Integer Programming Linear Progtramming Practice of OR

INTRODUCTION

This paper is a case study which discusses the difficulties in survival, of Operations Research models, in a flexible environment on time.

The need of capacity expansion in Babeer is a special case which involves a great number of variables, restrictions and constraints. In order to satisfy Beerland's national demand, the Babeer brewery system has grown very rapidly. Therefore, its management decision support has had to prepare for the complexity this growth involves. The alternatives are to expand or to close smaller old beer factories and/or to open new larger ones, which influences the strategy either to promulgate the Beerland monopoly of beer production or to export part of its production to neighbouring countries. This practical situation needs a very specific model in order to consider the real situation.

The Integer Programming model adopted here has become a central tool for analyzing the expansion problems of the beer factory. However, this model was highly sophisticated in covering the complex system in an underdeveloped country. The changing environment should have evoked adaptive, quick responses that the model did not in fact consider. This makes survival of the model difficult.

This paper underlines the need for a more flexible model as well as proper methodologies and systems design. As regards the capacity for planning, it is vital to analyse the overall performance of the company and provide the staff who way desire to do so with the possibility of contributing to strategic decision making. Systems analysis can be extremely valuable in helping management to analyse the complex interactions and effects among all the factories that make distributed planning important.

I. BACKGROUND OF THE FIRM

Babeer came into being through the merging of four separate companies. Today, all of the beer factories in Beerland belong to Babeer. However, the process of becoming a monopoly took time. Babeer had to find an opportune moment to buy its competitors' factories.

Since the late ´70s, Babeer's production capacity has been increasing constantly and there are several complementary industries which are dependent on its production: bottle, glass, labelling, caps, three malt and aluminium can industries. The employment it has generated, from the agricultural level (barley production) to the commercial level (retail distribution), and the taxes it pays have been very important to the Beerland national economy. Indeed, a percentage of the price of each of beer per bottle goes to the government to be allocated to hospitals and schools as well as rural area sanitation. The more beer you drink, paradoxically, the "healthier" your family will be.

II. THE PROBLEM: THE NEED FOR CAPACITY EXPANSION

Beerland's national demand for beer has grown at an average annual rate of 6.6% while its population (on average older than 15 years) has grown at 3.2% during the last few years. This implies a continuous increment in per capita consumption. Babeer's distribution network covers all of the major towns and cities in Beerland as well as many small villages. Further new markets have been explored, particularly premium markets, in which the products compete with other famous alcoholic beverages.

Top management is responsible for making decisions about total capacity expansion, such as the opening or closing of production, bottling or canning subsystems, equipment investment, change in labour force levels or any other modification which affects total system capacity. (However, augmenting beer demand implies a continuous increase in the total system capacity and high technological developments.) By how much, where, and how to increase the production and/or bottling capacities at minimum cost are major decisions of tactical and strategic planning in Babeer, which influence the strategy employed in the Beerland monopoly of beer production or export part of its production to its neighbouring countries.

The problem can be more simply stated as the need to balance production and demand. If the demand and the capacity are not balanced, expansion is necessary, especially when the difference between them reaches a critical level. Consequently, capacity expansion alternatives or projects across all of the breweries and periods of time must be evaluated according to production, transportation and investment costs and other technical constraints. The geographical and economic conditions in Beerland make transportation expensive. Therefore, it is necessary to have a large network of breweries around the country.

III. THE BREWERY SYSTEM

The Brewery system consists of production plant as well as bottling subsystems and agencies with all the relationships usual among them, such as transportation flows, capacities, costs, etc. In summary, the system has the following subsystems:

- 21 beer factories or production subsystems
- 21 container preparation or bottling subsystems
- 39 agencies or distribution depots
- five brands

A number of factors constrain the options that management can follow in attempting to counter possible problems. They are: political, space, time, demand, production costs, technical restrictions and transportation costs. Hence, the brewery system has approximately 4500 variables and 1000 constraints to be considered in the model.

Figure 1 shows the Babeer system as a network of nodes connected by direct links or pathways. The nodes correspond to demands by the distribution depots and sources of raw materials, both malt and barley; the links correspond to the flow of products between these points.

IV. THE MODEL

Adopted in the project was a Mixed Integer Programming (MIP) model involving a continuous and an integer part. Its continuity is associated with the production and distribution support module which guarantees the optimal environment from the brewery system operation. The integer part is associated with the capacity expansion alternatives and meets the major requirements of the global economic evaluation. Therefore, in the Babeer project the integer part was more interesting.

The time variable can also be considered with integer programming. Integer constraints were introduced to: guarantee the continuity of projects, detect a labour force net increment, control slack variables or

expressions of other variables according to the mathematical equations and to specify any contingency relationship between projects.

Two interface facilities were implemented: a matrix generator to introduce both basic and decision alternatives information to the optimisation package (MPSX-MIP/370) and a report writer to present results in the way that users require them. The matrix generator meets two main criteria: user-friendliness and flexibility. The first criterion implies that information as well as parameters and options be entered in an easy-to-use way. The second one implies that any of the above-mentioned decision alternatives with their possible contingency relationships can be included in the model.

Fig. 1 can be extended to include processes and sequences of processes at the nodes, that transform input products into output products. Such processes need not be limited to physical conversion; supply nodes can be viewed as points where barley is converted into raw materials and distribution nodes as points where final products are converted into revenue.

The following concepts can be simulated by the model: a planning horizon time, a project, a project comparison criteria considering the present value and the annual equivalent costs, investment alternative and the analysis horizon. In relation with the decision variables and decision alternatives the model is able to consider equipment investment, changes in manpower levels, system and/or subsystem closings, system and/or subsystem opening and decision timing based on the ideal and the actual capacity.

V. IMPLEMENTATION OF THE MODEL

The model discussed in this paper has become a central tool for analysing the expansion problems of the beer factories. With this model it is possible to plan production along this straightforward linear

sequence mentioned above: demand determines desired production, desired production determines expansion, and expansion determines investment.

The model should start with long-term projections of demand, cost, supply constraints, capacity restrictions and the other major factors that determine company policies, goals, objectives and the operating environment. Later, the model could be enlarged to include the process from the conversion of barley into raw materials to turning final products into revenue.

Technical

In a technical sense, the model needs to represent the real problem of planning for expansion and it should be at the same time a practical, robust, general- purpose management tool used to conduct accurate analyses of a wide variety of the company's planning problems, from strategic planning to the strictly tactical.

The model should be regarded as one segment of what should be called "The Capacity Expansion Process" the philosophy of which is summarised in three major steps: firstly, the methodology for formulating the capacity expansion alternatives for the breweries; secondly, execution of studies; thirdly, inclusion of alternatives arising from the studies in the model, which should be an interactive process. The results of studies and model should allow better recommendations for future studies. However, a learning system of the model was not considered.

People

The problem needs the attention of a multidisciplinary team over a period of time, which would make the implementation of the model possible. The expansion problem is the assumed responsibility of the production, marketing and operational research departments in the Company´s Head Office and

the individual factories. It is important to involve from the beginning the people who will be shouldering any responsibility within the model.

It is vital for different departaments to share the responsibilities, to define the various functions in each step of the implementation process, to define the control and efficiency measurement of the system and also to define how often to run the model in the computer and the activities necessary for bringing the model up to date. It is important to define each activity and link different functions and responsibilities before and after running the model on the computer. It is vital to explain to line managers that the model is a tool which helps them, especially those people previously involved in solving the problem manually.

Information

A logical and comprehensible model systematises the acquisition of data by defining the type and extent of data needed. With data specification it is important to have common units and measurements among the teams involved in the study. Given the data, the system should generate and optimise a model representing the total system. The resulting solutions should indicate optimal expansion, production, marketing and financial strategies as translated into labour, equipment and material plans. These different activities must be coordinated. It is important to mantain and have access to data bases to meet the specific requirements of the modelling system. The responsibilities of each department involved should be defined especially in relation to up-dating all the input data for the model.

VI. POST-IMPLEMENTATION OF THE MODEL

In the post-implementation stage, it is necessary to identify the questions that emerge as a result of the simulation and changing situation and for which the analysis and simulation should provide answers and

the assumptions inherent in the model. The definition of the model should have embraced all the relevant features of the problem and, at the same time, give maximum scope to the available analytical techniques. A flexible model with proper methodologies and systems design should allow managers to concentrate their efforts on developing and testing many different alternatives under changing conditions, rather than on one particular model or technique.

As regards planning capacity, it is vital to analyse the overall performance of Babeer and to make a global economic evaluation of the company's brewery system because of the complexity of the situation. Simultaneous projects may involve different levels of capital and human resource usages, may start at different moments of a planning horizon, may occur in different geographical places, may have contingency relationships among themselves and, may have been compared in the context of the best operation of the brewery system under each alternative. The complexity of the situation is further complicated by the possibility that some sort of a technological change may occur and certain assumptions may become obsolete.

Technical

The mathematical models could be extremely complex and take a large amount of computer time to apply. Although flexibility is the most important criterion it has to be limited to the maintenance of the computational efficiency of the matrix generator. To reduce the variety of the problem situations facing Babeer some special tricks and heuristic methods were used.

User manuals have been written to complement the user-oriented facilities. However, keeping the manuals up to date has been very difficult and has made it almost impossible to use the model at times. For example, the report writer takes the optimisation package output to select and present only the information required by the users.

The results of the model have been satisfactory regarding both its computer CPU time and its behaviour as a management decision support system. However, in relation to CPU time, improvements in MIP algorithms should be considered. Currently most of the CPU time (80% or more) is dedicated to obtaining the best integer solution on the optimal environment of the continuous part with an experimented branch-and-bound strategy.

People

Babeer is large enough to maintain a central OR group available to review these kind of models. Those who worked on the model have increased the number of variables and constraints included in the integer program and they were very proud of it. However, even with those enlargements the model is still at far remove from practicality and is very complicated to use. It is important to produce understandable results for managers. However, in most cases these evaluations have to be made by engineers and specialised interpreters of information in this format.

Information

The large amount of data that the model required as input made its survival very difficult. Major decisions depend on crucial information and gathering information is very difficult and expensive. There are a large number of expansion alternatives; establishing dimensions, and estimating investment and operational costs for capacity expansion alternatives is very complicated. For example, there is a large variety of equipment and technology with different specifications and service requirements, hand labour levels, specialised personnel utilities, etc.

The quality of data may also limit the usefulness of the model; if the data are poor, the solution obtained will necessarily be poor. Sensitivity analysis and scenario testing could help to point out

where the key uncertainties lie and thus assist in data refinement. It is important to have good estimates of data concerning production, transportation demands and expansion costs, and production capacities. Gaps in this information may produce an inaccurate and thus misleading result.

VII. RECOMMENDATIONS AND CONCLUSIONS

Over the past few years, the brewing industry has been changing rapidly. New equipment and methods permit more beer to be produced in fewer breweries. Top managers understand that the number and the expansion of breweries are functions of a large number of considerations, especially production and transportation costs. The control of these considerations and the efficient use of resources are central functions of management.

Implementation and post-implementation evaluation is an important part of every OR model. However, the model discussed in this paper helps managers to eliminate the risk and expense of actually implementing policies and to observe their possibly disastrous results; the changing environment should have evoked adaptive, quick responses that the model did not consider. Some of these changes include: the process of conversion of barley into raw materials to turning final products into revenues; the company has started to produce different products such as mineral water, tonic, carbonated drink; the expansion of the four largest factories has made the existence of the other beer factories redundant; the labour problems such as unemployment and strong unions which make it necessary to change the production of beer for substitute products in those expensive beer factories whith high production cost; the expansion of beer factories into different countries.

This kind of problem requires management to consider a large number of parameters and to balance them against each other according to a complicated network of constraints which may well be changing over time. Frequently, it is simply too complicated and the manager bases his/her decisions on the few

factors that past experience and present operating methods seem to show as being important. To gain acceptance for the decision support system, it is important that the initial problems to which the model is applied should be selected with special care in order to demonstrate the effectiveness of the system.

Systems analysis can be extremely valuable in helping management to analyse the complex interactions and effects that make distributed planning between all the factories important. The application of systems analysis to corporate planning should allow the manager to use modelling in a way that is effective. At the same time, modelling is important in providing the tools necessary for efficient resource management.

Top managers require a broad spectrum of overlapping methods and methodologies that can be easily generated, modified and aggregated to capture the structure of each problem at appropriate levels of detail. Initially, the model may represent the problem in very simple terms and it may subsequently be increased in complexity. As the complexity which the model is able to embrace is increased, it could possibly be expanded for use with different kinds of strategic decision-making, such as the integration of marketing activities, production distribution or warehouse location. Also, the model may be developed to include the barley fields, the malt factories, the beer factories and the distribution depots, thus achieving integration of the total system.

VIII. BIBLIOGRAPHY

Bender. Paul. S. Northup William. D. and Shapiro. Jeremy. F (1981) Practical modelling for resource management. *Harvard Bussiness Review.* March-April 1981. pp 163-173

Brown. R.W. Northup. William .D. and Shapiro. J.F (1981) Logs: An optimization system for logistic planning. *M.I.T. Working Paper*. January 1981.

Erlenkotter Donal (1975) Capacity planning for large multiallocation systems: Approximate and incomplete dynamic programming approaches. *Management Science.* Vol. 22, No.3. November 1975.

Morales Clemencia (1982) Distribution and expansion model for beer factories. *MSc. Operations research thesis*. Aston University, Birmingham, 1982.

Rosenhead. J. (1980) Planning under Uncertainty. 1. The flexibility of Methodologies. *J. Opt. Res. Soc.* Vol. 31, No. 3, March 1980, pp 209-216.

Rosenhead Elton and Gupta (1972) Robustness and optimality as a criterion for strategic decision. *ORQ 23.4* Dec. 1972. pp 417-431.

A Production Capacity Expansion Planning Model for the largest brewery system in Colombia (1983). *Bavaria. Planning Office. 1983*.