MODELLING A BIOTECHNOLOGY STARTUP FIRM

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ABSTRACT

The top managers of a biotechnology startup firm agreed to participate in a system dynamics modelling project to help them think about the firm's growth strategy. The paper describes how the model was created and used in order to stimulate debate and discussion about growth management.

There were several novel features about the process used for capturing management team knowledge in the model, and for representing unique structural features of biotechnology manufacturing and marketing. The paper highlights these novel aspects of conceptualisation. A heavy emphasis was placed on mapping the operating structure of the factory and distribution channels. In addition, much time and effort was spent on choosing model concepts and vocabulary suited to the business and to thinking carefully about units of measure and dimensions. Qualitative modelling methods (structural diagrams, long variable names and friendly documented algebra) were used extensively to capture the management team's descriptions of the business.

The size of the model (and partial models) was kept deliberately small to ensure the involvement of the management team. Simulation scenarios were designed to stimulate debate about strategic issues such as capacity allocation, capacity expansion, customer recruitment, customer retention and market growth. The paper describes how the management team was 'drawn-in' to using the computer to design and debate their own strategic scenarios. The paper concludes with comments on the impact of the project.

BACKGROUND

Bio Industrial Products BIP is a startup biotechnology company based in Southeast England. The company ferments, blends and packages naturally occuring microbes and sells them as commercial products. Among the company's product lines are grease cleaners used in the food service industry, silage additives used in farming and sewage additives used in waste water treatment. The top management team of the company agreed to participate in a system dynamics modelling project to help them think about the firm's growth strategy.

The modelling project focused particularly on commercial grease cleaning products which were the company's largest and fastest-growing product line. These products are intended to unclog grease that accumulates in drainage pipes of large commercial kitchens in hotels and fast food chains. Traditionally, powerful chemicals have been used to cut-through the grease in clogged pipes. But now biological products offer a gentler and more effective remedy. Kitchen staff receive sachets containing microbes and inert bran, much safer to handle than powerful acids or alkalis. They add the contents of the sachet to water and pour the mixture into the kitchen sinks. The microbes go to work, devouring the grease and so clearing the pipes. Moreover, it is possible for a colony of microbes to grow inside the pipes and so prevent future accumulations of greasy deposits.

Although the end use of the products is far from glamorous, there is potentially a large market for microbiological cleaning products, particularly given increasing public concern over food hygiene and chemical cleaning agents. Bio Industrial Products is a small company within this fledgling industry, with revenues of approximately £500,000 per year in 1987 and expected growth of 30 to 50 percent per year over the next 5 to 10 years (50 percent annual growth compounded over 10 years would lead to a company with revenues of approximately £30 million by 1997).

THE PROJECT TEAM AND THE EFFORT

An important part of the project was to involve the management team closely in building and using the model. Indeed our project was intended to explore how to structure the modelling process in order to secure involvement and commitment of the management team. Here the term 'process' includes the agenda of meetings, the composition of the project team, the use made of graphics and modelling symbols, and the use made of the computer and simulations (Andersen et al 1989, Richmond 1987, Vennix et al 1988).

The project team included the managing director, the head of manufacturing, the commercial manager (who was responsible for information systems and planning in this fledgling enterprise) and a new venture manager from the parent owning company.

These individuals are the strategic decision makers of the company; not technical specialists assigned to a modelling taskforce. The same group of individuals would be involved in any important strategic decision for the company.

The project team also included an experienced system dynamics consultant, and a model builder. The role of the consultant was to facilitate the project team meetings, and to act as an interface between the management team and the modelling technology. The role of the model builder was to create a working simulation model from an outline of model structure provided by the consultant and agreed by the project team as a whole.

The team brought together a unique combination of skills and knowledge that are a prerequisite for effective strategic modelling. The managing director, head of manufacturing and new venture manager provided a solid base of operating knowledge that included factory knowledge of how the products are made, marketing knowledge of how the products are distributed and sold, and industry knowledge of technology, customers, competitors, government legislation, and social trends. The consultant and the model builder provided facilitation and technical modelling skills. In addition, both the commercial manager and new venture manager had attended an intensive one-week introductory modelling course and were able to play an important and vital communication role at the interface between normal business debate, the model and model generated scenarios.

The project ran for a period of six months. During that time there were 5 half-day working meetings of the full project team. The consultant spent 10 days that included 2½ days in project team meetings and the remaining 7½ days in outlining the model structure and supervising the development of the algebraic model and model simulations. The model builder spent 40 days that included meetings, a fact finding visit to the factory, data gathering, mapping, equation writing, simulations and preparation for team meetings.

Tangible output from the project consisted of three STELLA simulation models (a factory model, a customer base model and a combined factory-customer model), a 37 page management report outlining the model and highlighting the major issues and recommendations from the project, and a 50 page technical report containing diagrams, equations and simulations of the three STELLA models.

CAPTURING MANAGEMENT TEAM KNOWLEDGE

Understanding and Mapping Sales and Distribution

BIP has a small salesforce that sells mostly to distributors rather than directly to individual commercial kitchens. The distributors themselves each deal with several hundred commercial kitchens and supply them with utensils, detergents, cleaners and paper towels.

BIPs sales and marketing expenses were high in relation to sales revenue. The managing director believed this high expense to revenue ratio was necessary to establish BIPs position in the market. The management team felt that, in the future, sales would continue to grow without further additions to sales and marketing expense, thereby reducing the expense to revenue ratio and improving company profitability.

But how can the business grow if sales effort is held constant? Is the product becoming 'easier' to sell? What are the limits to growth given the current size of the marketing and sales organization? These were the kind of questions the management team discussed with the help of STELLA (Richmond et al 1987) maps constructed from information gathered in an earlier team meeting (an expanded version of this paper Morecroft, Lane and Viita 1989 explains how the earlier meeting was structured).

Look at the lower left of figure 1 which shows the total marketing time available (TotalMktgTimeAvail). Suppose there are 80 marketing hours per month available (say 2 salesmen who spend 25 percent of their time in face to face meetings with distributors. The field salesmen are supported from central office by marketing and administrative staff). How does this selling time get used, and what volume of sales can it generate?

In figure 1, marketing time is divided between two principal activities: recruiting new distributors (MktgTimeToNewDist) and maintaining existing distributors (TotTimeToDistMaint). Let us assume, for the time being, that maintenance time (time spent dealing with distributors' product and supply problems) is very small. Then salesmen are free to spend most of their time recruiting new distributors. How do they win new recruits, and how long does it take?

A salesman must locate distributors and then arrange site visits to explain and demonstrate the product. A convincing demonstration is not a simple matter. You have to imagine yourself as a salesman. You appear at a site (a commercial kitchen, the customer of a selected distributor) with a handful of sachets full of harmless looking powder, claiming that it will improve drainage in the most grease-ridden pipes. You add some lukewarm water to your powder, to reactivate the microbes and pour the mixture down a slow-draining sink. Nothing obvious happens! Although the microbes go to work immediately it may be several weeks before they have consumed enough grease to noticeably improve drainage. Unlike strong chemicals, which often generate heat, gases and gurgling noises, the microbial product is silent and slow. But, in the long run it is much more effective! You can see that it is not an easy matter to win over the distributor.

The growth of distributors depends crucially on the time it takes a salesman to win a distributor. By studying company records of distributor growth the commercial manager

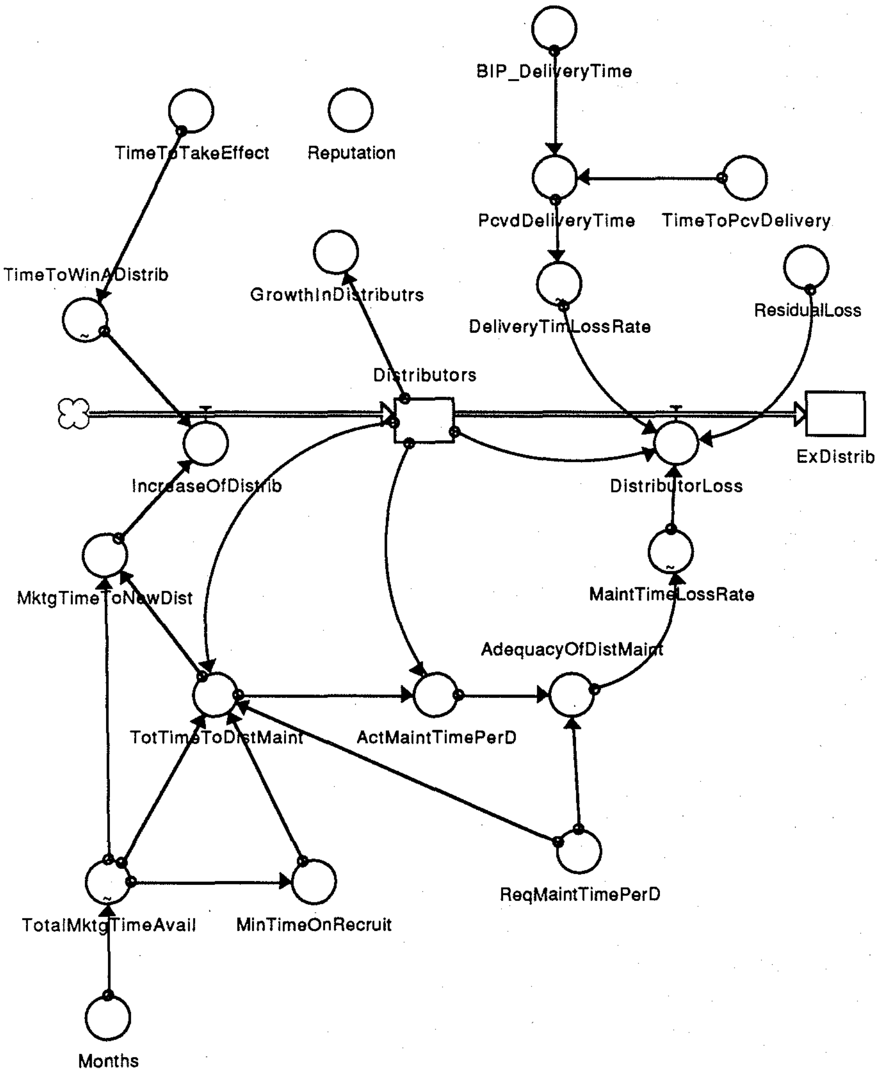


Figure 1 : STELLA Map of Marketing and Distributors

worked-out the average sales time (in hours per distributor) and found a number that was surprisingly high. So, it is reasonable to expect only modest growth in distributors, because the product is difficult and time consuming to sell. Later simulations provided a clearer picture of the growth rates possible under different marketing assumptions.

However, there is more to growth than just recruiting distributors. Once you have won them, you have to retain them. The model focused management attention on the factors that influence distributor loss. One important factor is distributor maintenance - the amount of time that salesmen spend dealing with product problems (e.g. incorrect application procedures) encountered by existing distributors. Figure 1 shows that distributor loss depends on the adequacy of distributor maintenance (AdequacyOfDistMaint) which in turn depends on the maintenance time, in hours per month, spent with each distributor (ActMaintTimePerD). The maintenance time per distributor depends on the total time allocated to distributor maintenance (TotTimetoDistMaint) and the existing number of distributors.

The diagram prompted two important lines of discussion. First, how in fact is marketing time allocated? How much time goes to recruitment and how much to maintenance, and who decides? What are the implications for growth of changing the time allocation, and say spending more time on (i.e. giving higher priority to) maintenance? Second, how important is maintenance to the distributors, or in other words, how sensitive is distributor loss to the amount of time salesmen spend dealing with distributor problems? The process of developing the algebraic model gave more precision to these questions, and simulations (discussed later) gave the team the ability to see the consequences of different assumptions about the sensitivity of distributor loss and changes in time allocation.

Distributor loss also depends on BIP's delivery time. The management team felt that a delivery time of 2 months was acceptable to distributors. If the delivery time were to become much longer, say 4 months or 6 months, then eventually some distributors would become dissatisfied with the product (despite its effectiveness as a degreaser) and cease to stock it. Figure 1 shows that distributor loss depends on delivery time loss rate which in turn depends on the delivery time perceived by the distributor (PcvdDeliveryTime). Nobody in the management team knew exactly how sensitive distributors might be to delivery. The diagram simply brought the issue into the discussion. Developing the algebra forced more careful thought about distributor sensitivity, and simulations allowed the team to see the consequences of different sensitivity assumptions.

Delivery time is a particularly important factor to consider, because it couples the market to the factory. If the factory for some reason falls behind on deliveries, then eventually poor delivery will accelerate distributor loss and restrain the growth of the distributor base.

How the Customer Base Grows

Figure 2 shows the customer base. The box in the middle labelled Repeat Customers represents all the commercial kitchens that have tried microbial degreaser, think it effective, and are placing regular repeat orders with distributors. Customers increase through the sales and marketing effort of distributors. Distributor salesmen have to demonstrate the product and win-over kitchen managers in much the same way that BIP salesmen first convinced the distributors. The diagram shows that the increase of customers depends on the number of distributors.

Each distributor serves a base of several hundred customers. It takes time to introduce the product to the entire customer base. Distributor salesmen select a few kitchens at a time and fit in site visits and demonstrations alongside their other selling and support tasks. Each distributor wins-over a certain number of new kitchens per month (represented in the figure by CustPerDisPerMnth). This number of conversions decreases as the product's time to take effect increases.

Repeat customers decrease for two reasons. Some customers (a small percentage per year) drop out because they find the product difficult to use. Other customers drop out because the distributor that supplies them stops ordering the product and offers a conventional chemical alternative.

Zooming-In on the Factory

Production of microbial products differs in important ways from the production of normal material products. The model forced the project team to think hard about the unique features of microbe production and to discover their strategic business implications (see Lyneis (1980) for examples of conventional production models).

A microbe factory uses fermentation vessels to brew batches of microbe-rich liquid. You can imagine the vessels as large metal containers, supported on frames with pipes and wires entering and exiting. Each day the fermentation vessels are filled with a fresh charge of liquid and 'starter' microbes. The microbe population is allowed to grow in the liquid medium for 24 hours. The batch is then drained off and the microbes are separated using powerful centifuges. The resulting precipitate is transferred into trays which are placed in ovens for a low temperature bake. The baked microbes are then blended (the factory can produce several different strains) mixed with bran, and packaged into sachets ready to be shipped as finished product.

One remarkable feature of microbe production is that factory capacity is difficult to gauge - in fact informed opinion put the factory's theoretical maximum output at several times the current output! Clearly the range of production that is possible from a given set of fermentation vessels makes capacity planning much more difficult than in conventional production processes. But where does this range of production come

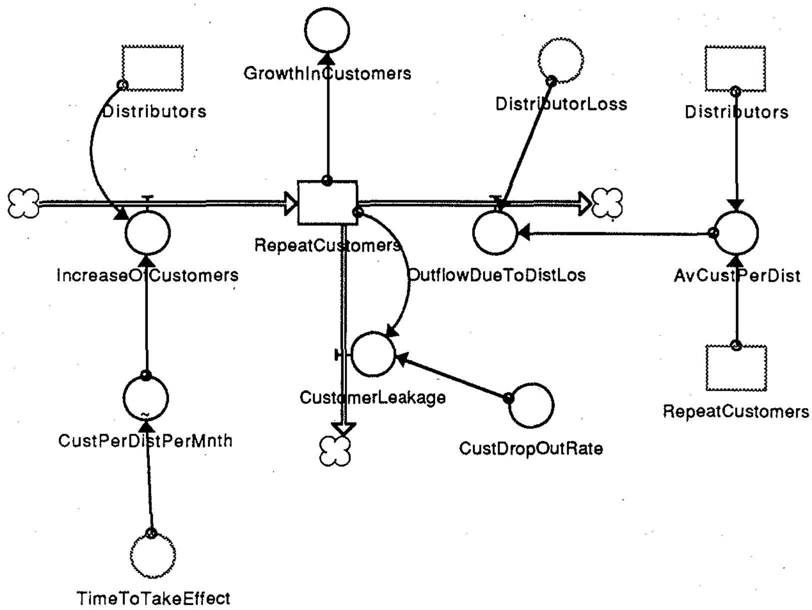


Figure 2 : STELLA Map of the Customer Base

from? By working closely with the factory manager, and visiting the factory, it was possible for the modellers to capture and represent microbial production and share the insights with the management team.

Figure 3 shows a STELLA map of BIP production. The current output of finished product (BIP-Production) depends on fermentation capacity, the number of batches run per month, microbe yield and agreed bug density. Here, fermentation capacity is thought of as the capacity, in litres, of the existing fermentation vessels. The yield of the fermentation vessels is measured in terms of the number of microbes grown per production batch (in thousands of billions). Finished output is measured in terms of kilograms of finished product (microbes plus bran) produced per month. The microbiological and blending processes that convert litres of liquid first to microbes and then to kilograms of finished product, reveal why factory capacity is so uncertain.

Microbe yield measures the number of microbes produced per litre of fermentation capacity. But yield depends on manufacturing conditions and factory workers are still learning how to improve the conditions. The factory manager believed that the maximum theoretical microbe yield was considerably higher than the current yield.

Bug density measures the number of bugs that go into each kilogram of finished product. What concentration of bugs do you need for the product to work? For a microbial product there are widely differing opinions because the microbes reproduce when put to work in greasy pipes, so that only a 'seed' colony need by applied. The product works at both low and high bug densities. However, at very low bug densities it takes a long time (though no one knows for certain how long) for the product to cause a noticeable degreasing effect. Conversely at very high bug densities the time to take effect is lower. The current bug density (shown as Agreed Bug Density in the diagram) is considerably larger than the minimum theoretical bug density. In other words factory output could, in principle, be increased by cutting the bug density from its current value to the minimum theoretical.

The diagram shows two different measures of plant output. On the right hand side is BIP Production which comes from multiplying Fermentation Capacity, Batches Per Month, Microbe Yield and Agreed Bug Density. On the left hand side is Theoretical Plant Output which comes from multiplying Fermentation Capacity, Batches Per Month, MaxTheorMicrYield and MinTheorBugDensity. In the model, theoretical plant output is much higher than current output - because it is boosted by the possibility of higher yield and lower bug density.

What are the strategic implications of this potential boost to factory output? One implication, of particular significance to a growing company, is the difficulty of gauging when and by how much to expand capacity. In most factories it is clear when extra capacity is required (not always though; Forrester 1968 provides a good counter example). Backlogs are rising, inventory is falling, forecasts exceed current capacity, delivery times are rising. In microbe production all these signals are available. But they are overshadowed by the fact that production can expand substantially by

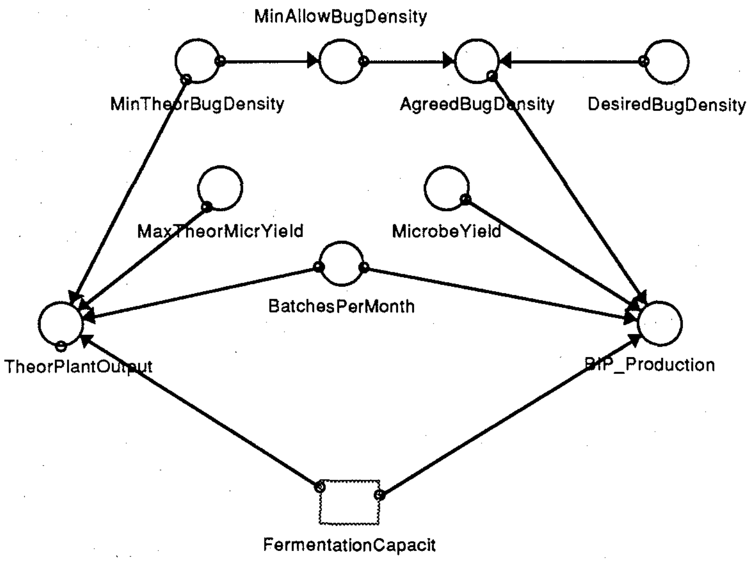


Figure 3 : STELLA Map of Production - Actual and Theoretical

raising yield or decreasing bug density. The need to add new fermentation vessels is less obvious and less pressing.

Figure 4 is a STELLA map which captures the uncertainties of capacity planning in a microbe factory. The signal for capacity expansion is adequacy of capacity which measures plant output in relation to required production (BIP - ReqProdn). Here required production depends on the backlog of orders and the company's target delivery time. When the backlog is high then required production is high. The relevant measure of plant output is the output that is believed possible (PlantOutputBlvdPoss) by the management team. This number is a matter of judgement but lies somewhere between the theoretical plant output and current output (shown as BIP - Production). The management team's judgement is the consensus deriving from the weight of opinion in favour of the theoretical output versus current output.

The factory model provided a forum to discuss the special characteristics of microbe production and to address the fundamental question - does the factory have enough capacity? The managing director took a special interest in bug density - how and by whom is it determined, is it really possible to dilute bug density so the factory can handle short-term (or even long-term) capacity shortages? What are the production/marketing tradeoffs in using bug density as a lever in capacity management? How sensitive are distributors and customers to the strength of the product? Simulations of the model (in the fourth and fifth working meetings) enabled these questions to be explored and discussed in depth.

The management team also talked about microbe yield. What R&D efforts are being made to improve yield? What is the priority given to the R&D budget? Should the budget be larger? What would be the likely payoff in terms of yield and improved understanding of the product? (Notice that the STELLA map does not have to explicitly include R&D in order for R&D budgets and priorities to be discussed by the management team. The map (and the simulation model) are triggers for a wide-ranging dialogue in the team).

Use of Documented Algebra

For most of the project, the management team 'saw' the model as STELLA maps. However, occasionally the team 'took a look inside' the STELLA icons to see the model's underlying algebra.

There is no reason why algebra should not be an integral part of a management team dialogue - providing the algebra is 'friendly', meaning that it can be read, uses phrasing that the management team is familiar with, is well documented and organized with a clear visual layout. These criteria for 'friendly algebra' may sound like 'motherhood and apple-pie'. But they are of vital importance in models used for communication. Moreover it takes real effort and discipline on the part of the modellers to write algebra that obeys the criteria.

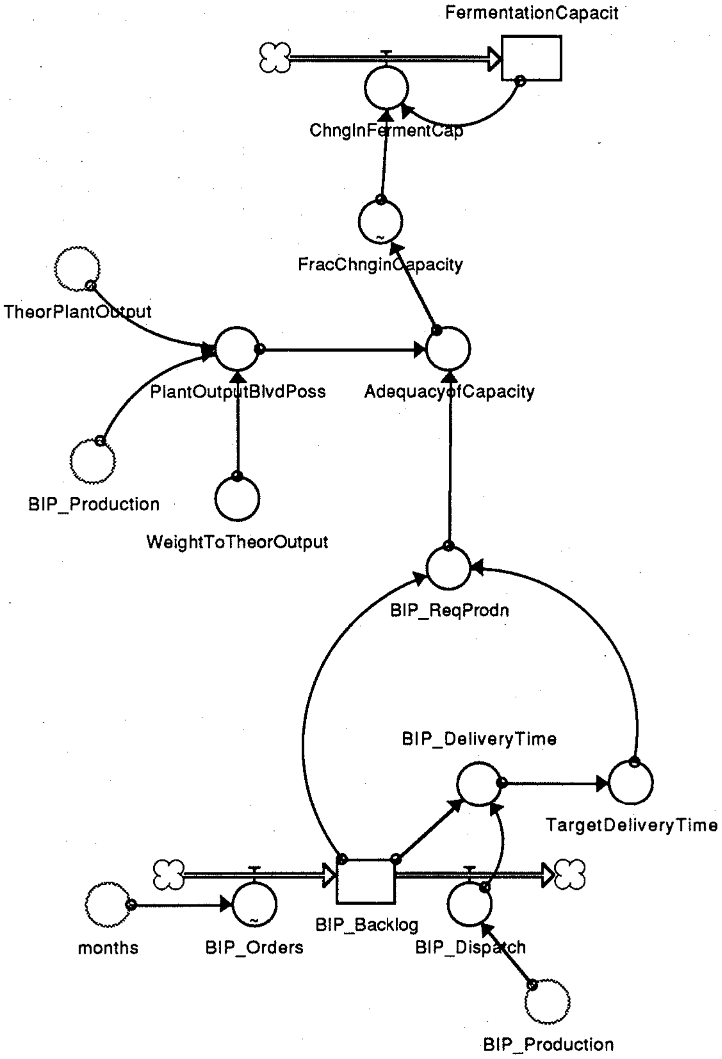


Figure 4 : STELLA Map Of Capacity Expansion

Figure 5 shows the algebra corresponding to the STELLA map of the factory in figure 3. There is not space here to explain every equation. However, look at the visual layout and 'readability' of the algebra. Each equation is made up of straightforward plain english phrases (the variable names), numerical values, and simple algebraic operators (multiply '*', divide '/', '='). Each equation is followed by a brief note that explains the meaning of the left-hand-side variable and its dimensions. The modellers used these notes to store important numbers and other pieces of information and deliberately tried to make any comments have a 'chatty' style.

For example, Microbe Yield (at the centre of the page) is explained as the 'number of bugs produced per litre of capacity per batch, averaged across all strains and all fermentation vessels'. Just below, MinAllowBugDensity is explained as the 'minimum bug density, measured in number of bugs per kg of finished product, that management is willing to allow in its products'.

The algebra, when used with the STELLA map, brings additional clarity to the team discussion, forcing people to think carefully about microbial production processes, and establishing the factory manager's terminology as a part of the team's vocabulary.

SIMULATION SCENARIOS AND MANAGEMENT TEAM INSIGHTS

The modellers designed simulations around a series of strategic issues. The customer base model (figure 1 and 2 combined) was used to examine sales growth and marketing time allocation. The production model (figures 3 and 4 combined) was used to explore capacity shortages and production parameters (yield and bug density). The combined customer base-production model (which included a financial subsystem) was used to explore the supply demand balance in a growing business and the sensitivity of distributors to poor delivery times. (Such a progression, from partial model to full model simulations, is designed to improve understanding and communication of a model (Morecroft 1985, Sterman 1985)).

Simulations were the centrepiece of the fourth and fifth working meetings. The meetings lasted for four hours each. The modellers spent the first ½ hour reviewing the STELLA maps to refresh the team members' memory of model structure and vocabulary (bear in mind that intervals of one or two months separated team meetings). The remaining time was divided equally between discussions of pre-prepared simulations and new simulations proposed by the management team.

A computer was installed in the meeting room to allow instant simulation. This real time use of the computer proved to be popular with the management team and was certainly effective at drawing people into the discussion. For example, the managing director was curious about the relationship between bug density, capacity and sales growth, and proposed several simulations with different bug densities. The commercial

FermentationCapacit = FermentationCapacit
INIT(FermentationCapacit) = 'A'
{Weighted average in litres per batch for the existing fermentation vessels in the factory initially}

AgreedBugDensity = MAX(DesiredBugDensity,MinAllowBugDensity)
{The agreed number of bugs to produce a Kg of finished product. Must be greater than or equal to MinAllowBugDensity}

BatchesPerMonth = 'B'
{Batches produced per calendar month}

DesiredBugDensity = 'C' {The bug density the factory and management would like to use given the prevailing production pressure. Measured in thousand-billion bugs per Kg of finished product}

BIP_Production = BatchesPerMonth*FermentationCapacit
*MicrobeYield/AgreedBugDensity
{The mass (Kgs) of finished product produced per month.}

MaxTheorMicrYield = 'D' {Maximum number of bugs that could possibly be produced per litre of capacity per batch under ideal manufacturing conditions: yield = max laboratory value : compare with 'E' below}

MicrobeYield = 'E' {Number of Bugs produced per litre of capacity per batch -- averaged across all strains and all fermentation vessels}

MinAllowBugDensity = MinTheorBugDensity* 'F' {'F' > 1 Minimum bug density, measured in number of bugs per kg of finished product, that management is willing to allow in its products. Must be a multiple of MinTheorBugDensity}

MinTheorBugDensity = 'G' {Minimum theoretical bug density, measured in number of bugs per Kg of finished product, that could be used in a product}

TheorPlantOutput = BatchesPerMonth*FermentationCapacit
*MaxTheorMicrYield/MinTheorBugDensity {The maximum mass (Kgs) of finished product that could theoretically be produced per month under ideal operating conditions and with perfect product knowledge}

Figure 5 : Friendly Algebra Representing the Factory
(numbers omitted for confidentiality)

manager was particularly interested in customer and distributor loss and proposed simulations that involved changes in marketing time allocation.

It is impossible to show all the simulations used in 8 hours of management team meetings, or to review the full range of topics discussed. Instead, a few simulations are presented in order to give the 'flavour' of the meetings. (Readers should note that, for ease of presentation, the simulations shown here are not the originals used in the meetings. They are made from edited versions of the real company models. Also, for confidentiality, all financial variables have been removed).

Limits to Growth from the Sales Force Size

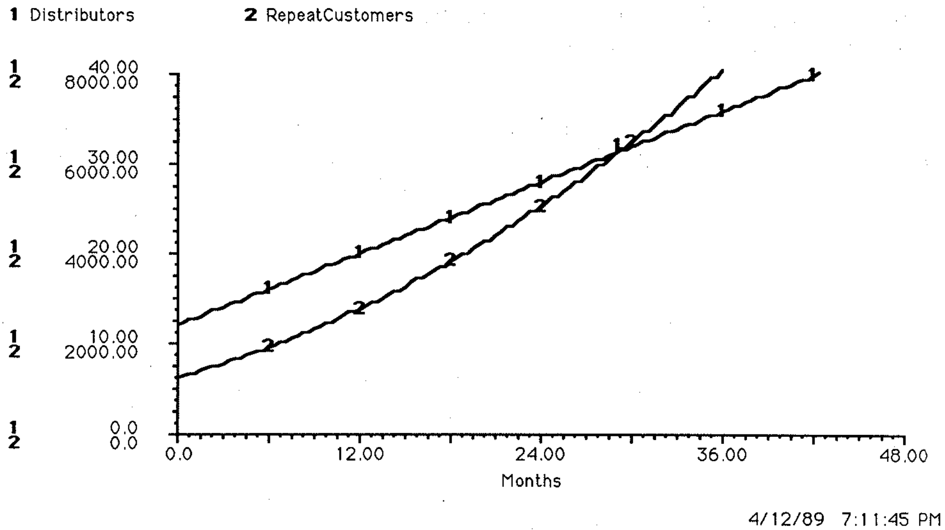
Can the market grow without proportional growth in the sales force and sales expense? Understanding this question is vital if company profitability is to improve alongside market size.

Figure 6 shows an optimistic growth scenario in which 100 percent of marketing time is allocated to distributor recruitment and there are no losses of distributors or customers. The top half of the figure shows the number of distributors and the number of repeat customers plotted over a 48 month time horizon. The lower half of the figure shows the annual fractional growth rate of distributors and customers.

The simulation starts with 12 distributors and 1250 repeat customers. The number of distributors grows linearly (reflecting the steady recruiting efforts of the fixed sales force) reaching more than 30 by month 36. Interestingly the number of customers grows more quickly, because customers are recruited in proportion to the number of distributors, which is steadily increasing. By month 36 there are more than 8000 repeat customers!

The simulations show there is a basis for optimistic sales growth opinions. Despite the long selling time and the need to restrain marketing costs, it is possible (admittedly under ideal conditions) to generate healthy growth of the customer base that averages around 50 percent per year for 4 years! A fixed sales force that leverages its effort through a distributor network can reach a large customer base.

There are however limits to growth of a fixed salesforce, even under ideal conditions. The lower half of figure 6 shows a steady decline in the growth rate of distributors and customers after month 24 (growth rate here is defined as an annual fractional increase). What is happening, and is the trend likely to continue? The growth rate of distributors (line 1) is bound to decline since the fixed salesforce recruits a constant number of distributors per month which is a declining proportion of the growing distributor base. But surely extra distributors will guarantee a high and sustained growth rate of customers? Strictly speaking the answer is no. The distributor network only guarantees that, in the long run, the growth rate of customers exceeds the growth rate of distributors (line 2 above line 1). Both growth rates eventually decline as (intuitively)



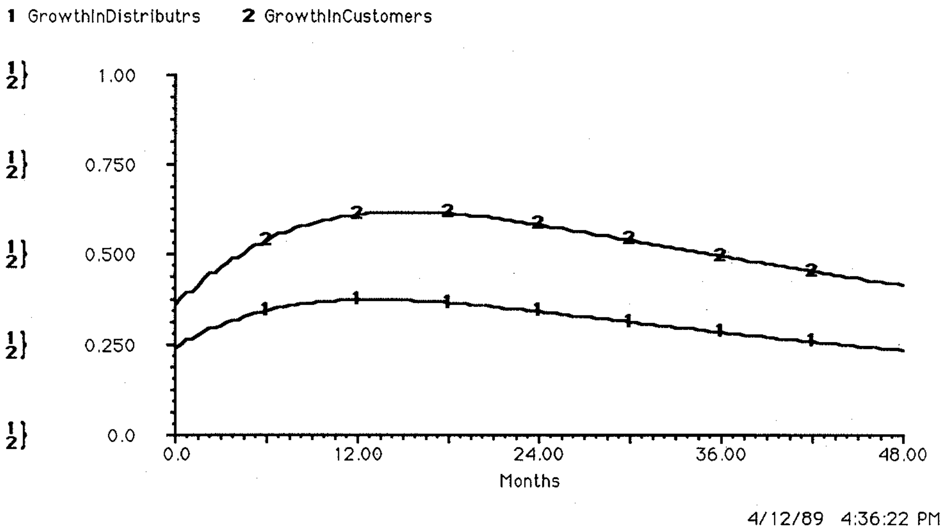


Figure 6 : Optimistic Growth Scenario

distributors (line 2 above line 1). Both growth rates eventually decline as (intuitively) the efforts of the fixed salesforce become proportionally ever smaller relative to the market size. However, for all practical purposes, a fixed salesforce operating through a distributor network (with no losses) can sustain a high growth rate of sales. A 96 month (8 year) simulation shows the growth rate of the customer base always remains above 25 percent per year.

Limits to Growth from Distributor Maintenance

The previous simulation, in figure 6, shows the upper limit to BIP's growth rate assuming that distributors require no 'handholding'. Distributor maintenance however is a fact of life and puts practical limits on the market size possible to sustain with a fixed salesforce.

Figure 7 shows a scenario in which the sales force allocates 50 percent of its time to recruitment and the remainder to distributor maintenance. The scenario also assumes that distributors will stop stocking the product if they feel they are being neglected by the salesforce (questions not answered, phone calls not returned promptly, few site visits). In addition, 1 percent of distributors and 1 percent of customers are assumed to drop-out each month due to unexplained loss of interest in the product.

By comparison with figure 6, the annual growth rate of distributors and customers is, on the average, 25 percent lower during the 48 month simulation! The result through compounding, is a much lower customer base - about 3000 customers in month 36 versus 8000 in month 36 of the optimistic scenario.

The simulation focused management attention on the importance of distributor and customer retention - a topic that previously had not been appreciated. Discussion centred on marketing time allocation (the priority given to distributor recruitment versus maintenance) and on the sensitivity of distributors to maintenance (how much handholding do they really need?). Interestingly, the team members did not wrangle over the numerical accuracy of the simulations (e.g. will the customer base be 3000 or 2500 in month 36?).

Limits to Growth from the Factory

Unfortunately there is no space in this paper for factory simulations. However, the simulations (which provided important insights into capacity constraints on growth) are described in Morecroft, Lane and Viita 1989.

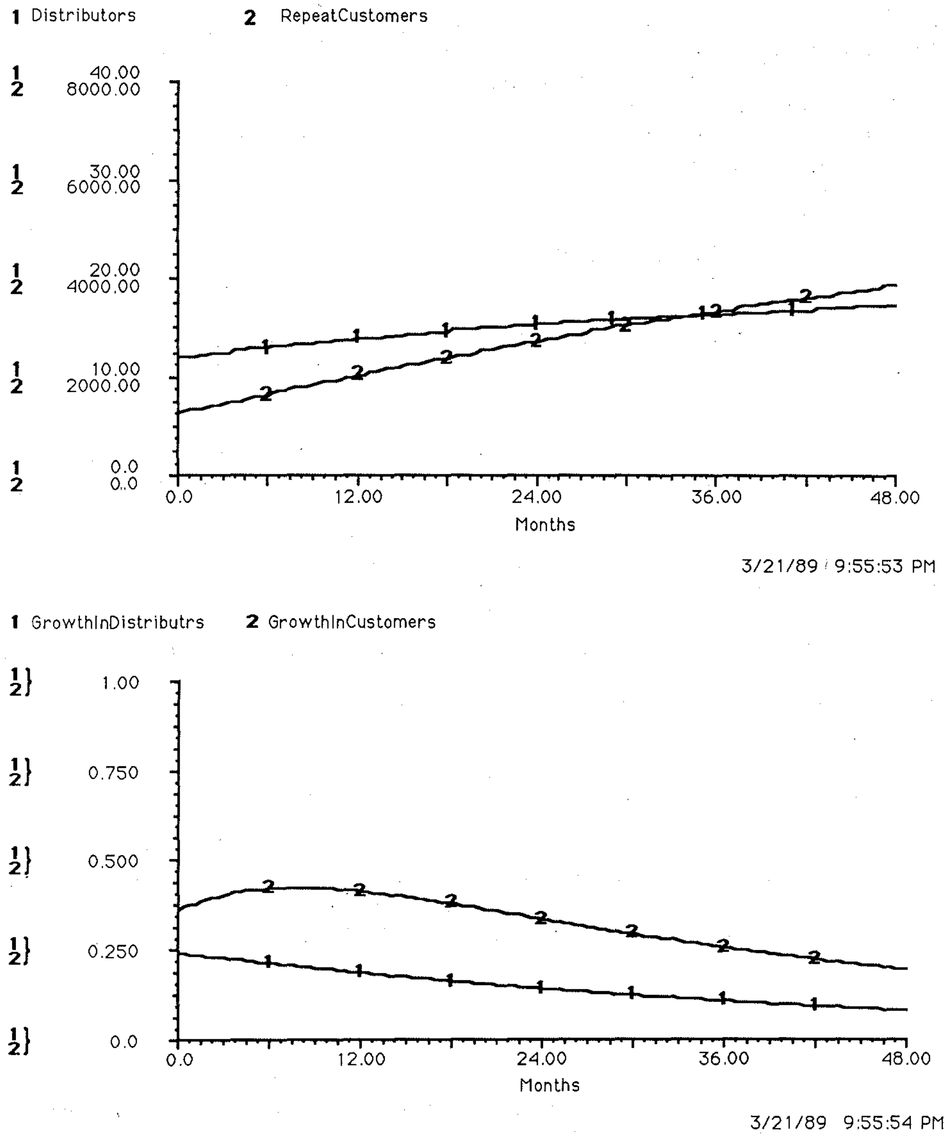


Figure 7: Growth Limited by Distributor Maintenance

IMPACT OF THE PROJECT

Did the project have an impact on management thinking and company strategy? There is no clear scientific answer to this question, but there are the comments of the participants (for a review of current literature on the measurement of computer-based learning see Andersen et al 1989, Graham et al 1989). The last ½ hour of the final meeting was specifically set aside to obtain the opinions of the management team on the project. The managing director was most forthright. He admitted to being sceptical of modelling at the start of the project. In particular he believed that a computer model could not capture the 'flavour' of his fledgling company. At the end he acknowledged that the model did represent the business. Specifically, he felt that the project had raised his awareness of several strategic issues: the importance of microbial production parameters in capacity planning, the short time-window before capacity constraints might stifle growth, the recognition that small improvements in production parameters can defer scarcity problems and the importance of knowing distributors' sensitivity to delivery.

He said that the first two meetings were frustrating because he felt he was giving more information than he was receiving. However this negative feeling was outweighed by his positive views of the 3rd, 4th and 5th meetings in which model simulations and 'hands-on' sessions had provided him new insights into the business. His overall conclusion was that he had learned a considerable amount about the business from the project - <u>but</u> he wondered whether a similar <u>length</u> process without the use of modelling and computer technology would have yielded similar or equivalent insights.

The commercial manager said that he had learned a lot about the factory from the project and had been made aware of the critical importance of distributor loss (and the factors that influence loss) in limiting the growth potential of the business. As a result of the project he had begun to monitor distributor loss, delivery times and maintenance time.

The new venture manager viewed the project as a test of the methodology in the special circumstances of a startup firm, where formal business data is scant and there are few established operating procedures. He felt that the <u>process</u> was a very useful way of getting everyone to understand how the business 'ticks'. However, after the project, the model was not used regularly by the management team as he had hoped - mainly due to the time pressures on management in a small company. The process proved more useful than the final model.

Insights from the project led to increased priority for two ongoing programs: product improvement and R&D. Product improvement was aimed at making an easier-to-use microbe mix - perhaps a liquid instead of powder. The limits to growth from distributor maintenance emphasized the strategic importance of an easy-to-use product. The R&D program was aimed at enhancing yields and was given higher priority by the head of manufacturing who recognized, as a result of the project, the market payoff from adequate capacity.

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