Combining Relativism with Logic and Empirical Knowledge: Integration of PIMS with System Dynamics for Formulating Effective Strategies

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Abstract

This paper presents an attempt to integrate the two major rather opposing streams of philosophy of science, that is, the traditional reductionist/logical empiricist approach with the more modern relativistic/holistic approach. Even though the two approaches represent opposite views in the philosophy of knowledge creation, the combination of the two is possible as they also share common characteristics. As a result, the synergetic effects of the combination draw new directions for research methods and model development.

The aim of this paper is to combine the explicit knowledge on strategic management stored in the Profit Impact of Marketing Strategy (PIMS) database, with the conceptual framework of Systems Thinking, and the simulation capabilities of System Dynamics. The combination is implemented in the form of an integrated generic System Dynamics composite model, that includes market related factors, quality related factors and system structural factors that would influence the success of any management strategy.

Although, in this paper we mainly focus on the model development process, our claim is that the integrated generic system dynamics model could serve as a strategic management centre that can be utilized by a Strategic Business Unit in deciding how to compete in an uncertain and rapidly changing environment. Various business scenarios can be tested by simulating organizational operations and environmental processes. In this sense the composite model becomes a solid shared platform for experimenting and learning, whereby effective strategy formulation can be carried out.

Keywords: PIMS, System Dynamics, Knowledge Management, Strategic Management, Simulation

Introduction

Models have become widely accepted as means for studying complex phenomena. A model is then a substitute for some real problem-situation or system. As such, models are necessarily simplifications and abstractions to some degree of the reality of the problem situation. As John Sterman aptly stated all models are wrong (Sterman, 2002). Successful models should rather be assessed on their usefulness and appropriateness to deal with the current problem situation. It is not possible to examine either all the variables or all their possible interactions in the problem situation. Therefore, the decision maker should attempt to abstract the important elements of the problem situation represent them so that they are simple enough to be understood and manipulated, yet realistic enough to portray the essentials of the situation.

In this way, the value of a model emerges from its improving our understanding of obscured behavior characteristics more effectively than could be done by observing the real system. In this sense, a model compared to the real system, can yield information at a lower cost, while knowledge can be obtained more quickly and for conditions not observable in real life. By sorting out variables and relationships it becomes possible to recognize structure patterns and configurations that can significantly contribute to the solution.

Models can be classified in many ways. They may or may not represent situations that change with time, which makes them static or dynamic. Further, models may be physical or abstract. Physical models are usually reduced replicas of the phenomena under study and they can be either static e.g. an architectural plan, or dynamic as the models used in wind tunnels to test the aerodynamics of new aircraft designs. Abstract models are the ones in which symbols rather than physical devices, constitute the model. The symbols can be language or a thought process. The conceptualization of a specific problem by the decision maker even though is implicit, it is still a model (mental model). It may be, in fact, that an explicit model is not worth the cost of externalization. Explicit models may be expressed by a verbal statement, a graph or an equation. Models described verbally are known simply as verbal models. Those that are expressed as a graph or diagram are known as diagrammatic models and those expressed as a logical sequence of questions are called logical flow models. Models represented in equation form are called symbolic (mathematical) models. All explicit models may be described in one or more of the above forms (Green *et al*, 1988).

The aim of the work described in this paper is to combine tacit and explicit knowledge and present it in a form of a dynamic model. That is, extract the tacit knowledge residing in the minds of people and combine it with hard data obtained from facts. The captured knowledge is then stored in a composite system dynamics model. As we will see in the next section the tacit and explicit knowledge are somehow supported by two opposing schools of the philosophy of science.

The major philosophies of science

The major philosophies of science can be divided in two major schools. These are the logical/empiricist/reductionist school and the relativist/holistic school. Philosophy of science is in fact, a relatively new discipline that emerged at the beginning of the twentieth century, but it is closely related to an older philosophical subject, epistemology (the theory of knowledge). The underlying epistemologies of modern philosophy of science are to be found in an evolution starting from Descartes' (1596-1650) rationalism and John Locke's (1632-1704) empiricism (Barlas and Carpenter, 1990). Immanuel Kant (1724-1804) synthesized the two, taking from Descartes the concept of the active mind and from Locke the role of sensation (experience) in knowledge acquisition.

An assumption held common by all mainstream theories of knowledge up to that point, is that knowledge is entirely objective, asocial, acultural, ahistorical truth, rather than socially justified belief. Consequently according to this mainstream, knowledge acquisition can be understood by pure philosophical analysis, independent of all social, cultural and historical conditions of a particular era. This is what philosopher Richard Rorty (1979) describes as foundationalist philosophy. All foundationalist philosophies he observes, are based on the unified assumption that knowledge results from our "privileged relationships" with the world and once we understand them, we can exactly tell which statements are "objectively" true. He uses the metaphor "mirror of nature" to describe this privileged relationship: the foundationalist's concept of knowledge is the reflection of nature on an "unclouded mirror".

A completely different theory of knowledge, on the other hand, claims that knowledge is socially justified belief rather than a product of mirroring nature. The theory was first formulated by Georg Hegel (1770-1831) and later articulated by John Dewey (1929). According to this stream, a knowledge claim is true not because of some privileged way it was acquired but because of the arguments given to support it. Knowledge is socially, culturally and historically dependent. There are no neutral foundations of knowledge and entirely objective verification is not possible.

The social/holistic epistemology formed the basis of the relativist philosophy of science and the foundationalist formed the logical empiricist philosophy (Barlas and Carpenter, 1990).

PIMS (Profit Impact of Marketing Strategy)

Profit Impact of Marketing Strategy (PIMS) is a database of the market profiles and business results of major American and European companies. As a source of knowledge PIMS rather belongs to the logical/empiricist reductionist school of philosophy of science. PIMS was developed with the intention of providing empirical evidence of which business strategies lead to success, within particular industries. Data from the study is used to craft strategies in strategic management and marketing strategy. The study identified several strategic variables that typically influence profitability. Some of the most important strategic variables studied were market share, product quality, investment intensity, and service quality, which were all found to be highly correlated with profitability.

PIMS holds information on the characteristics of the business environment, the competetive position of the business, the structure of the production process, how the budget is allocated, the current strategies and the operating results. Based on these parameters, PIMS seeks to address what strategies are likely to help improve future operating results.

The PIMS project was started by Sidney Schoeffler working at General Electric in the 1960s, then picked up by Harvard's Management Science Institute in the early 1970s, and has been administered by the American Strategic Planning Institute since 1975. It was initiated by senior managers at GE who wanted to know why some of their business units were more profitable than others. With the help of Sidney Schoeffler they set up a research project in which each of their strategic business units reported their performance on dozens of variables. This was then expanded to outside companies in the early 1970s.

The survey, between 1970 and 1983, involved 3,000 strategic business units (SBU), from 200 companies. Each SBU gave information on the market within which they operated, the products they had brought to market and the efficacy of the strategies they had implemented. The PIMS project analysed the data they had gathered to identify the options, problems, resources and opportunities faced by each SBU. Based on the spread of each business across different industries, it was hoped that the data could be drawn upon to provide other business, in the same industry, with empirical evidence of which strategies lead to increased profitability.

Businesses wishing to use the service provide detailed information, such as details of their competitors and market, balance sheet, assumptions about future sales. In return, PIMS provides four reports. A 'Par' report showing the ROI and cash flows that are 'normal' for this type of business, given its market, competition, technology, and cost structure. A 'Strategy Analysis' report, which computes the predicted consequences of each of several alternative strategic actions, judged by information in similar businesses making similar moves, from a similar starting-point and in a similar business environment. A 'Report on Look-Alikes' (ROLA), which is aimed at predicting the best combination of strategies for that particular company, by analysing strategically similar businesses more closely. An 'Optimus Strategy' report, which is aimed at predicting the best combination of strategies for that particular company, again based on the experiences of other businesses in 'similar' circumstances.

Although PIMS has repeatedly proved its usefulness in the field of Strategic Management (Wakerly, 1984), it has also been criticized. Clearly, it could be argued that a database operating on information gathered in the period 1970 - 1983 is outdated. It can also be suggested that PIMS is too heavily biased towards traditional industries. Further it is also heavily weighted towards large companies, at the expense of small entrepreneurial firms. Mintzberg (1998) claims that because the database is dominated by large established firms, it is more suitable as a technique for assessing the state of "being there rather than getting there".

Tellis and Golder (1996) claim that PIMS defined markets too narrowly. Respondents described their market very narrowly to give the appearance of high market share. This self reporting bias makes the conclusions suspect. They are also concerned that no defunct companies were included, leading to "survivor bias".

Despite the criticism, PIMS is an invaluable source of knowledge that once used in the appropriate way can lead to developing effective strategies. The way to use PIMS as suggested later is in conjunction with System Dynamics were some of the weaknesses of PIMS may be alleviated.

Towards Integration

Different modeling paradigms cause their practitioners to define different problems, follow different procedures and use different criteria to evaluate the result. Paradigms deeply bias the ways modelers see the world and thus influence the contents and shapes of models. Regardless of this selective "blindness", induced by the paradigm basis, most computer modelers, when confronted with the task of learning about complex phenomena - such as those involved in strategy development - try rigorously to avoid the reductionistic approach of "taking it apart and examining each of its pieces". On the contrary, they pursue a systems approach, focusing on the whole and on the pattern of interrelationships among pieces.

Econometrics and system dynamics, although philosophically further apart than any other pair of modeling paradigms, are primarily driven by some common basic assumptions that define the whole modeling approach to problem solving. These assumptions can be summarized as follows (Meadows, 1985):

- Social system models of both paradigms value rational, logical scientific mode of thought. Whatever happens is not totally senseless or unknowable. The source of understanding is observation and thinking, clever experimentation and logical deduction, not intuition or mediating.
- Modelers share a "managerial" world view. The world is not only known but also to a degree controllable. One does not passively follow the process of social evolution, but one tries to direct it.
- Computer modelers use historic observations to form their hypotheses, but their concerns are primarily about the future, where their problem solving efforts are directed.

- They both make entire organizational systems as the subject of their analysis. Because they see complex interrelationships in the world and they need the computer as a tool not only for accounting, but for representing and keeping track of their theories.

In spite of these commonly held assumptions, different modelling schools emerged. The reason is that each was originally developed as a result of the managerial theories in practice at the time and in response to a specific need. Each was developed to solve the type of problems as perceived and described at different stages of evolution of management theories. Thomas Kuhn (1970) writes characteristically about the problem: “Paradigms changes cause scientists to see the world of their research - engagement differently".

Because of the pervasive effect of methodological paradigms on the modeller’s thoughts and perceptions, we find it useful to briefly describe here the underlying paradigm basis within which models are made.

For the traditional reductionist/logical empirical philosophy, a valid model is an objective representation of the real system. The model is compared to the measured empirical facts and can be either correct or false. In this philosophy validity is seen as a matter of formal accuracy, not practical use. In contrast, the relativist/holistic philosophy would see a valid model as one of many ways to describe a real situation, connected to a particular purpose. Models are not necessary true or false but more or less suitable for their purpose. Although different types of System Dynamics models can be distinguished and ascribed to different purposes such as policy design, theory testing, generic models and so on, one basic assumption remains the same for all models. The modeling effort in both paradigms is essentially an experiment with the purpose of generating high quality reliable information, which is generally used in the following three ways.

- General understanding: how the feedback structure contributes to dynamic behaviour, identifying dominant structures, defining new concepts and constructs, organizing and communicating ideas and hypotheses, and generally learning.
- Policy design: selecting objectives, evaluating strategies under different perspectives, finding and analyzing sensitive parameters, optimizing structure against objectives etc..
- Implementation: examination of long term patterns of different configurations of the modeled system extracting operating plans and instructions etc..

Thus it is in the reinforcement of these tasks that we must seek synergy and the integration as shown in the following sections.

This will enable the model-builder to avoid sterile arguments and conflicts across paradigms, while at the same time create the framework for a skillful combination of the two approaches in a composite model, benefiting from the combined strengths that produce synergetic effects in order to tackle some of the problems of strategic management.

PIMS-lnstruments as explained above may be regarded as belonging to empiricist view. PIMS' statements have also a meta-character in that a model-builder can mainly be used for two purposes: depicting relationships between variables of a general invariable character and for comparisons with real world observations, for the purpose of increasing model's credibility and validity. This, as will be seen, is a valuable point of synergy with system dynamics in a composite model. We are not saying here that PIMS methodology is the typical representative of the econometric modeling paradigm. It is nevertheless a fact that methodological assumptions, research paths and procedures adopted by PIMS researchers, are those typically prescribed by the econometric paradigm, as it will be shown.

Having in mind the nature of strategic management problems and the limitations of the two approaches, we are attempting to integrate the synergistic effects of the two modeling paradigms.

In summary, the combination of PIMS with system dynamics is expected to create synergistic effects, mainly in the following areas (Hadjis, 1995):

- Eliminating the problem of lack of relevant data banks (weakness of system dynamics)
- Dealing effectively with the problem of reduction without redundancy (weakness of system dynamics)
- Dealing effectively with the problem of "accuracy" (strength of PIMS)
- Giving valid first orientations on the direction and magnitude of variables interactions (strength of PIMS)
- Bridging the gap endogenous-exogenous variables, internalizing important external factors in a model capable of simulation and enabling like this the diffusion of ideas and discussion of hypotheses in a pragmatic way (weakness of both)
- In freeing from structural restrictions (weakness of PIMS)
- Enabling the exploration of conditions that significantly differ from the historical past (strength of system dynamics)

The above synergies can be accomplished by incorporating PIMS explicitly stated knowledge in a generic system dynamic model as shown in subsequent sections. In this manner the system dynamics model becomes a composite, structurally well defined model, enabling experimental simulation and learning. The composite model can be used as a research tool for a strategic planning method combining the two approaches in one model. That is, the data to theory approach of PIMS and theory to data approach of System Dynamics, in a mutually reinforcing manner.

Methodological Issues the Selected Case

The integration of PIMS with SD was carried out as part of a case study regarding a Strategic Business Unit (SBU) of a large German company active in the field of software development. The study started as a PIMS product/market strategy project. The typical PIMS Associates procedure (data collection, quality workshop, limited market research, etc.) was followed in order to construct among other PIMS instruments, a Value Map (Price/Quality Diagram) and a Quality Profiling Worksheet for the client. For a detailed description of the process see Luchs and Neubauer (1986).

Then, out of the two reports, strategy recommendations were derived and presented to the client. The reaction of the client (in this case the quality team (QT)) was that this "snap-shot picture" of how their product or SBU are perceived in the market in comparison to their main competitor's, presented not more than "visible" symptoms, already known to them in fact. It said very little about the underlying pathology. Further, although it did give a priority to the attributes to be corrected, it did not give any guidance as to what ought to be internally corrected and what effects different corrective measures could have at different time points in view of a set of achievable objectives. In other words, the reports resulted in a new problem definition, requiring also a different solution approach.

Realizing that this could be an opportunity to combine the PIMS with System Dynamics approach, a composite model was created with the purpose of investigating solutions to the new problem definition. Our primary target in this case was, from the standpoint of the participant observer to make the first steps towards designing a strategy-producing mechanism, something that appeared to be an urgent need for the new SBU. This mechanism should be in a position to constantly adjust the position of the SBU within its broader, general system (Company) and its environment.

The target of the SBU was to develop a strategic conception for its particular product/market-segment. This, in systems thinking, meant that the object-level system as a self organizing unit had to be in such a way connected with its meta-system that it would be in a position to develop the necessary strategies, activate processes, construct and control other subsystems, promoting and strengthening in this way the adaptation ability of the whole system. In the language of the Viable System Model (Beer, 1972) we were dealing with a system 3 and its environment and with its system 4. Decisions on capacity increases, new additional product-attributes or services and finally the "Go-No-Go" decision were explicitly positioned at the meta-level, that is the long-term strategy making.

This gave us enough architectural insight to model the object-system (operational) rather as an integral part of the organization, having thereby, the influence and steering possibilities available to the meta-system (strategic) wide open. In our opinion this is a representative case of the majority of "Start-Ups" where the need for central control at least at the initial phase, predominates. From the systems-analytic point of view, the object-system should be in a position to generate the kind of information necessary for the decisions of the meta-system. That meant that the interaction with its market and with itself should produce models of orientation, principles' clarification and pattern recognition and explanation that its structure was causing, with the purpose of feeding the meta-system with the decision-information needed, until, with the increase of its self-awareness, it could claim more autonomy. In other words, until double loop learning could change the cognitive maps and hence behaviour of the participants responsible for the SBU strategy.

In attempting to build a formal out of the implicit mental model of the situation we were confronted with two risks: On the one hand, one had to avoid the trap of believing that a greater amount and more detailed data leads to more accurate information. After all, what this would simply mean was finding more about what correlations the system's past output behaviour has generated. Given that the SBU was at the end of the second year of operation, the value of such information was doubtful. On the other hand, moving from a static to a dynamic orientation and seeking an operational specification of the structural assumptions and the relationships producing the output, the danger was to reduce model variables, constants and their parameters to a minimum neglecting the complexity of the situation. There were two extremes of the two paradigms: collecting excessive data and hoping to derive more information than there is in the data as contrast to the problem of redundancy, i.e., omitting important variables for simplicity's sake. In other words, we needed a model that enables the analysis of the object-system from the point of view of its meta-system, with meta-systemic instruments. Only then, could object-level corrections be enlightened and purpose fully undertaken. The meta-systemic elements of the SBU were located in the market (or the system's own model of it), its internal policies (still decided by top management) and its processes (activities) as implied by the system's built-in pre-engineered structure.

Our intention was to build a model useful for orientations of a general character. A second consideration was to facilitate the application of the Trial and Error method by making safe experimentation (not involving changes of the real system) possible. That means we needed to find out the invariables responsible for generating persisting patterns and then, through simulation, find out the most favourable configuration reducing the vulnerability of our system to internal and external stress. The model should thus contain the important linkages between object-system (operations), meta-system (strategic management) and environment (market), responsible for the whole system's constant adaptation.

The amplification, attenuation, delays and the distortion (noise) at each decision point that could make the system more sensitive to certain kinds of disturbing influences rather than others, were to be accounted for. Further and apart from the requirements imposed by strategic management, the methodological aspects deriving from the integrated planning theory had to be met.

Questions like what consists information at different levels (object-meta) and phases (analysis, diagnosis, design) of the strategy producing process, could then be effectively illuminated.

The problem as we saw it, was to construct a cybernetic strategy map (as a form of the congregate strategy map) out of the idiosyncratic individual cognitive maps of the members of the quality team. Since the PIMS methodological process was well under way, the "fertile ground" for building further was already in place. A common language of descriptions and congregating labels was available. Further, indications about important structural variables and the direction of the effect of their interaction were more or less clear. What was needed was the agreement on a model structure capable of generating the expected patterns of behavior.

Specifically the modeler can give answers to four major areas of questions on which, later, validity of the model as a description of the specific system could be tested. These questions are:

- What could be the model of objectives?
- What is the direction and magnitude of interactions?
- What are the system boundaries?
- Which interactive variables to include?

Before we present the proposed modelling method, it is important to outline in short the PIMS methodological steps. With few variations, the typical steps undertaken for developing a product-market strategy with the PIMS methodology are outlined in Figure 1 below (Luchs and Neubauer, 1986).

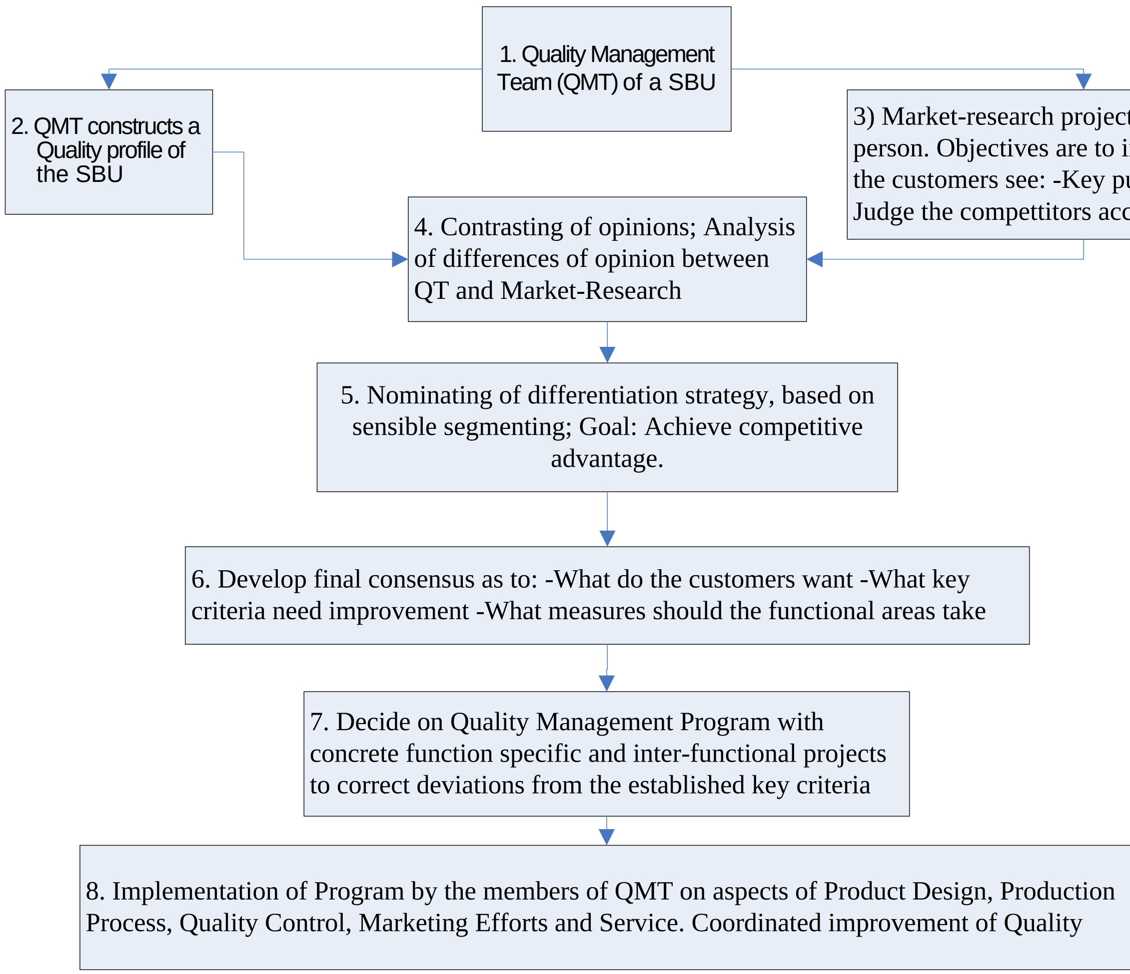

Figure 1: The PIMS Quality Management Processes

The Modelling Method and the Resulting Integrated Proposed Model

As a starting point of our modeling effort the advantages of using System Dynamics were explained to the Quality Team. The fact that a large electronic screen was available enabled a first demonstration, after which the approval for going ahead with the project was obtained. The basic modeling methodology which is based on the suggestions of High Performance Systems Inc., appears below in Figure 2. Methodological aspects, resulting from our previous discussion were taken into account in developing the proposed modeling method and they will be explained further. During the experiment our main concern was to verify if the expected synergistic effects and complementary strengths of System Dynamics really exist, and if they were capable of widening the scope and enhancing the effectiveness of strategic decisions.

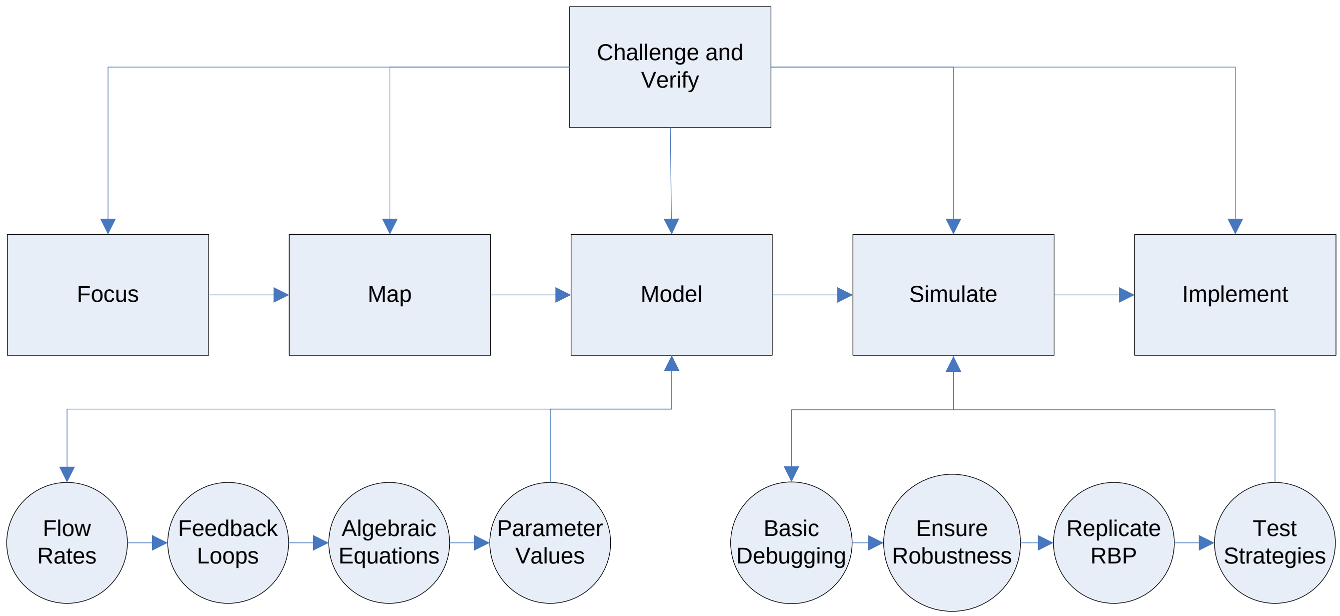

Figure 2: The Proposed Modelling Methodology

The arrows represent the iterative nature of the process's stages, which are not sequentially executed during the modeling effort. Instead, one returns to each stage numerous times with each cycle, hopefully refining the work of the previous iteration. The various stages, which include Focusing, Mapping, Modelling, Simulating, and implementing, are discussed below.

Focus

Focus consists of clarifying the purpose of our modeling effort. In our case the purpose was to model the "system producing market share through relative attractiveness". The first steps towards an explicit formal model were already undertaken to a degree enabling the first attempts for extracting mathematical relationships, corresponding to the described phenomena. The iterative character of the process would enable us to return and correct or improve accordingly. A suitable way of accomplishing this is to create a Reference Behavior Pattern (RBP), which is a plot over time of one or more variables that summarizes the dynamic phenomenon we are interested in understanding and improving.

A RBP is not a hypothesis in an objectivistic sense whereby the hypothesis should carry clear implications for testing the stated relationship, that is, variables must be measurable or potentially measurable. It is rather a description of a pattern or a determination of universal elements and an apprehension of relationships. It is not a matter of acceptance or rejection according to a predetermined set of criteria because the criteria for the pattern's utility and validity to us are in most of the cases decided on an ex post basis. It documents how a process has been performing in the real system or, when no history exists, how it is expected to perform.

For example, an RBP relating Product Quality and Market Share is expected to follow an S-shaped curve. It is the fundamental, meta-level, generalized relationships that are important here. Quality is here taken to mean a combination of all characteristics and aspects (including usage-context and production processes, e.g., engineering tolerances, etc.) of the product. Garvin's ideas on the issue (Garvin, 1983), which are incorporated in PIMS methodology, are indicative of the meaning of quality in this sense. It is what the market perceives as being the purchase decision criteria, which PIMS methodology rather accurately measures, and uses to establish the differential advantage over competitors. PIMS supports empirically how this leads to increased market share (Buzzell, 1978). The relationship is valid, has dynamic meaning and is descriptive of any product.

What the curve says is that until a certain level of quality is achieved, the product or service will not meet the needs of the potential market. Thereafter, increases in quality rapidly expand the possible market. Finally, large increases in quality are necessary to satisfy the remaining more demanding customers. Curves of interacting price and value would simultaneously be at work at the various quality levels.

Empirically supported assertions of many authors indicate the existence of such a pattern. For instance H. Assael (1987) who studied consumer behavior and E.M. Rogers who researched the diffusion of innovations (Rogers, 1962) clearly confirm the pattern. Similar conclusions can be drawn from the work of K.R. Harrigan on strategies for declining industries (Harigan, 1980) as well as from I. Ansoff's discussion of demand and technology (Ansoff, 1984).

It is exactly at this point that the critics of PIMS failed to see the meta-character of PIMS statements and the meta-level patterns resulting from PIMS/SPI (Strategic Planning Institute) empirical research. With these general purpose patterns we are now in a position to:

- Formulate a pattern of interaction of variables
- Decide the objectives of our model
- Choose the pertinent variables
- Define the boundaries of the system significant to us

Then for each of the significant variables to include, we will have a rather clear indication on:

- What is the direction of the effect
- What non-linearities should be recognized, affecting the decision functions.

The model in turn will reveal the magnitude of the effect.

Finally, when we are to judge the validity of our model, we will direct our attention to the values of its parameters (constant coefficients). We may choose them anywhere within a plausible range. Obviously the wealth of PIMS observations and measurements can assist in choosing this plausible range. Then the model's dynamics (unfolding with simulation) will identify the few sensitive parameters by model tests. It is in this sense that it is less important to know their past values because our purpose is to control their future value in a system redesign.

In a later stage, when confidence in the model's utility and validity requires a comparison of the model's results with real world observations, then again PIMS offers valuable help in assessing what constitutes passing a relevant statistical test of the sensitive variable's parameter values. That is the point we will decide what more data we need and selectively and economically then collect it. We have now a clear model objective that determines the value of new information and hence enables a meaningful cost and benefit analysis.

The clear, operationally expressed objective of our modeling effort can now be stated: "Construct a model of the high-tech Start-Up (SBU), capable of self-generating (at least) the growth indicated by the Reference Behavior Pattern”.

Taking the cybernetic stand that the model is doing it to itself" the question to be answered is: "How can the company's policies give rise to this behavior pattern?" Obviously that frames the boundaries around the organization and focuses our effort to where one should look for means of improving performance. It does not deny the existence of external forces. In our case the SBU really faced some hard competition. However, the relevant standpoint for the company management to adopt from a Systems Thinking perspective is: "What are we doing to make ourselves vulnerable to these competitors and how can we re-engineer our structure to curb this vulnerability?" In other words, what system elements produce low perceived quality, how are the market dynamics reacting to this and what impact different corrective measures could possibly have.

The RBP serves as a device for operationalizing our effort to achieve a sharp behavioral focus. The System Map stage that follows plays the role of incorporating the structure needed to exhibit such behaviour in our model.

Map

A system map is a high level diagram of the key actors and/or sectors within the model. It thus defines the boundary of the model. A sector is a major structural grouping. We are looking at the system from the forest vantage point seeking to gain some perspective of the trees. The primary objective of this step is to lay out the basic stocks or levels and flow infrastructure for generating the behavior identified in the Focus stage. What we are set out to identify are:

- Conditions that the sector monitors to determine the state of the system. These conditions may be material (i.e., inventory levels) or non material (Quality Index, Learning). These conditions will become levels.
- The action taken in response to the conditions being monitored by the sector. These will become flows.
- The resources consumed in the process of taking actions. Resources may be material (bank balances) or non material (capacity). These will become stocks. Following the methodological path of PIMS (See figure 1 above), the decision was reached that the interplay between market dynamics, Quality Index and the SBU's internal workings or system structure was responsible for generating the Reference Behavior Pattern.

Thus three sectors that are related to the market, to quality and to the system structure should be mapped and then connected. We discuss each sector separately below.

Market Map Sector

A market is composed of many interacting ideas and relationships. Many of these concepts are obscured in our unreliable intuition about dynamics and although we are confident about their existence they are ignored in a quantitative analysis, because of the misleading assumption that we must omit those factors presently unable to measure accurately (Forrester, 1961).

Going through the steps 1, 2, 3, 4 of the Quality Management Process proposed by PIMS as shown in Figure 1 (Luchs and Neubauer, 1986), we realized the valuable help of PIMS in clarifying these concepts, establishing that they are not necessarily controversial and in many cases measurable. For example, it became clear that normally in every market, concepts such as price versus utility, purchase deferability based on relative attractiveness, re-buy dependence on degree of satisfaction with previous purchases, influence on new customers from attitudes and opinions of past customers (word of mouth effect), really do exist and play an important role in explaining the strategy dynamics.

PIMS has in some cases measured or quantified the direction and the magnitude of the effect of interactions among important variables. However, a lot of hidden variables, corresponding to important learning processes, levels of awareness and purchase readiness in the market, had to be extracted. Creative initiation of variation was necessary. The emergence of a culture of productivity where vigilant information processing could lead to generation of new useful concepts to act as congregating labels, had to be instituted. A subtle interference of the coordinator (ourselves) has achieved the task.

Soon it was realized that in a model of the entire life-cycle of a product, customer levels should reflect the different levels of awareness and readiness to purchase. Those customers vaguely heard (potential), those interested, first buyers, satisfied who repurchase or dissatisfied reverting to non buyers, etc., represent important dynamic states.

Flows between them would be non-linear functions of the same customer levels, of information and awareness levels existing and, in our case, of relative attractiveness (as expressed and measured by the Quality Index and its different dimensions). Where PIMS results could not help was in specifying these non-linearities.

The uncertainties (mainly for the purpose of redesign) lie in the relative importance and possible interactions between these levels that are known to some degree. Questions remaining unanswered were for instance:

- How could market dynamics function under different conditions?
- What conditions make a particular factor predominate?
- What is the relative importance of various dynamic (time varying) characteristics of the product itself, as for example the product's sales attractiveness versus the owner satisfaction it creates?
- How could specific marketing initiatives be formulated, what dimensions of the Quality Index could they influence and how in turn could flows be affected and to what extent?

In general these are questions that a systems dynamic model can easily answer. Once more at this point, it becomes obvious how we can benefit from the complementary strengths of the two approaches (PIMS and SD).

After the initial stage, there is no rigid algorithm to put a straightjacket on our effort to experiment. We may change not only the plausible parameter values, but also the fundamental assumptions about the relationships as the augmentation of knowledge unfolds. The model is extensible and thus can effectively cope with the eventual substitution of present value potentials with the future ones.

As new value adding activities (Porter, 1985) emerge, how they are internally performed (solution technologies) and their external linkages in the value chain or defined business system (PIMS' served market), they become definable and hence explorable. For example take an S- shaped curve Vs a Bell-

Shaped curve on a product Quality – Cost graph. By superimposing the two curves on the market evolution curve as indicated by the RBP of the market sector, the effect will become apparent and hence the decision between strategy alternatives possible. What makes it possible is the fact that the system producing customers and market share through relative attractiveness remains essentially the same! We have a way of inventing the future as S. Beer implies (Beer, 1972). That is the remarkable advantage of searching for the invariants, an insight obtained from Management Cybernetics.

In our case study the character of the market was essentially "closed", consisting of fifteen (15) Government or Semi-Government organizations in the whole of Germany, all having similar needs in the field of conductor technology (Leittechnik). As part of their technological upgrading and development, they will buy the software - hardware offered by the SBU or its competitors. In case new customers or new competitors enter the market, our model should effectively deal with this. The proposed market model is depicted in Figure 3 as follows.

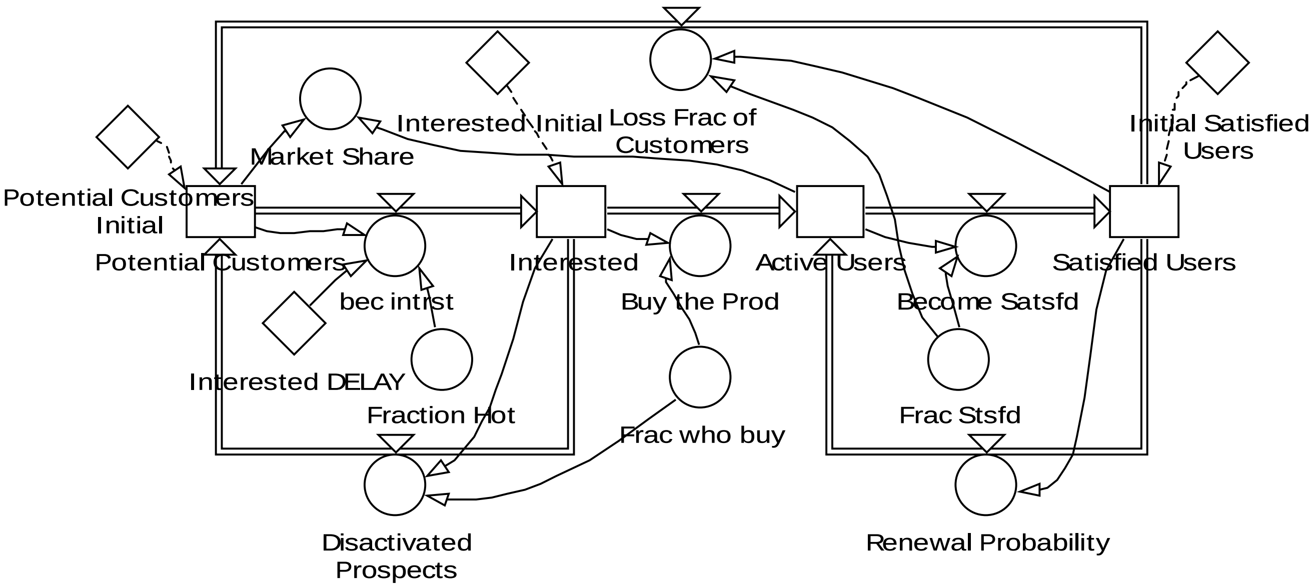

Figure 3: The Market Sector Map

Quality Index Map Sector

The first problem to address here, was that the price/quality ratio of the internal view (that of the participants) had a 20:80 value while the external view (customers point of view resulted from market research) gave a ratio of 30:70. The insight gained through the unavoidable discussion was that this ratio is not a constant but also a variable with time, its variability changing with market evolution and the product life-cycle, as the relative importance of price versus quality changes (see RBP curve above). In this case though, we were not dealing with a standard product but with solution packages. The only standards of the various competitive offers are to be found on the “architectural features", which in turn are being determined by a rather unconstrained technology transfer and diffusion, normal in this type of business. They could thus be shared by all competitors after short adjusting periods, hence they were not decisively influencing the original RBP.

The PIMS solution to this would be to keep taking measurements at time intervals in order to observe the change in subsequent measurements of the ratio, a process described in detail by Luchs/Neubauer (1986). The use though of a dynamic model capable of simulation, enabled the representation of eventually different effects by simply examining the behavior in relation to variability. Our simulations with a provisional model proved that this variability of the ratio with time, has a relatively low effect, except in extreme cases when the intensity of the need to be covered "blinds" the customer to the price required (e.g., a Price:Quality ratio 2:98).

This would normally happen by the last stages of the curve of the RBP when the most exact demand is difficult to satisfy, but also when a technological breakthrough is normally a dream and the transition to new value potentials is well under way.

From our market sector map it became quickly apparent that the impact of the various attributes constituting the Quality Index on the flows between different levels of customers is not homogenous and equally distributed. For example, Potential Customers become Interested Customers basically through the "word of mouth" effect. Once they become interested then the "word of mouth" effect subsides, while the sales attractiveness of the SBU's offerings emerges as the specific factor changing the customers into Active Users (See market sector map above in Figure 3). Then of course, the emergence of the positive word of mouth effect could only be traced in the stock of satisfied customers as growing with it. Moreover, customer satisfaction would only affect Active Users and turn them into Satisfied re-buying Customers or Unsatisfied, returning to the Potential Customers. One could argue that they would be lost forever but that would be equivalent to admitting that competitors will always be better than we are and our possibilities to regain them through better strategies do not exist.

An additional consideration was that the market is known to be highly sensitive to product/service lead-times (delays in delivering service and product-package). High growth rates (projected at 15 percent per year by the QT) and an intensive competition from a few key players, made lead-times a clearly important component of the relative attractiveness of the SBU's offerings.

The clear implication was that the structural internal relationships responsible for generating lead- time (which by the way were totally within management's sphere of influence), had to be included in the model (see Figure 4 below).

This showed us once more that the course of the modeling effort (essentially a learning process), does not follow sequential steps, but unfolds cyclically in many iterations. The work of each iteration refines and complements the previous, in a Trial and Error manner. The question that now emerged was which attributes could be grouped under a factor "sales attractiveness" and which ones under "customer satisfaction", the two new cryptic labels emerging now as the links to adhere the PIMS results to the individual cognitive maps, that would then merge into the cybernetic congregate strategy map. These two, being the dominant factors controlling the flows between levels in the market sector map, were also the factors responsible for generating the Reference Behavior Pattern and hence ensuring a “normal" growth for the company. The agreement logically deduced through consensus was as follows (numbers as per PIMS Quality Profiling):

A. Sales Attractiveness

- Availability (6)
- Delivery promises (2)
- Location of supplier (10)

- Service reaction time (8) also affecting Customer Satisfaction
- Image (11)

B. Customer Satisfaction

- Keeping promised quality (3)
- Personal customer service (4)
- Service quality (part of 8)
- Technical similarity (1)
- Technical field competence (5)
- Customer specific service (7)
- Documentation (9)

We realized that for the purpose of examining important re-engineering policies we needed two quality indices. One relating the sales attractiveness to the market and the other the customer satisfaction. This was another example of learning through enacting creative variation and then selection and retention.

A very simple map structure capable of producing the subtle quality feedback loops is the one below in Figure 4 chosen as the Quality Index sector map.

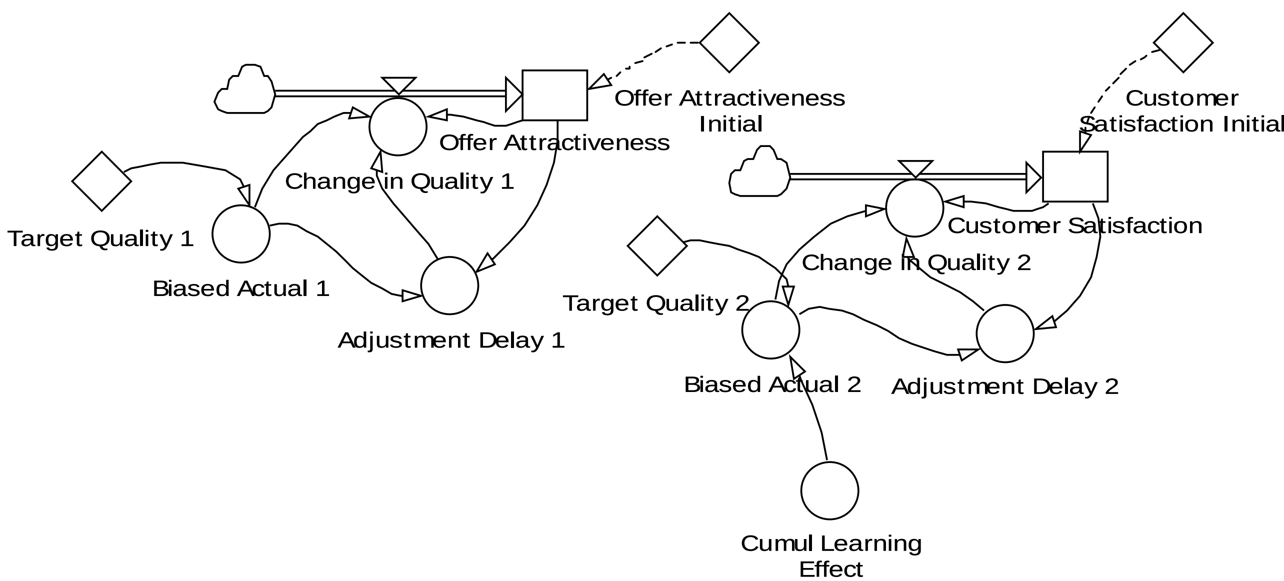

Figure 4: The Quality Index Sector Map

The reason to represent it like this was the following: Perceived conditions differ from actual conditions because of two reasons: bias in perception and delays (Bagozzi and Philips, 1982; Tybout et al, 1981). It is not actual quality that consumers respond to, but perceived quality. For instance Ford company (or any other) can claim that quality is a priority target but it may take the American car-buyers a few years before past quality disasters fade in their minds and a new quality image sets in. In the common sense everyday language, the phenomenon is captured as "bad news travel faster than good news", or failures and disasters are remembered longer than stories of "getting it right". The management literature and press are flooded with examples (from airplane crashes, through flops in introducing new products, to even rumors about unhealthy packaged foods, etc.) whereby a quality failure leads consumers to quickly adjust their perceptions of quality downwards. In contrast, when quality standards are raised, consumers tend to adjust their perceptions very slowly (Bagozzi, 1981).

Although perceptions are not physical quantities, they nevertheless operate just like physical accumulations. Perceptions build up over time and are adjusted slowly as actual conditions change. It is again a point where the subtle intervention of the coordinator can help the process of learning by bringing in his context-specific knowledge. The existence of this phenomenon is supported in the literature and empirical research. The members of the strategy team however, may have no way of knowing that. Reminding then the team of the "natural" observed behavior can enlighten this significant point, where noise in the decision function can have significant effects. Absolute quantification is not necessary, because what exerts impact, is the general pattern and not its exact values. If there is hidden sensitivity which can drastically change the influence, then specific knowledge can be sought.

To capture this asymmetry we only need to make the length of the adjustment delay depend upon the direction of change in the current actual condition relative to the current perceived condition. The quality index model depicted in Figure 4 above does this quite well. As it shows, the adjustment delay now depends upon the relationship between current perceived and target quality (to be achieved as a result of quality improvement measures). This adjustment of perception is "slippery" downwards and "sticky" upwards.

As the function indicates, when (target) biased actual is higher than current perceived (i.e., the value of the ratio is greater than 1) the adjustment delay takes on quite large values (10 months for example if the time unit is months), meaning that it would take rather a long time to adjust current perceived to biased actual. By contrast, when biased actual lies below current perceived then adjustment delay is short, implying rapid adjustment of perception.

The work on quality learning curves of Fine (1983), Buzzel (1978) and a host of other PIMS data bank researchers confirms most of the points on this graph, while all PIMS strategy consultants (Malik and Chansen, 1983) who are united in their strong recommendations to Start-Ups to strive for quality and market share (instead of profit) right at the beginning of their life, seem to base their recommendations on this premise. It is true that the data points and the numerical values of the parameters have not been empirically tested in an "accurate" measurement experiment. But our concern is the general form of the pattern as represented by the varying rates of change at different areas of the curve, i.e., its meta-character. In any case, the sensitivity to different bandwidths' values can be tested in our simulations. Then we may concern ourselves with the emerging (or not) need for further investigations.

What remained to be answered was what structural elements and relationships in the "system structure" sector created the bundle of attributes now known as Sales Attractiveness and Customer Satisfaction.

The System Structure Map Sector

As mentioned above, the first concern was to detect the structural relationships generating lead-time and then of course, what attributes could significantly raise customer satisfaction. At this point the temptation to include "everything" in the map had to be resisted. Therefore, the questions asked were: "Are there any chances for aggregation? Could this reduction be done without redundancy?" The guide was given from the established objective of the model. We could aggregate variables being influenced by the same type of decisions. As J. Forrester (1961) suggests:

"In the absence of an all inclusive model, which we are unlikely to achieve, there may well be different models for different classes of questions about a particular system. And a particular model will be altered and extended as each question is explored."

Questions to be answered control therefore the content of the model. Since the objective is to include those factors that influence the answers sought, the basis of model building cannot be limited to any one narrow classification of intellectual discipline. This means that in formulating a quantitative model, we must have the courage to include all the facets that we consider important to the verbal description of the phenomena under study. A wealth of descriptive knowledge exists and obviously the best experts are the participants themselves. Selection and retention will then take their natural course. In the past, mathematical models were restricted to those which could be solved analytically. The demands of such models exhausted very quickly the mathematical skills of the average manager. Similarly, these models could not accept the wealth of concepts that exist in descriptive knowledge, obstructing so the fundamental way in which consensus, or social order (as discussed in earlier sections), or congregate strategic maps could be constructed. Simulation models and computers have changed this picture.

Bearing the above discussion in mind and since the objective was to represent the system producing customers and market share through relative attractiveness, we constructed the following map for the system's structure:

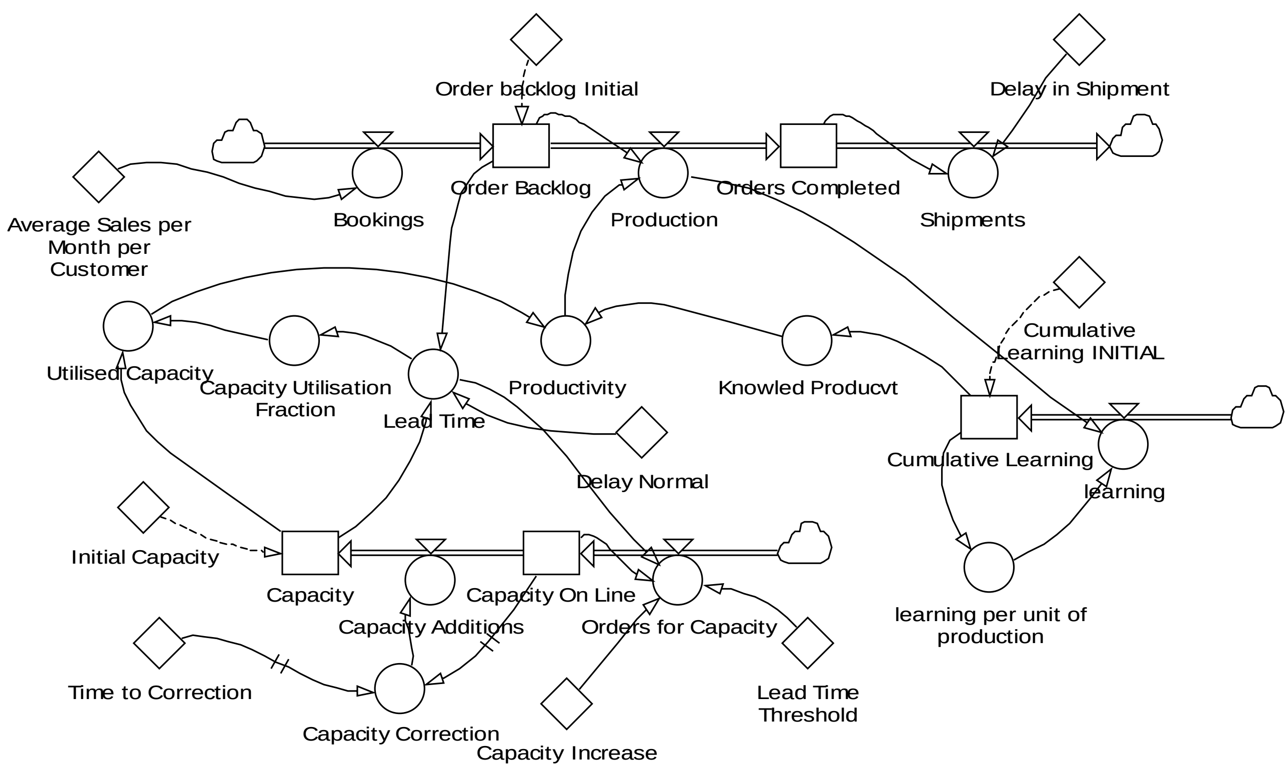

Figure 5: The System Structure Sector Map

As the map indicates, lead-time is generated out of the interplay between the firm's order backlog and its production capacity. If backlog is large, relative to current capacity, the firm's lead-time will rise. Conversely, small order backlogs relative to the SBU's current capacity, enable it to quote both short service and product delivery times which in turn affect the sales attractiveness factor, that is driving through perceived Quality Index 1 the fraction who buy flow rate. The flow fraction who buy is then an

S shaped curve that causes the Reference Behavior Pattern generally valid between quality and buyers, or as in this case turning interested into active users.
The first insight in the company's problems was already obtained: The "symptom" perceived in the market as long lead-times, seriously affecting sales attractiveness had a very real internal structural cause, that management could correct! Something though remained contradictive and dark. Why did the internal point of view classify Location of supplier (factor 10 on the Quality Profiling Worksheet) as not important, an opinion that the relative weights given by customers seemed to verify (step 3 of PIMS process, Figure 1), even if not to the extent of the internal opinion?

The explanation given revealed some of the pitfalls of marketing research particularly when the sample of respondents is very small (which is a usual the case for a Start-Up) and consequently the PIMS methodology. Out of the total 15 large customers comprising the whole market, only four responded, out of which two knew the company and bought from it. These two happened to be very near the company and thus location was not a significant factor to them. This opinion was also shared by the company, because the market experience acquired up to then was only with these two customers. In that case the weights given should not be statistically "blindly" interpreted - another insight revealed by the modeling effort. Although present capacity utilization fraction as appeared on the relevant PIMS data collection form was small (only 40 percent), what has appeared there, was simply reflecting the small production rate that the small market share of the company was causing.

Normally the logically deducted recommendation on the grounds of a PIMS-analysis would be to reduce this spare capacity. The truth was that the people were very busy preparing offers for contracts which they did not obtain and hence quoting delivery times "in the event of contract award". Since capacity was measured in man/hours/production of finished contracts (programming time, systems engineering, etc.) obviously this capacity utilization to prepare offers was measured on the PIMS instrument as a marketing expense. Hence, the worries that marketing expenses (although still below the PIMS data bank average) were very high and perhaps the major cause of the losses reported. A real situation that could not "algorithmically" be described and leading to a vicious circle, which the modeling effort uncovered.

As a result the SBU's management did not detect a problem of capacity utilization (found to be low in relation to existing) and underestimated the role of lead-time as a dynamic factor in the future expansion plans, which were set at an average growth rate of 14 percent per year for the next 4 years, convinced that enough capacity was already available.

Similarly, in seeking to find what causes customer satisfaction, we realized that the ability to create and keep satisfied customers, understand their problems, offer them custom made solutions, etc., is essentially driven by the "Cumulative Learning" stock (see system structure map in Figure 5), which again although not a physical stock, operates like one. Cumulative learning comes with experience and exposure to the customers' problems, i.e., from production and project-execution of the tailored-made products of the SBU. Under Cumulative Learning (an extensible variable and loop) other factors pertinent to amplifying existing value potentials (or solution technologies) or exploring new emerging value potentials, could be eventually examined. Further, the effect of various learning-promoting programs (i.e., training, etc.) could now be studied and related to its proper purpose, which was mainly increasing Quality Index 2 and hence customer satisfaction. Obviously the sales attractiveness would also be increased but the effect could be captured with reasonable accuracy by the "word of mouth" effect that satisfied customers could exert when asked. Hence, we directed the points of influence of the two quality indices to where the actual policies of the company could have an impact on customers, as can be seen from the market sector map. This has demonstrated the unparalleled strength of the composite model to represent the system as in reality works.

Production capacity is expensive. Thus, firms like to make reasonably certain that new increments of capacity are justified. Our high-tech SBU would need for example very expensive "Programming Platforms" used in software development, the cost of which is approximately 0,5 million EUR each (information obtained from SBU), and hiring and training of highly qualified people. As no signaling mechanism for capacity extensions was at work, it was agreed with the QT that the justification should come in the form of lead-time signals that could reveal the applicability of company expansion plans. These signals - and provided that capacity increases came in chunks of man/hour/value of average yearly production - should also serve the purpose of an early warning system (Ansoff, 1975; Krystek et al, 1989), giving management the time to react. Once the need for new capacity was recognized as valid, the delays involved in bringing it on line (financial approval, acquisitions, hire and training, etc.) was estimated at six months, hence the stock of capacity coming was mapped as a converter with six months transfer time. An important facility of the mapping language chosen, i.e., the ability to depict hidden inertia and delays, which raised the QT's appraisal.

In this case, the policy making mechanism enabling the comparison between desired and actual conditions and translating that as a function of the action to be taken, offered a good case for aggregation, because the decisions and actions involved within it were rather of an overt, standardized, repetitive character.

PIMS research supports the premise "early market share, early capacity for Start-Ups", giving also the average percentile values at different time points (benchmarks) as already mentioned. This is another case where PIMS statements could be used as first orientation for describing the desired state. The formal model can then facilitate the investigation of the relevant industry, system structure, context specific assumptions, opening like this the way to management intuition, experience and area specific knowledge to unfold. The confidence in management judgment achieved in this manner is perhaps the best way to organizational learning. It is again a point of valuable synergy between the two approaches.

Once we developed the maps, we moved on to define the flows and feedback loops, specify the algebra, and set parameter values in our model.

Model

The four most important sub-steps associated with this step are to define the flows, feedback loops, specify the algebra and set parameter values. We discuss each one separately as follows.

Defining the Flows

At this stage we are concerned with determining the nature of the activity at work in producing the particular inflows and outflows to stocks. Closing loops means looking for feedback relationships that regulate the flow activities in the model. The primary target here is to achieve an operational specification of how each flow works in the real system. The question is not "what are all the things that influence this flow?" but "what is the nature of the activity generating the flow?".

Out of the literature of systems methodology and Management Cybernetics the basic flow processes with typical generic behavior patterns are amazingly few (Gomez and Model, 1981). Normally the activities would be of a self-reinforcing positive feedback compounding nature, or the opposite, i.e., a draining process (negative feedback).

First there is the case of a production process, whereby some resource, other than the stock to which the flow is attached produces the activity (see Figure 5 system structure sector map generation of order backlog). This external resource is either increased or depleted. Most of the other generic patterns that appear in a dynamic socio-technical (goal-seeking) system, can be traced by the stock-adjustment processes, resulting from the interplay between compounding and draining processes (see Quality Index sector). Naturally, stabilizing or destabilizing couplings can be easily detected by using these valid principles as diagnostic tools (Gomez et al, 1975).

PIMS research can not help much at this sub-step. It is rather the knowledge of operations research and observations of the real system at the operational level that will reveal the nature of these activities. On the other hand, PIMS assistance can be appreciated on the next sub-step, where connections between sectors are mostly of a meta-character. It must be emphasized here that the lines between object and meta-level within the model cannot always be clearly drawn, for one simple reason: In any real system model the recursive levels may be found in different parts and organizational units (e.g., functions, departments, etc.) of the real company. As S. Beer (1972) states:

"System 4 (Strategic Management) must contain a model of the corporation .... There is no doubt also that this model may be disseminated in separate chunks of cognitions around the firm rather than being cohesive and well formulated. Certainly, no one may think of it or refer to it as a model, but it most be there."

We may quite often come across the situation where the levels of the invariable cycle information-decision-action are located in 2 or 3 recursive levels. This most certainly has diagnostic implications for the viable system designer or the management information systems architect, but for our purpose the implications are limited. We are interested in the nature of existing processes, where ever they are. At a later stage when viability will take a different meaning and the people involved are in a position to better understand the architectural principles of viability applied to their case, then these principles can take a more definite form as decision rules for finding solutions to diagnosed and localized problems. Then again the constructed model can be the best tool for the experimentation needed before design.

Feedback Loops

Here we are seeking to make the linkages between existing model elements. In searching for loops to close we must distinguish between what is desired and what is possible to achieve. We must make sure to include constraints which may act to limit performance in the real system. Further, we must ask if the converter or flow regulator depends upon one (or more) other variable (s) construct outside and make that connection. We are mainly interested in deciding how to formulate a particular decision function (finding policy as defined previously).

The choice of factors must be made from the viewpoint of what affects the characteristics of information feedback systems. The decisive test in choosing factors with direct influence is to observe model performance with and without the factor. In this way the model itself can help determine what it should contain. Care must be taken to recognize feedback or repercussion of the decision on the factor entering into the decision and the timing of such feedback. That is where we try to detect positive and negative feedback loops operating between flow and stock. Positive feedback creates exponential growth and can ultimately lead to oscillations causing the collapse of the system. An example here would be advertising. If the advertising budget is set at appropriations of sales, then sales increases advertising as well. In this case the degenerative cumulative cycle will continue until maybe the depletion of the customer pool will put an end to commercial activity. Thus, in many cases a negative feedback loop should be at work and repercussion on the factors entering decisions should be investigated, because the effect might not be unidirectional.

Screening most of the research published on PIMS, we were able to identify only three cases where due attention to the above phenomenon was given and the need to depart from the methodology investigating uni-directional effects among variables recognized.

First, it was the work of Philips, Chang and Buzzell (1983) where quality, cost position and performance are tested, using the conventions of structural equations modeling (Joreskop, 1979), common, as they claim, in the social sciences. Second, we may quote the work of Prescott, Kohli and Venkatraman (1986) in which using a causal modeling and taxonomic approach to research, they investigate the direct effect of Market Share on Profitability. However, the authors admit that feedback effects have not been addressed in their study. Finally, characteristic is also the study of Lutz Hildebrandt (1992), where the above model of Philips *et al* (1983) is transformed into a causal network model, in which indirect and some feedback relationships are also recognized. In all three exceptions quoted, although the need was recognized, no serious effort was undertaken to study the true nature of possible feedback loops. Thus, PIMS help on the subject is extremely limited. One has to rely on intuition, observations on the real system and existing descriptive knowledge.

An example in our model is the effect of the Customer Satisfaction Quality Index (see Figure Quality Index 2 on market sector map) which has an impact on turning Active Users into Satisfied Customers. As the stock increases, then production increases, which then affects learning through which the Quality Index reaches its target value faster. That is how the real system works and transmits its impulses through closed loop information channels. During that transmission the decision for the model-builder is what factor to include, the direction of the effect, its magnitude and what non-linearities appear. PIMS research reveals to us what to include and traces to a certain extent the direction of the effect.

But there is another dimension to the direction of the effect: The short-term and long-term influences on a decision by a particular factor, are often in opposite directions, and consequently the dynamic behavior of a model can seriously appear misleading if only the long-term effects are included. J. Forrester (1961) (as well as many doctorate dissertations at M.I.T.) gives a few examples on that, one of which is: In an expanding research activity more people may be needed to accelerate the completion of a project, but the first effect may be reduced progress, while those people are trained and absorbed into the organization. Thus a short-term negative effect becomes positive with time. In our example (see system structure map) without representing the capacity increases coming on line with a converter stock that takes six months to produce its output which is more capacity, the first effect of hiring new people would definitely be increasing the order backlog and the lead-time with its already known consequences on achieving Quality Index 1.

The magnitude of the effect - which is basically the dynamic behavior of information feedback systems as determined by the way in which changes in one variable cause changes in another over time - and the effect of non-linearities, can only be assessed in a continuous interaction composite model where the non-linearities of the decision functions can also be considered. In our example, it becomes obvious from the Reference Behavior Pattern (see market sector map) that, depending on which area of the curve the company under study is found, the effect of quality differs decisively. Thus, if we take a measurement at a point in time when the company is on the flatter area of the curve and we consider design policies for the future, we will very soon find out that the expected effect will not appear. These non-linearities of the decision functions are discussed in the last two sub-steps which are to specify the algebra and set parameter values.

Specify the Algebra

In specifying the algebraic relationships, we are providing the computer with a precise description of how the flow or converter operates. The equations tell how to generate the system conditions for a new point in time, given the conditions known from the previous point in time. As the computer program (based on the Dynamo Compiler developed originally by Forrester *et al*) automatically calculates the system's equations for levels, rates (decision functions) or auxiliary, supplementary and initial values, our concern is how to pass the logical checks (most of them incorporated in the software as correcting signals), so that the dynamo compiler can create a computer running code for simulation. Then, the choice of the solution interval time-DT (delta time or time increment) becomes the second concern. By definition this interval must be short enough, so that we are willing to accept constant rates of flow over the interval, as a satisfactory approximation to continuously varying rates in the actual system. This means that decisions made at the beginning of the time interval will not be affected by any changes during the interval. The entire computation sequence can then be repeated to obtain a new state of the system at a time that is one DT later than the previous state. The model traces the course of the system as the environment (levels) leads to decisions and action (rates) that in turn affect the environment. Thus, interactions within the system will unfold according to our description or logic set down in the equations of the model. In almost every case this logic, which will generate the system of equations, can be very easily constructed using addition, subtraction, multiplication and division. When, the need arises to use higher level algebraic operations, the program offers a wealth of tools ranging from trigonometric to financial and statistical operations, capable of capturing a great variety of relationships and patterns.

Set Parameter Values

Parameters are the constants in our model and hence the last thing to worry about before conducting simulations. We are now dealing with the numeration part of quantification, quantifying taken here to mean the transformation of implicit models of the situation, as discussed in previous sections, into a formal model shared by everybody involved. If the model is properly constructed to represent the actual information feedback structure of our system, it will have the same self correcting adaptability of real socio-technical systems. Thus, in a model, the sensitivity to selected values of parameters should not be greater than the sensitivity of the real system toward the corresponding factors.

Obviously, as many real world observations suggest, the actual industrial and economic systems, must not be highly sensitive to their fundamental parameters, nor do these parameters always change rapidly. The successful company tends to remain so for extended periods, a success traced back to its basic organization and policies (including all essential aspects of its leadership, etc.).

Conversely, before the system's output pattern becomes visible on measurable performance indicators (ROI, Market Share, Quality Index, etc.) a rather large time elapses, during which the parameter values will be worsening. It is these time lapses that have enabled us to speak about "weak signals" (Ansoff, 1984) and the need for early warning - early resolution strategic radar systems. The task is to investigate when discontinuities in trend and "third variables" appear (Krystek *et al*, 1989) and test parameter values which lead to other than the past output values with the purpose of uncovering pathologies.

The reason for this phenomenon is simple: Our social systems are known to exhibit their structurally inherent inertia (Beer, 1985). As already discussed, it is the system's inertia (or resistance to change, either desirable or undesirable) that increases or decreases its longevity. If the basic design permits the system to be called Viable in terms of the Viability Principles of the Viable System Model (VSM), then this longevity as a function of the systems inertia will lead to the preservation of the systems identity and its development capability. Both, they will manifest themselves on healthy performance measurements taken at different points in time. The change in the parameter values will unfold gradually and the recorded history of this change will be the result of the dynamic properties "genetically" injected to the system by its management and interaction with its environment or by "healthy" or pathogenic mutations. They will be reflected in the form of structural-organizational elements and decision policies that convert information into action. In Management Cybernetics terms, the correct functionality of the system's homeostats will achieve that.

The subject of examining the value regions after which the variable under study "breaks" and new third variables occur is vast and obviously represents another exciting field of research open to the model building approach proposed here.

The implications of the above discussion for the model-builder and after considering the ultimate objective which is variety control through variety engineering can be summarized as follows:

- S/he must choose the steady-state parameter values that enable the model to show the "normal" expected or as behavior observed in the past.
- S/he must establish which variables and parameter values are more likely to fundamentally change the system's behavior and then experiment on the system's inertia with other value bandwidths or value regions, challenging the inherent pathology to emerge.
- S/he should be more concerned with what the model tells us about the factors that will cause changes in the rates and levels than about the accuracy of determining the average magnitudes of rates and levels.

Obviously in order to do this we must have the composite dynamic model first, as our discussion in previous sections has clearly shown. The results of PIMS/SPI research have shown to us which factors to include (aggregation of variables), how to measure their parametric values and what would be reasonable constants. System dynamics can help to investigate then the concealed pathology unfolding over time and manifesting itself on the visible symptoms or as falling values of performance indicators. We can then direct our design effort at the causal factors and not their symptoms. Then the results of these re-engineering efforts can be tested toward benchmarks, to be set again with the help of empirically proven PIMS observations. The synergy becomes obvious, because we know now what to forecast and have a good indication to the bandwidth of the expected values. Thus, forecasting is done within a specific pattern or law of behavior reducing like this its inherent uncertainty (Makridakis, 1990).

The final point to be made here is about the graphical functions. These will enable us to implement either time series inputs to decision functions for linearly changing relationships or, most importantly, to represent the kind of non-linearities often appearing in socio-technical systems, where effect affects cause and vice versa. If we limit the range of variation of graphical functions to what has been observed historically, the model will not be able to provide any insight into what might happen, should we successfully change the way the process is working. Thus, graphical functions are very good ways of testing our assumptions about the forms of a pattern. Then non-linearities will occur in the model in the decision functions that determine the rates of flow. Our task is to find out how they play their role of effects or impacts on this flow regulation. When used in this manner the graphical function typically appears in a flow equation as a multiplier, taking values between 0 and 1. Correctly curved functional relationships facilitate self-adjustment, wherein the model seeks values that balance one another. An example in our model is the non-linear relationship regulating the effect of productivity (See Figure 5 the system structure map).

An example of the first source of non-linearity where the influence of a factor that affects a decision is not proportional, can be seen in our model (sector system structure) with utilized capacity and order backlog. As order backlog increases, utilized capacity increases fast at the beginning of the "travel", but then slows down. It is not a proportional linear change exactly as in reality. In the range of "normal" lead-times the effect or impact is very small. As lead-time increases the impact shows an increasing importance. An example of the second source of non-linearities, when the decision is not independently responsive to the two or more causal input variables but to a product or other combination of the variables, can be seen in the market sector of our model. The flow buy the product is determined by the product of "Interested" and the fraction who buy which stands in a non-linear relationship with Quality Index 1. If there are no "Interested" then the value of the flow is 0.

The models we formulate should be valid over wide ranges of the variables, because we shall want to explore wide ranges of conditions. "Normal" operations will vary over ranges wide enough and therefore non-linearities are highly significant. We shall want our model to be useful outside the operating ranges of the past, because the design of new systems implies operation outside of historical practices.

At this point the three basic steps of the modeling process are completed, meaning that we can continue with our simulations (step 4).

Simulate

The basic sub-steps here as described originally by J. Forrester and P. Senge (1980) and then regrouped here as follows.

- Do basic de-bugging
- Ensure robustness
- Replicate reference behavior
- Test policies, sensitivities and scenarios

The purpose of passing the model through an increasingly sophisticated number of tests with simulation, is to increase confidence in the model. The breadth of the confidence building-tests in dynamic models stretches from tests of the model's structure, through tests of model behavior, to tests of the model's policy implications. In other words, having eliminated the obvious implausibilities, we focus attention to the finer aspects of performance. In our case, attention was focused on all of the model behavior characteristics that can be compared with the real system.

There is no single test that serves to validate a system dynamics model (see our previous discussion). Rather, confidence accumulates gradually as the model passes more tests and as new points of correspondence between model and empirical reality are identified (Barlas and Carpenter, 1990). Therefore, seen like this, validation includes transferring confidence to persons directly or not directly involved in model construction. It is this need that steps 5 (Implement) and 6 (Challenge) from figure 2 are to satisfy.

The must for complying with the necessity of this confidence building process, has led to emphasize the importance of choosing the right mapping language, for achieving the transition from the individual to the congregate cybernetic strategy map. We discuss the subjects of philosophical and epistemological roots of model validation, relevant here, in the third part.

In this example special attention was given to establish if the intrinsic structural elements were capable of producing the Reference Behavior Patterns expected from various sectors and the original problem definition.

The policy/strategy testing unfolded in workshops tracing out answers to the questions pertinent to the objectives outlined below:

- How would policies work under a variety of altered scenarios?
- What would be the hidden potential of different tactics to achieve a better quality? Learning through intensive training? Specific marketing initiatives for awakening customer awareness? Other?
- What demands would the different policies put on the system structure?
- Should "sales attractiveness" be emphasized or "customer satisfaction" and at which points in time?
- What would be the best quality index to set or, in general, what measures should be undertaken so that the company materializes the plans for growth?

The last two steps of the modeling process presented in figure 2 above, "Implement" and "Challenge", are discussed in turn.

Implement

After completing the testing step (in fact something we never complete in an absolute sense), we were concerned with implementing the results of the effort. A critical component of successful implementation was the effective communication of the acquired insights to others - many of whom did not have any connection with the mapping or modeling process.

Actually, implementation should be continuous throughout the process. People who will experience the change must be involved in thinking it through. We found that involving a critical mass of stakeholders from the very outset, greatly enhances involvement. Ways of achieving participation are to involve these people at least in the steps of focusing the effort, mapping-reviewing and conducting policy tests with the model. The objectives are basically to enhance assimilation of the model's structure and model's behavior.

Practical ways of achieving this can be the use of mapping sectors, pictures, text or even a film (facility offered by the software as Quick-Time movies) suggesting the underlying structural groupings and relationships. For instance, by typing descriptions in the document fields within the dialog boxes available in the software entity, people can "visit" these dialog boxes and read the assumptions rather than having to de-code them from algebraic representations.

Another way is to facilitate interactions with the model. By facilitating user interaction we can draw stakeholders into ownership of the process. The used software offers the facility to make a control panel (a special sector) which enables people to change parameters in the model from one location of the diagram, without having to wander around looking for the variables they may wish to test. Like this, we may organize an array of sensitivity set-ups and investigate any change of variation (e.g., minimum and maximum for each selected variable). The last step was again the purpose of reinforcing confidence in the model's use.

Challenge

The final step in testing process consists of taking a fresh look at the structure of the model. The basic questions to consider are: What would happen if we replaced this cloud with a stock? Is it likely to alter the policy conclusions that we have reached? In other words, we take a critical look at both the external and internal boundaries we have chosen.

Clouds represent infinite sources or sinks for flows in the model. They reflect a modeling decision that any stocks, flows and feedback linkages implied by the clouds are not relevant to the modeling purpose. In our case we have observed that by challenging boundary choices, people became more aware of the limitations and simplifications of the model.

The final integrated proposed model is shown in Figure 6 below. As shown in Figure 6 the market sector is interrelated with the quality sector and the system structure sector. The offer attractiveness influences the "fraction who buy" while the customer satisfaction influences both the fraction Hot and Fraction Satisfied via non linear relationships. Further the active users determine the booking rate and the cumulative learning influences the change in quality, which increases or decreases customer satisfaction.

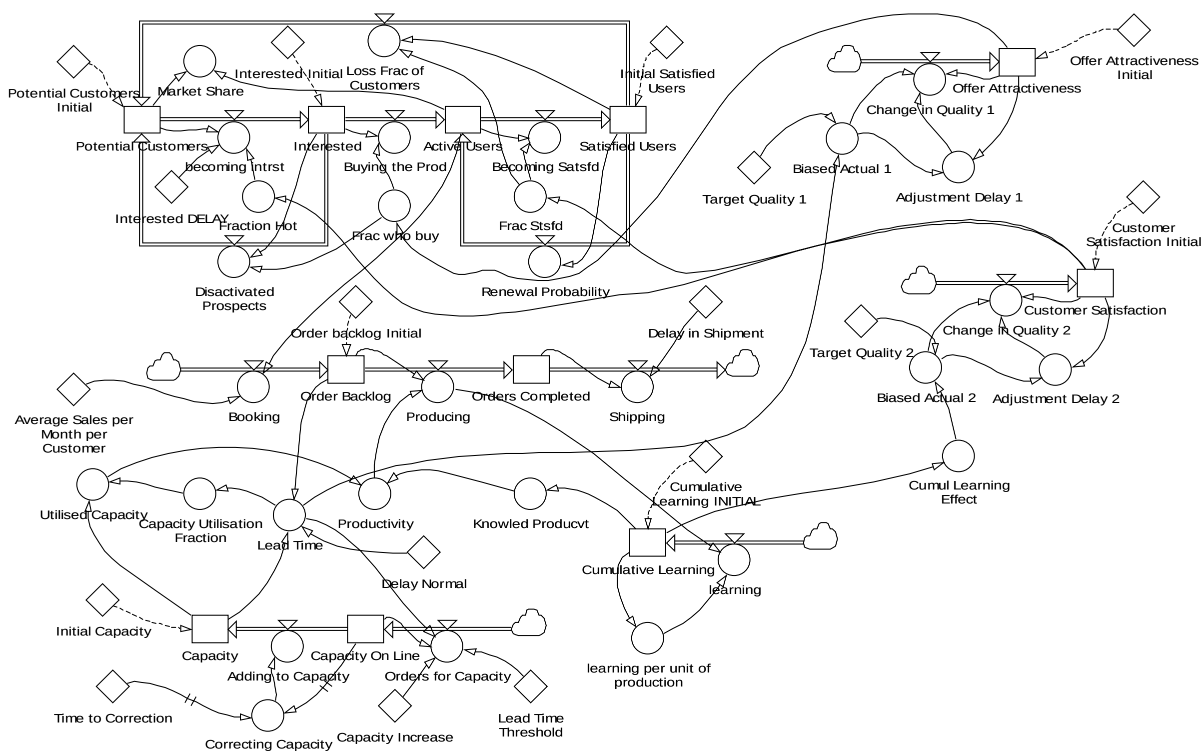

Figure 6: The Integrated Proposed Model

Conclusions

The main objective of this paper was to bring closer together the two main philosophies of science, that is, the traditional reductionist/logical empiricist approach and the more modern relativistic/holistic approach. By integrating the two opposing modelling schools it is expected to gain synergies, which will enhance the effectiveness of the strategic management process but also to open new horizons for research methods and knowledge creation.

Despite the different paradigm bases as well as definitions and procedural rules of the two main streams of philosophy of science, there is general agreement that any meaningful solution approach to strategic management problems can be divided in three main stages. Those are the general understanding of the problem situation, the policy-design stage and the detailed implementation stage. On this basis we developed an integrated composite model, which proved to deliver many benefits to the strategic management process.

For example, regarding the problem of numerical analysis and the problem of pattern recognition we see that both modeling schools are needed. PIMS can more effectively deal with the numerical analysis while system dynamics can be more useful in pattern recognition. The two can be used synergistically in both stages of problem-solving (diagnosis-design) in a confidence-building spiral of reciprocal reinforcement. The beneficial effects, (some of which are overlapping) from the proposed integration are summarized below.

- The integration enables investigation of policy beyond the one contained in historical data (strength of system dynamics)
- It enables a selection of a range of plausible, realistic parameter (strength of PIMS)
- It guides sensitivity analysis appropriate at this stage to the important variables and decision functions having the same potential for change, as in the real system (combined strength)
- It promotes focused model validation through selective and economical collection of data and choice of statistical tests (combined strength)
- It gives indications about both the trends and the limits of a system's performance.
- It enables the application of the Trial and Error method, through simulation and controlled experimentation in a desirable way, i.e., by connecting structure to behavior and screening of a large number of alternatives (combined strength).

In general it can be concluded that the PIMS methodological approach, which is mainly uses data to develop theories, is complemented and further developed by combining it with SD, which uses theory to create data.

This paper provides a detailed description of how to go from a general understanding of the problem situation to policy/strategy design and implementation. This is carried out using basic techniques of two opposing schools of knowledge creation (reductionist/logical empiricist approach and the relativistic/holistic approach). Namely, the Profit Impact of Marketing Strategy (PIMS) technique is combined with Systems Thinking and System Dynamics to form an integrated generic model that can be used as a basis for simulating artificial business environments, whereby effective strategy formulation can be carried out.

Further, an evolutionary strategy development methodology is depicted, where we focus our effort on understanding the problem situation, we map the important interrelationships between significant organisational and environmental elements, and we model the system structure, where via computer simulation we formulate and implement effective strategies to increase organisational effectiveness.

Finally, it has been illustrated that once tacit knowledge is externalised and shared the Strategic management process can greatly be facilitated. Also, knowledge can be created and tested for its validity before we apply it. The mechanism devised for this externalisation and sharing of knowledge was the combined integrated PIMS/System Dynamics model. Even though we made the first steps towards, definitely there is a lot of further work that needs to be carried out until we reach the level to creating the brain of the firm and the true learning organisation.

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