System dynamics for business strategy: a phased approach

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Abstract
Detailed, calibrated system dynamics models offer an effective tool for supporting business strategy. They correspond to the business lines and planning approaches of the organization, serve as an important check on the adequacy of the model as a representation of the system, provide accurate assessments of the cost–benefit tradeoffs of alternative strategies, and allow results to be more easily sold to others. However, detailed models also have disadvantages: they are complex, can be more difficult to understand, and run the risk of becoming “black boxes”. This paper discusses a four-phased approach to consulting that, building from other system dynamics modeling styles (“systems thinking” and small, insight-based models), offers an effective means of developing detailed models while simultaneously educating the client. The approach is illustrated with case examples from the credit card and aircraft industries. Copyright ©1999 John Wiley & Sons, Ltd.

Over the past 20 years, covering more than 50 consulting engagements as the principal modeler, I have worked with my colleagues at Pugh-Roberts Associates to develop a unique modeling style and approach to business strategy consulting. This approach is premised on what we see as the primary purpose of our use of system dynamics models—to aid managers in establishing strategy and tactics. We provide tools, analysis of strategic issues, and business advice. The education of managers in the ideas and concepts of system dynamics is a secondary purpose in some, but not all, engagements.

Most corporate strategic analyses are episodic, often triggered by a crisis or the need to solve an urgent problem. The situation is analyzed, options evaluated, and decisions made. The result of these strategic analyses is usually a decision to take a certain set of actions, for example, to build a new plant, to enter new markets (and/or abandon others), to introduce a new product (and/or drop others), to engage in a price war, and so on. System dynamics models can play an important role in understanding the problem and its causes, determining the consequences of alternative courses of action, and testing alternatives under different scenarios.1

Our approach to business strategy consulting has evolved over time. In the early years, the approach was heavy on “product” and light on “process”. Like many in system dynamics, and in management science in general, we took the view that as experts we would solve the client’s problem for him, and present him with the solution. We gradually recognized that elegant solutions did not

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necessarily lead to implementation, and our style of consulting changed to include increased client involvement (Roberts 1977; Weil 1980). At the same time, our “product” was evolving to meet the needs of clients (and to take advantage of the increased power of computers). We evolved from the smaller, policy-based models which characterized the M.I.T. approach to more detailed models, along with the use of numerical time series data to calibrate these models (Lyneis 1981).

During the 1980s, academic research began to focus more on “process” and the use of models in support of business strategy. In his papers “Strategy Support Models” (1984) and “The Feedback View of Business Policy and Strategy” (1985), Morecroft describes his view of the use of system dynamics in the support of business strategy. He proposes that strategy models should support the development of business strategy in the same way that decision support systems support day-to-day decisions—by providing appropriate information and analyses. He argues that the role of the model is to extend management argument and debate rather than provide answers. The model is used to enhance management intuition (mental models) through an iterative exchange between those mental models and the computer model structure and results, with appropriate revisions to each until a consensus about strategy emerges. And he describes a two-phase process involving first, Business Structure Analysis, and second, Simulation Modeling, to achieve this. Additional research started in the late 1980s focused on more effective ways to involve the client in the actual building of the model (see for example Richardson and Andersen 1995; Vennix 1996).

More recently, “process” seems to have gained the upper hand over “product”. Following the publication of Peter Senge’s *The Fifth Discipline* (1990), the use of “systems thinking”, archetypes, and organizational learning by consultants, with little if any computer modeling, seems to have grown dramatically. In some of these uses, the “product” seems to be an afterthought.

This paper describes our approach to business strategy consulting. The approach strikes a balance between “product” and “process” that produces successful change in business strategy. The approach is an extended and refined version of that described by Morecroft (1985) (and of that of Richmond 1997). It contains four phases:

2. Development of a Small, Insight-Based Model.
3. Development of a Detailed, Calibrated Model.

The approach builds on the strengths of three styles of system dynamics practice that have evolved over the years: (1) systems thinking and the
archetypes; (2) small, insight- or policy-based models; and (3) large, decision-oriented models. The successful application of this approach is illustrated with two case studies.

**A phased approach to successful implementation**

I define a successful consulting engagement as one in which the client implements a solution to the problem, and that solution works. To achieve such success, the consultant must achieve the right mix of “product” and “process”. Four outcomes are needed:

1. An effective understanding, structuring, and analysis of the client’s problem.
2. Education of the client in the dynamics of their business, so as to obtain their active and knowledgeable participation in the structuring of the problem and in the analysis and interpretation of results (and avoid the “black box syndrome”).
3. Selling of others within the company, but not involved in the project, on the recommended course of action.
4. For long-term success, providing the means for ongoing learning and planning with the model (“strategy management”).

The four-phased approach discussed below is designed to accomplish these objectives.

In the ideal situation, we work with a small client team that “owns” the problem and is responsible for making the required decisions. However, this is not always possible and often we must instead work either with a team of advisors to the key decision maker(s) or with a support unit such as strategic planning (drawing in functional expertise as needed). In these less optimal situations, while we try to engage the real decision-maker(s) along the way with regular briefings, the need to “sell” the results of the analysis becomes much more important (see Graham and Walker 1998 for a more detailed discussion of the consulting process in this type of situation).

At the beginning of the project, a project plan and timeline describe the phases of work, the objectives of each phase, and planned meeting dates and deliverables. Expectations for client participation in the project are described. We have found that setting expectations regarding participation and deliverables at the beginning makes for a smoother project, and reassures clients anxious for “bottom line” results. They know when they will be getting insight and when they will be getting accurate assessments of expected performance improvement.
Phase 1. Business structure analysis

The purpose of the first phase of analysis is to clearly define the problem of interest, the likely causes of that problem, and any constraints that may arise in implementing a solution. It identifies the performance objectives of the organization and possible solutions—all to be rigorously tested in later phases.

During this phase, the consultant team reviews company documents, the business press, and available company data. It interviews company managers, and possibly customers and competitors. It identifies the key drivers of business performance: what compels customers to buy this product, what compels them to buy from one supplier rather than another, what drives the internal acquisition and allocation of resources. It identifies where major externalities affect the business (e.g., the economy, regulations, etc.).

Phase 1 builds heavily on the tools and techniques of what is now commonly called “systems thinking”:

- behavior-over-time graphs (reference modes);
- causal-loop and mixed causal, stock-flow diagramming;
- system archetypes;
- mental simulation.

Graphs of problematic behavior over time, often with objectives for future performance highlighted, focus the model design discussion. Figure 1 illustrates the behaviors of interest in the two case studies presented below. In the first case, the client, a major association of credit-card issuers, had been losing market share steadily over a number of years. Would this trend continue? What could be done to turn the situation around? In the second case, the client was concerned with the future behavior of commercial jet aircraft orders. Was the market peak at hand? How low would orders drop, and how long would the next downturn last?

With the problem behavior in mind, causal-loop diagramming or mixed stock-flow, causal-loop diagramming is an effective means of conceptualizing the cause–effect structure of the system believed to create the behavior. It is also one of the primary techniques used to facilitate group model-building discussions. Clients find this approach extremely valuable as a means for discussing the dynamics of the business, and for getting “everything on the table”. It begins to create the shared understanding of the business problem that will be essential to achieve agreement and buy-in for the solution. Indeed, as discussed in a later section, some clients feel that this is the most valuable phase of the whole process.
Fig. 1. Behavior modes of interest in the case studies

**Case 1 – Market Share Trend for Credit Card Company**

*Share of Total $ Charge Volume*

**Case 2 – Cyclical Orders for Commercial Jet Aircraft**

*Dashed Line is Data. Solid Line is Simulated.*
In some cases, model diagramming draws on the “system archetypes”, common generic problem behaviors and structures observed over and over again in different businesses (see for example Senge 1990 and Kim and Lannon 1997). We make very little explicit use of archetypes in actually structuring the problem. The situation at our credit-card client contained several examples of “success to the successful” and “limits to success” archetypes (illustrated in Figures 2 and 3). However, these were noted after the model was developed as a means of explaining some of the dynamics, rather than as a means of identifying structures creating problem behavior.

Once a “conceptual model” is developed using these techniques, “mental simulation” is used to estimate how the structure can create the problem behavior. Mental simulation is a first check on the logic of the analysis—does the assessment embodied in the conceptual model seem capable of explaining the observed problem(s)? Mental simulation is also used to identify the possible impact of alternative courses of action.

In summary, Phase 1 delivers:

- an understanding of the nature of the problem in dynamic terms, objectives for the business, and constraints imposed on possible solutions;
- a conceptual model showing how the pieces fit together;
- a description of how the conceptual model is believed to create the observed problem;
- ideas for possible solutions to the problem;
- lists of issues, uncertainties, and insights or key ideas (“nuggets”) (If the client is involved in the process all along, by the end the solutions to the problem often seem obvious and in hindsight they sometimes wonder what value the project has been, other than in confirming their intuition. It can be extremely important therefore to document insights along the way to serve as a reminder of the learning that has transpired);
- lists of numerical data and other information that will be needed to support later phases of work.

While Phase 1 and the systems thinking that is a key part of it are a necessary start, it should not be the end point. Two problems limit its effectiveness in supporting business strategy. First, simple causal diagrams represented by system archetypes, while useful pedagogically, take a very narrow view of the situation (typically, one or two feedback loops). In reality, more factors are likely to affect performance, and it is therefore dangerous to draw policy conclusions from such a limited view of the system. A more complete representation of the problem considers more feedback effects and distinguishes levels from rates, but introduces the second problem: research has shown that
the human mind is incapable of drawing the correct dynamic insights from mental simulations on a system with more than two or three feedback loops (Sterman 1989; Paich and Sterman 1993). In fact, without the rigor and check of a formal simulation model, a complex causal diagram might be used to argue any number of different conclusions. In addition to overcoming these
limitations, as discussed below, formal modeling adds significant value to the development and implementation of effective business strategies.

Phase 2. Development of a small, insight-based model

The power of system dynamics comes from building and analyzing formal computer models. This is best done in two steps. In the first, a small, insight-based model is developed to understand the dynamics of the business so as to generate insights into the direction of actions needed to improve behavior. The small, insight-based model is also the next logical progression in the education of the client in the methods and techniques of system dynamics modeling. In the second quantitative modeling step (Phase 3 below), a more detailed version of the first model is developed, and is calibrated to historical data. Its purpose
is to quantify the actions needed, to assure that the model accurately reflects all relevant knowledge, and to sell others.

Small models (anywhere from 20 to 400 equations, depending on experience as discussed below), make it much easier to understand the relationship between structure and behavior: How is it that a particular set of positive feedback loops, negative feedback loops, and stocks and delays interact to create the behavior shown in the simulation output? This can only be learned by experimentation and analysis. One cannot effectively achieve that learning with large models.

Small, insight-based models, to fulfill their purpose, should have a number of characteristics:

- Allow the modeler and the client to explore the relationship between system structure and the problem behavior (“Why are we losing market share in spite of actions taken to reverse the trend?” “Why do our projects continue to require more staff and take longer than planned?”).
- Include only those structures (feedback loops, delays, stocks, and flows) necessary to create that behavior.
- Be highly aggregate (i.e., little detail).

All of these characteristics help focus the model on insight generation, communication, and learning. Typically these models are not used to help managers make a decision regarding a major shift in strategic direction or investment. These models can help managers improve their intuition (mental models), and thereby make better decisions, but are generally insufficient for critical strategic decisions.6

Figure 4 is an example of a small, insight-based model—Jay W. Forrester’s classic “Market Growth” model (Forrester 1968). It has three feedback loops and 27 active equations. It offers great insights into why growing organizations can fluctuate—the forces that drive growth, and the forces that create stagnation and decline. It offers policy insight—that sales are not necessarily demand, that waiting for sales to exceed capacity as evidence of the need to expand is a sure way to drive customers to competitors and lose market share, and therefore that a company should avoid being short of capacity. However, without further detail and calibration, my experience suggests that it would be difficult to get managers to make specific decisions based on these insights, for example how much capacity to add and when.

In a practical consulting engagement, “How big is a “small” model?” For purposes of generating useful insight into a business problem, a model would probably need a minimum of several feedback loops and 20–30 equations; at the upper end, Morecroft suggests 100–200 equations (Morecroft 1985, p. 16),
and Hines and Johnson 200–400 equations (Hines and Johnson 1994). The 200–400 equation range is the typical size of our “small” model. In part, the appropriate size of a model for learning also depends on the experience of the modeling team. With experience, the formulation, analysis and understanding of many different business structures become second nature. Therefore, experienced modeling teams can quickly construct and understand (gain insight) from models at the high end of the size range noted above. Inexperienced modeling teams must first learn on models at the low end of the range.

In summary, Phase 2 delivers:

- a small model that recreates the observed pattern of behavior or hypothesized future behavior (and is roughly right quantitatively);
- analysis and understanding of the principal causes of that pattern of behavior;
ideas of high leverage areas that could improve behavior into the future (nuggets!);

recommendations as to where additional detail will improve the strategy advice, or will make the results of the model more useable and/or easier to accept by others.

Phase 3. Development of a detailed, calibrated model

The final phase of model development entails the construction and calibration of a more detailed model.7 The purpose of this more elaborate modeling phase is to:

- **Assure that the model contains all of the structure necessary to create the problem behavior.** As discussed below, conceptual models and even small, insight-based models can miss dynamically important elements of structure (often because, without data, the reference mode is incomplete or inaccurate).

- **Accurately price out the cost–benefit of alternative choices.** Strategic moves often require big investments, and “worse-before-better” solutions. Knowing what is involved, and the magnitude of the risks and payoff, will make sticking with the strategy easier during implementation. Understanding the payoff and risks requires quantifying as accurately as possible the strengths of relationships.

- **Facilitate strategy development and implementation.** Business operates at a detail level—information is often assembled at this level, and actions must be executed at that level. Therefore, the closer model information needs and results can be made to the normal business lines and planning systems of the company, the easier strategy development and implementation will be.

- **Sell the results to those not on the client’s project team.** Few, if any, managers can dictate change—most often, change requires consensus, cooperation, and action by others. The “selling” of results may be required for a number of reasons. If, as in the optimal client situation, consensus among key decision-makers is achieved because they are all a part of the project team, then the only “selling” may be to bring on board those whose cooperation is needed to implement the change. Under less optimal client circumstances, where the project is executed by advisors to key decision-makers or by a support function, then selling to decision maker(s) and to other functions will be required.

There are three important elements in this phase of work: adding detail to the model; calibrating it to historical data; and selling the results to others.
ADDING DETAIL
Adding detail to the small, insight-based model usually involves some combination of:

- Disaggregation of products, staff, customers, etc. For example, the small model might have represented all of the company's product lines as one aggregate product, its staff as one aggregate staff category, and all competitors as one competitor. The small model, with the same basic cause–effect structure, becomes larger by representing additional categories of products, staff, competitors, market segments, and so on.
- Adding cause and effect relationships, and feedback loops, often where the more detailed disaggregation requires representing allocations, etc., but also to represent additional feedback effects that may seem secondary to understanding key dynamics, but may come into play under alternative scenarios, or may later help to “prove” that the feedbacks were not important.
- Including important external inputs, typically representing the economy, regulatory changes, etc.
- Adding detailed financial sectors, which entail numerous equations, with important feedback from profitability and cash flow to ability to invest, employment levels, pricing, and so on.

CALIBRATION
Calibration is the iterative process of adjusting model parameters, and revising structure, to achieve a better correspondence between simulated output and historical data. Whereas the Phase 2 model primarily relies on our store of knowledge and information about cause–effect structure, the Phase 3 model relies on our store of information about what actually happened over time. In addition to “hard” recorded time series data, this historical “data” can, and often does, include managers “observations” of how unmeasured factors, such as service quality, morale, and the drivers of these factors, might have changed over time (and the anecdotes that support these observations). When “fitting” to this observation-type data, however, we are less concerned with the exact numerical values than with the shape and relative strength of effects.

Calibration is not curve fitting via exogenous variables, but systematically comparing simulation output to data and identifying causes of error. Discrepancies are first corrected by improving the structure of the model and/or its parameterization. In some cases, discrepancies are ignored because they are deemed to be caused by factors irrelevant to the problem of interest, or may be “fixed” by exogenous factors if these are deemed significant by the client and are consistent with the remaining model structure and calibration.
As Homer (1996 and 1997) argues, the use of historical data and calibration is essential to scientific modeling.

Accurate calibration can greatly enhance confidence in a model. This can be especially important when trying to convince others of the appropriateness of actions a management team is going to take, or to demonstrate to others the need to take action themselves based on the results of the model. Calibration can also be important for other reasons:

1. **Numerical accuracy is often necessary.** In some situations, the purpose of the model requires numerical accuracy. For example, when using a model to evaluate the relative cost and benefits of changes in strategy and/or alternative investments, managers want to know the impact on profits and shareholder value. Especially where the short-term results are likely to be worse before improvements occur, managers need to know how much worse, and what the ultimate benefit is likely to be. But even in circumstances where significant accuracy is not strictly required, a model which is calibrated to data allows us to more accurately determine relative sensitivities (e.g., price, quality, performance effects on market share), and therefore leverage points.

2. **Calibration often uncovers errors in the data or other models.** In order for a system dynamics model to match the combination of the cause–effect logic and the hard and soft data, a considerable degree of internal consistency is required in the data—if the model is internally consistent, so the data must also be in order for calibration to be possible. Particularly in the early stages of a modeling effort, it is not unusual to find that the available data is not fully consistent. Often, the model calibration process results in the discovery of errors in the data or internal company models. For example:

   - On one project, the inability to match simulated staffing with progress data led to the discovery that the computer system for recording drawing data was not consistently treating work products of different types.
   - On another project, the inability to match simulated staffing with progress data led to the discovery that Department “X” had stopped charging to the project.
   - For an aircraft manufacturer, the inability to match simulations of available aircraft seat capacity and passenger miles flown with the data for aircraft load factor led to the discovery that the company’s internal models were calculating load factor differently than management had assumed (specifically, on a flight segment basis, rather than weighted by flight length).
For a telecom company, the inconsistency between the simulated projections of call volumes and those from internal company models led to the discovery that the internal (econometric) models were incorrectly combining demand and market share elasticities. These errors would not have been discovered without a concerted effort to accurately calibrate the model to the data.

While the discovery of errors in the client’s data may not be of particular significance to the system dynamics modeling effort, they can be important to the client. Management is continually making decisions based on data and models—to the extent that those numbers and models contain errors, management is at risk of making bad and costly decisions. Calibration to an internally consistent system dynamics model is often the only way to detect such data problems.

3. Calibration often reveals incorrect or incomplete mental models. The initial definition of a problem and the formulation of the structure of a simulation model are based on managers’ “mental models”. These models are rarely complete or one-hundred percent correct. Homer notes that “Hard data can materially affect the final structure and key parameter values of a model, and, consequently, its predictions and even its policy results” (Homer 1997, p. 297). Winch discusses how a large, quantitative model is used to correct two common types of problems encountered in consensus-building in management teams: (1) different views (structure or resultant behavior) held by different managers; and (2) the collective view is incomplete or unrefined (Winch 1993, pp. 289–90). Examples from my experience include:

- At a major teaching hospital, faculty were concerned that, in an effort to increase revenues, the institution was focusing more and more on patient care at the expense of research and teaching. This concern was based on faculty perceptions of day-to-day pressures, and “verified” when data showed that an increasing fraction of institution revenues were coming from patient care. However, in order to calibrate the model to available data, the amount of time spent on patient care had to decrease (and the time on teaching and research had to increase)! After additional interviews and modeling, it turned out that the real reason patient care revenues were increasing was not because more time was being spent, but because of more rigorous charging for services that in the past had often been given away. A subsequent survey of faculty time expenditures confirmed what the model showed. So while the revenue pressures were still real, they had not as yet produced the originally hypothesized problem behavior.
At a major development bank, management was concerned about the bank’s ability to continue increasing its loan portfolio in the face of pressures to dramatically slow staff growth. Initial simulations of the model, based on managers’ mental models of cause–effect structure that included assumptions that staff productivity should increase as the staff became more experienced (along several dimensions—years with the bank, years working in a specific sector and country, and the bank’s experience in a country) indicated that staff productivity should be increasing. The data showed that productivity was essentially flat. It turned out that the bank’s budgeting processes and measures of productivity created a situation in which, as the staff gained experience, they “reinvested” their potential productivity gains into doing a better quality and/or expanded job. This was an important insight, because the reinvestment was an unmanaged process. It highlighted the need for management to devise improved measures and budgeting processes so that it could decide how much of the improvement in productivity would be used to grow the volume of loans, and how much used for improving “quality”.

Having just attended an executive development program at M.I.T., the Vice President for Catalog Sales at a large printing company was convinced, based on Forrester’s classic “market growth” model (Forrester 1968), that inadequate capacity expansion was limiting company sales. He brought us in with the hidden agenda of convincing other managers of the need to be more aggressive in expanding capacity. In fact, after building a model, disaggregating it to represent small and large customers, and calibrating to data, we were able to demonstrate that past capacity expansion for large customers was driving the company’s growth. Large customers required significant amounts of dedicated capacity at certain times of the year. During the rest of the year, that capacity would be idle unless the sales force could sell to (mostly) new and smaller catalog customers. Expansion to meet the guaranteed needs of large customers drove the growth of total capacity. How much of that capacity was utilized was controlled by growth of the sales force. So, rather than being more aggressive in adding capacity, the company needed to be more aggressive in adding to the sales force! At certain times of the year, when major catalogs were printed, capacity was in fact limited. This contributed to our client’s misperception of the dynamics driving his business. Based on a mental model and the “limits to growth” archetype, the wrong actions would have been taken. However, the model also indicated that in the future, as the company succeeded in creating
new catalog customers, and as their business grew, the “smaller” customers would begin to dominate the business and a new capacity expansion strategy would be required. We were able to get agreement among the management team on the required shift, and on a pricing increases to finance it!

In summary, while calibration is important in enhancing confidence and accuracy in a model, it is also essential to assuring that the model accurately captures all important factors affecting the issue. While some of the structural omissions noted above might have been caught without data and calibration, the calibration process forces the model builder to examine the model’s consistency with all available information. It is the final check on the adequacy of the model—the final check in learning about the structure of the system.

**Selling**

In many situations, not everyone who may have an input to a strategic decision or be necessary for successful implementation can be a part of the client team. As surprising as it may seem, the selling of results (as opposed to understanding) is easier to accomplish with a detailed, calibrated model than with a small model. First, the numerical accuracy gives the model face validity. Second, a detailed model more often allows the modeler to counter the “have you considered (insert pet theory)?” criticism. I have often found that when you start explaining the model to others, they respond by asking “Have you considered this feedback? Or this effect?” And if you have not, that ends the discussion. Even though you may think that feedback or that effect may not have any impact, if it is not included in the model you cannot say “Yes, we looked at that and it did not have any impact”, and explain why. If it is not in the model, the critic, and there are many, can argue that your results would be changed by the inclusion of their pet theory. One has a hard time countering that assertion. Finally, a detailed, calibrated model helps tell a convincing story. The simulation output, which corresponds closely to the data, can be used to explain (again with output) why, for example, a loss of market share occurred. How price relative to the competitions’ price was the key factor, and/or how the factors affecting share changed over time. The simulation output can and should be tied to specific events. We have found that an explanation like this is compelling, and is important in enhancing the credibility of the model and the modeler.

The benefits of large, complex models in a consulting setting are also noted by Winch (1993). He specifically finds that “For the executive team to have
confidence in the impartiality of the model, each person must feel it captures the detailed pressures and processes of his or her own sphere of responsibility yet produces a holistic view of the organization". (Winch 1993, pp. 295–6), and that the model was essential to getting everyone to agree: “The process of building system dynamics models, in each case ostensibly as a forecasting and evaluation tool, enabled the managers eventually to develop a shared view, which formed the basis for formulating and agreeing upon a final strategy.” (p. 298).

**DISADVANTAGES**

There are some disadvantages of large models. They can be even more like black boxes; they can be difficult to understand (not only for the nonmodelers, but even for the modelers); and they are costly to develop. We avoid and/or minimize the first two problems by executing the model development in the three phases. This allows the client to grow slowly with the concepts, and it allows the modeling team to develop a solid understanding of the model. The third problem is generally not an issue if you are working on significant problems—the cost of the consulting engagement is trivial relative to the expected payoff. We would expect a payoff of at least a factor of 100.

Morecroft argues that a detailed model “loses its agility and becomes less effective as a basis for argument” (1984, p. 227). This is certainly a valid concern, but in my view boils down to the skill of the modeler and his/her ability to internalize/understand the model and its results, and to communicate those results to clients. The modeler stands between the model and the management team. The consultant must acquire the necessary technical and facilitation skills to play that role effectively.

In summary, Phase 3 delivers:

- an internally consistent data base of strategic information;
- a detailed, calibrated model of the business issue;
- a rigorous explanation and assessment of the causes of performance problems;
- analyses in support of strategic and/or tactical issues;
- specific recommendations for actions;
- expectations regarding the performance of the business under the new strategy, and the most likely scenario.

**Phase 4. Ongoing strategy management system and organizational learning**

In 1980, my former colleague Henry Weil (now with the MIT Sloan School of Management) and I described the idea of using system dynamics for strategy
management (Weil and Lyneis 1980). In that paper, we presented the iterative view of strategic management illustrated in Figure 5 (in contrast to the one-shot, episodic approach to strategy, which largely persists to this day). As illustrated in the figure, the overall strategy management process can be divided into three components: analysis, planning, and control. “Analysis” is usually triggered by a significant and/or persistent deviation between actual and expected performance. It involves the iterative structuring, testing and refinement of an organization’s understanding of its strategic problems and of the options open to it to deal with the performance gap. The process of evaluating alternative strategies often sheds new light on the strategic problems faced by an organization or reveals the need for further analyses. “Planning” is also an iterative process, involving the evaluation, selection, and implementation of strategies. Evaluation of alternative strategies depends not only on projected accomplishment of organizational goals but also on the realities of current performance. The existing strategy and goals are subject to refinement, as required, based on the successes and problems encountered, and in response to changing conditions.

Traditional, episodic strategy involves only analysis and planning. Once the strategy is selected and implemented, the process “shuts down” until another crisis ensues. Typically missing is the control phase on an ongoing basis (rather than waiting until a performance gap becomes large and/or persistent again). True strategy management (“control”) involves the ongoing, systematic
monitoring of performance and the effective feeding back of successes, problems, threats, opportunities, experience, and lessons learned to the other components of the strategy management process. The control phase is where organizations continue to learn.

The model provides an essential element to the control process—a forecast of expected performance against which actual performance can be monitored on a regular basis. Deviations provide a signal for additional analysis: Has the strategy been implemented effectively? Have conditions about the external environment changed? Are competitors acting differently than expected? Has the structure of the system changed? The model provides a means of assessing the likely causes of the deviation, and thereby provides an early warning of the need to act. This feedback is only possible with a detailed, calibrated model.

Client use of a model for ongoing strategy management has, in my experience, been successful in only a few cases. In spite of best intentions, clients have difficulties sustaining an effort for a number of reasons:

1. The problem has seemingly been “solved”.
2. Internal resources trained and devoted to the model are siphoned off to other, more pressing concerns, or move on to other opportunities.
3. Given the seeming solution to the problem, managers are reluctant to spend money on consultants to keep the model active.
4. The senior managers who championed the original effort move to other opportunities, often outside the company.

Can you stop anywhere and still deliver value?

Given the significant increase in cost as one moves through the phases, and particularly between Phases 2 and 3, the question of value for money often arises. While I believe that the client obtains value, regardless of when they stop, strategy consulting is one case where the “80/20 rule” does not apply—the client does not get 80% of the value for 20% of the cost (which would be essentially at the end of Phase 1). In part, this is a function of what I view as the objective of the project—providing tools, strategic analyses, and advice in support of an important strategic and/or investment decision. In this situation, the “value” is back-end loaded.

However, there is clearly value all along the way, especially regarding insights into the interrelationships driving the business. Phase 1 is often the most enlightening phase for the client as they are moving fast up the learning curve and developing a shared consensus on how their business works. However, its ultimate value as a strategy support tool would be limited without...
the remaining rigorous phases of analysis. Phase 2 is where the real insight-generating capacity of a model often occurs, because of the ability to test alternative theories and understand why or why not they work, and thereby improve managers’ intuition (see Hines and Johnson 1994).

However, the detailed, calibrated model provided in Phase 3 is where the full value of the modeling effort is likely to be achieved. Phase 3 assures that the model is consistent with all available information, that the proposed solution is worth the effort, and that the company is in agreement on implementation (everyone sold, worse-before-better recognized). Without Phase 3, the wrong solution might not be fully implemented! The question of where diminishing returns set in, in terms of model size and accuracy of calibration, is also important. It can only be answered in a specific client setting—how well articulated is the problem and the client’s understanding of it; what does it take to make the client comfortable with the solution, and to sell to others.

**Case examples**

Cases from the credit-card and commercial-aircraft industries illustrate our approach. These cases were chosen because they are both about five years old, and therefore are no longer competitively sensitive and the outcomes of the work are known.

**Credit-card industry**

This project started late in 1990 for a major association of credit card issuers, specifically one of the two cards issued through banks (the major issuers of cards in the USA at that time were American Express, Discover, MasterCard, and Visa). Our client faced the problem of continual and steady erosion of market share illustrated earlier in Figure 1. Share erosion continued in spite of numerous attempts to reverse the trend. Our client was becoming very concerned that if share fell below 25% the downward spiral would accelerate, because banks would begin to drop the second, low-market share card in order to reduce the overhead of handling both. The project was executed in two formal stages, with the first stage covering Phases 1 and 2 described above and taking about three months. The second stage covered Phase 3, and lasted about six months. Efforts to bring the model in house were abandoned after about a year as a result of a major reorganization.

During Phases 1 and 2 of the project, we worked with a Senior Vice President from the client, who felt that dynamic modeling could help them
understand their situation, and specifically help them stop working at cross
purposes in trying to solve it. Our client related one example in which one part
of the organization was working with merchants to offer a discount to
customers who purchased using our client’s card, while at the same time
another part of the organization was encouraging member banks to reduce the
amount cardholders paid every month by reducing the minimum payment
(thereby increasing bank revenues from finance charges). These actions worked
at cross purposes by aggravating the “limits to success” archetype illustrated in
Figure 3: while discounts encourage additional sales, lower minimum payments
increase outstanding balance and therefore result in a reduction in available
credit. Cardholders were not able to buy more in spite of the discounts! This
executive was not directly responsible for the credit card business, but felt
strongly enough that she funded the first stage of work. During this phase, we
worked with this executive and another consultant who was an expert in the
industry to develop a conceptual model, which we believed captured the drivers
of the steady erosion of market share.

While I do not intend to describe the model in detail, Figure 6 provides an
overview of its breadth (covering member banks, merchants, suppliers of cards,
cardholders, the issuing associations) and complexity (most of the key relationships and feedbacks are illustrated in the figure; even in the small, insight-based model, however, we replicated structure to capture four major competitors). We then constructed a relatively simple computer model that roughly reproduced the observed behavior. With that model, we conducted a range of sensitivity tests to determine the highest leverage areas for reversing the situation. Perhaps not surprisingly, the highest leverage areas were not the ones where they had been focusing their efforts! Most of the client’s efforts had been directed at getting more cards in circulation. However, the high leverage areas were in getting people to use their existing cards more (which as a secondary effect led to increases in cards in circulation through the “success to the successful” feedbacks illustrated in Figure 2). This insight was one of the “nuggets”.

Once these phases were completed, moving forward required selling a Phase 3 to additional executives. A three-hour presentation and demonstration was arranged with the key superiors of our sponsor. At the end of the first hour (describing the structure of the model), the meeting was not going well, in large part because the work was outside the charter of this executive group. Nevertheless, we were able to move into the second hour and begin describing results—how our client was caught in a number of vicious circles, and why past attempts had failed to reverse the situation. The sensitivity tests, together with the ability to execute online tests of interest to the senior executive, presented a compelling explanation and clearly demonstrated the value of formal modeling. Phase 3 was sold and executed with a few additional senior executives, though still not all the executives who owned the problem.

During Phase 3, additional model structure was added, along with a fifth competitor (just getting started). Extensive data was collected, and the model calibrated to that data (no surprises this time). Inputs characterizing expected economic conditions were then used to generate a “business as usual” scenario. Part of that calibration and scenario are illustrated in Figure 7. The projection indicated that with no changes in management policies, and even though the number of client cards in circulation continued to increase, their share of charge volume would continue to erode. The trigger point for a rapid downward spiral (not built into the model), was likely to be reached soon.

Near the end of Phase 3, a several hour presentation was made to the entire executive group responsible for the credit card business. The comprehensiveness of the model structure (presented in a buildup of the key feedback loops, and with several large diagrams of the model illustrated in Figure 6 at the meeting), the quality of the calibration to historical data, and the persuasiveness of the explanation of the causes of the erosion of share that the model
Fig. 7. Historical simulation and projection.
provided, together generated sufficient interest in the power of the model that we were asked to help them assess specific initiatives to turn the situation around.

First, we tested the initiatives that our client had recently undertaken, or was considering. None of these reversed the loss of share. This failure of management efforts to correct the situation is common (Graham and Walker 1998, pp. 1 and 8). We therefore executed a thorough sensitivity test, varying most of the parameters in the model by plus or minus 25%, and graphed the change in market share five years into the future, and the change in cumulative member bank profits over those five years (a selection is illustrated in Figure 8, somewhat disguised to protect client-sensitive information). I will not discuss specific tests, but with these results we worked with the client to identify initiatives that produce improvements in the areas of the highest leverage. From these discussions, it became clear that there was an initiative under discussion that almost everyone was opposed to, but that actually affected four of the highest leverage items. This initiative was issuing “affinity”, or “co-branded” cards (e.g., the American Airlines Visa Card, the GM MasterCard), which typically offered a value to the cardholder above and beyond the ability to charge purchases (e.g., mileage credited toward free flights, or a credit toward purchase of a car, for every dollar charged). The first affinity card, the AT&T Universal Card, came out under our client’s brand name in the late 1980s, but with little enthusiasm and against the wishes of the major banks (the banks held key positions on the Boards of these credit card associations). In response, our client’s major competitor association banned the issuing of such cards
under its brand name (they were afraid that having the major corporations of the USA issuing cards, usually by buying a very small bank or working in conjunction with a bank specializing in serving credit card customers, would cost the banks a significant amount of high-margin business).

Our client’s board was about to take similar action. However, our analyses showed that, if done correctly, co-branding could reverse the erosion in market share, even if the competing bank card eventually responded (see Figure 9). In fact, because the competing bank card was likely to respond, and because other competitors (American Express, Discover) would not be able to offer these same “affinity” cards on a wide scale, our analysis indicated that the competing bank card would regain most of its lost share in the future, and that the share of both bank cards and bank profits would improve significantly (Figure 10). The client shortly thereafter decided to make a major push into co-branding and was able to sell the push to its Board, in large part because of the model results. Our client was first to market, and they gained a significant lead. The initiative resulted in a 25% improvement in market share. In 1996 we went back and obtained more data from the client, and our projection was almost exactly what happened. It was a very successful turnaround.

Commercial aircraft industry

This project was conducted between 1987 and 1991 for a manufacturer of commercial jet aircraft, and later for a supplier of parts. The problem faced by our client is illustrated in Figure 1: going back to 1970 (and even before), orders for commercial jet aircraft exhibited highly cyclical behavior. At the time of the project, critical questions were: Are we at another peak? Should we be adding more capacity? When will be the best time to introduce the next generation of aircraft (i.e., when will the market bottom and grow again). In addition, the client was interested in a number of alternative scenarios: How will future orders, in total and by size category, be affected by the speed and success of “liberalization” of the European airline industry? By growth in the “freight” business? By future oil prices and economic conditions?

The project was also executed in several stages. The first contracted stage covered Phases 1 and 2 described above. We interviewed client managers and a number of customers. We then worked with the client to develop a conceptual model that we felt explained the cycles in the industry. Finally, we built a model of the European market, using external inputs to represent the used aircraft market and the manufacturers of aircraft, and roughly calibrated the model to data.
Fig. 9. Impact of the recommended cobranding initiative on cards in circulation and market share—dashed line is base case, solid line is client Co-branding.
The dynamics of the industry, at the simplest level, are illustrated in Figure 11. There is one major "negative" or balancing feedback loop and three amplifying positive loops. Starting on the left of the figure, travel demand (revenue passenger kilometers or RPK) is influenced by GDP and population (exogenous inputs), by fares, and by travel experience. For example, suppose that GDP increases, inducing an increase in business and recreational travel. Two reinforcing feedback loops amplify this increase in the short-term: (1) as demand goes up, given that a significant fraction of airline costs are fixed, target fare required to maintain the same profitability can go down—the airlines can spread their fixed costs over more passenger kilometers; as the airlines reduce fares (relative to inflation), the positive stimulus from the economy is reinforced; and (2) an “experience effect” further reinforces the economic stimulus—the more people fly, the more they get used to flying, and so they fly more (or are reluctant to reduce flying in a recession).

As demand for travel grows, the airlines begin to project demand forward. They decide how many aircraft they will need to meet that demand, and compare that to their fleet. They order aircraft to meet that gap, which introduces another reinforcing feedback loop—as the order backlog approaches
manufacturing capacity, delivery lead times increase. Instead of taking two years to get an airplane, it now takes three. As a result, airlines order further ahead. As they order more, because manufacturing capacity is slow to increase, delivery lead times increase further. As lead time increases, airlines order more aircraft and sometimes "play games" in order to get a better position in the delivery queue. For example, they might order aircraft from different suppliers, with the intent of canceling or delaying one after the first arrives. These ordering policies, in combination with the stimulus of price and experience to demand, creates overexpansion in the industry. The phenomena of double and ghost ordering is cited in the economics literature (see Mitchell 1924).

After a while, orders are delivered and enter the fleet. This raises the airlines' fixed costs, and fares must increase to cover these costs. Fare increases put downward pressure on demand growth. It happens that the cycle delays around the manufacturing delivery loop are three to five years, which corresponds well to the business cycle. So, just as fares are increasing with the growth in the fleet, often GDP is going down. This triggers the downwards spiral with the reinforcing price and experience loops, not to mention all those airplanes ordered that are still being delivered! The dynamics just described are the essential causes of cycles in the aircraft manufacturing industry.
While the dynamics described above create the industry cycles, such a simple model would not have served our client's needs. Detail and calibration were necessary to answer questions about the timing and size of the peak, the need for more capacity, and the prospects for particular size categories of aircraft. Detail was added to the model in a second stage of work—Phase 3 (see Figure 12, a more detailed “block” diagram of the model of the industry): demand was disaggregated into domestic and international components (different size and operating characteristics of the aircraft), and into major regions (because of significantly different growth potential). Airlines were similarly disaggregated by region. The used market, leasing companies, and prime manufacturers were added. The same basic dynamic structure underlies the detail. Once you understand the dynamics, it becomes easier to understand the big model.

With the detailed and calibrated model, we were able to accurately predict first the peak, and then the downturn (see Figure 13). As a result, our client was better able to introduce a new family of aircraft into the upturn. The client also avoided unnecessary capacity expansion because using the model, we demonstrated that a significant portion of the orders in the 1989 peak were double orders that would be canceled or delayed when the bottom fell. Having a detailed, calibrated model resulted in significant savings to the client, who continued to update and use the model after our involvement ended (Phase 4).
Conclusions

System dynamics models offer an effective tool for supporting business strategy. They allow a company to consider interactions among all parts of the business, as well as interactions with competitors and customers, and thereby develop strategies which truly account for the dynamics of the organization. In addition, they provide an effective means for communication and consensus-building within a management team.

However, to achieve the full value of system dynamics for strategic decisions requires detailed, calibrated models. These models correspond to the business lines and planning approaches of the organization, serve as an important check on the adequacy of the model as a representation of the system, provide accurate assessments of the cost–benefit tradeoffs of alternative strategies, and allow results to be more easily sold to others. But these advantages come at a price. Detailed models are complex, can be more difficult to understand, and run the risk of becoming “black boxes”. These potential disadvantages can be overcome with a four-phased approach to consulting that, building from other system dynamics modeling styles (“systems thinking” and small, insight-based models), offers an effective means of developing detailed models while simultaneously educating the client.
The four-phased approach has proved successful for many years, particularly for strategic and tactical decisions. However, while a number of clients have used and evolved the model following completion of the initial work, true strategy management remains elusive in all but these few instances. Most managers still treat strategy development in an episodic, crisis-response fashion, and are unwilling or unable to use models in an ongoing fashion to learn and adapt strategies over time.

Notes

1. System dynamics models can be used to support organizations in other ways. First, models, and perhaps “systems thinking”, can improve managers mental models of their organizations. Many managers think linearly, and often ignore or downplay potential feedback effects of their actions. The enhanced thinking processes provided by the system dynamics discipline can allow them to make better decisions now and in the future. However, as discussed later in this paper, insight without detailed, calibrated models does not provide the full power of the discipline and may lead to incomplete or even erroneous assessments. System dynamics models can also allow CEOs to act as designers of their organizations, in much the same way as engineers design airplanes to be flown by pilots (Forrester 1965; Keogh and Doman 1992). In this use, many actions within the organization would be controlled by the “auto-pilot” of established policies (decision rules) for setting production rates, ordering for inventory, pricing, and so on. While this is a worthy objective and may some day be common, most organizations and CEOs are not yet ready for this. The primary use of modeling for business strategy remains the episodic support of specific decisions and actions.

2. The substantially faster growth and size of the softer, process side of system dynamics is evidenced by journal subscriptions and conference attendance. The more academic, product-oriented System Dynamics Society and its journal System Dynamics Review, founded in 1983, has approximately 600 members (at $85 per year). Its last annual conference in July 1998 attracted approximately 300 attendees. The more process-oriented journal The Systems Thinker, founded in 1990, has approximately 5000 subscribers (at $189 per year), up from approximately 2000 in 1994. Its annual conference attracts approximately 1000 attendees. Efforts by Pegasus Communications, publisher of The Systems Thinker, to attract interest in the harder, model-based side have been less successful. Its last model and
modeling-focused Power of Systems Thinking Conference in 1997 attracted only 250 attendees (small compared to the 1000, but significant nonetheless). The change in consultant attendance at the International System Dynamics Conference is also indicative. Between 1994 and 1998, attendance by consulting organizations whose founders and/or members were academically trained in system dynamics at MIT, Dartmouth, or one of the UK universities doubled, from about 15 to 30. Attendance by consultants from the big accounting and/or strategy firms grew from 4 in 1994 to 30 in 1998. While undoubtedly some of these large organizations use formal computer models (just as a number of MIT-trained system dynamics Ph.D.s focus on process), their consulting style and modeling experience dictate a heavier process emphasis. Likewise, attendees affiliated with what sounded (to this author) like process or learning-organization firms grew from 4 in 1994 to 25 in 1998.

3. Business Structure Analysis is Morecroft’s terminology. Since we do not have an explicit title for the phase, and it seems appropriate, I will borrow it.

4. The modeling styles are listed in the natural progression of executing a project. Chronologically, however, small-policy based models came first. Next came the large, decision-oriented models that evolved out of Pugh-Roberts and others doing consulting. Finally, in the 1980s Barry Richmond, Peter Senge, and others popularized the concepts of “systems thinking”, although causal-loop diagramming was developed during the 1970s primarily as a means of communicating models. Another category, management flight simulators or games, is not discussed in this paper.

5. There was and still are controversies within the field about the value of causal loop diagramming (versus level-rate diagrams). We have found that they alone, or a mixed level-rate/causal diagram, are extremely valuable for eliciting ideas in a group setting about the cause–effect structure of the business, and later for explaining the dynamics observed in simulation output. However, one cannot build a model literally from a causal diagram, and either explicit or implicit translation is required. I find that when working with clients to develop a model, if the stocks are not shown explicitly in the diagram, I know which variables are the key stocks and use this knowledge in structuring the discussion.

6. Small, insight or policy-based models are extremely valuable for two other reasons. First, small models form generic structures that then provide the building blocks for larger, more detailed models. Building blocks make it easier to build and understand larger models. Small models used as building blocks would usually contain far fewer equations than would be required of a small model for policy insight. And second, small, insight-
based models are the foundation for learning about system dynamics—not systems thinking and not large, detailed models. One gains insight into the relationship between structure and behavior by building a small model, changing its structure or parameters, and observing the resulting simulated change in behavior. By building lots of small models, one gains the intuition that helps identify, in real life, the causal structures causing the problem behavior. One also learns how to analyze, debug and test models. Learning about structure-behavior and good analysis approaches is much harder with large models, and I have seen many people struggle to understand the behavior of a large model because they do not have the foundation of learning on many small models.

7. As a practical matter, even this phase is iterative. One progressively adds detail and structure, initially to make the process manageable, and then as necessary to correct discrepancies between simulated output and data, or to add policy handles and implementation constraints. Further, model development is likely to continue in the “ongoing learning” phase as additional structure and/or detail is required to address new issues that arise.

8. This lack of staying power is not limited to system dynamics models. Graham and Walker (1998) cite the example of a large spreadsheet model which also fell into disuse.

9. See Lyneis (1996) for a more detailed explanation of this case.

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