Table of Contents

Go Back

Mitsubishi® Rayon's Penetration Strategy, Balance and Profitability

Nicholas C Georgantzas, Kengo Sasai, Philip Schrömbgens, Karl Richtenburg and Hirofumi Uno
SD Consultancy, Fordham University @ Lincoln Center, New York, NY 10023, USA
Tel.: (+212) 636-6216, ƒax: (+212) 765-5573, e-mail: georgantzas@fordham.edu

Abstract–Socrates argued that virtue is knowledge. Ackoff (1981) concurs. System dynamics modeling for learning helps Mitsubishi Rayon compete by creating new knowledge about the system structure lurking behind its strategic situation. Creating new knowledge often requires capturing unknown and unknowable aspects of system structure that may be neither easy to observe nor easy to measure. The system dynamics model this essay presents reveals a lot about this Japanese giant conglomerate's strategy design and implementation tactics. The model shows a tiny fragment of Mitsubishi Rayon's gigantic effort to re-perceive itself. The firm wants to see its Keiretsu infrastructure transform into an agile *virtual enterprise network* (VEN) of active agents that collaborate to achieve their transnational business goals. Although still flying low under the media's collective radar screen, VENs receive increased attention by strategic managers. By becoming a VEN, Mitsubishi Rayon is poised to bring the necessary people and production processes together to form *autopoietic,* i.e. self-organizing, customer-centric value chains in the specialty chemicals industry. Many of its rivals are still fighting the last war over what they collectively call the *bullwhip effect* in their customer-supplier value chains. But Mitsubishi Rayon is using system dynamics to design efficient processes that satisfy the peculiar needs of particular customers in specific marketspaces or niches within its industry. Mitsubishi Rayon's strategy of balanced marketing and production dynamics aims at sustainable profitability through superior performance that goes beyond the cross-shareholding of equity.

Keywords: Chemical Industry, Marketing, Processes, Production, Sales, Strategy, Tactics, Value Chain, VENs

Introduction

Twenty miles southeast of downtown Houston, Texas, the Clear Lake region covers more than three hundred square miles of prime real estate. Home of NASA's Johnson Space Center, this region boasts strong high technology, biotechnology and specialty chemical industries. Among them, Mitsubishi Rayon Co., whose recent capital expansion will help the Clear Lake region continue its stalwart role in Houston's regional economic expansion (Hodgin 2001).

Mitsubishi® is one of the world's largest industrial companies. So large in fact that the company's main website, www.mitsubishi.com, does not even mention its automotive division! An active member of this famous Japanese giant conglomerate, the history of Mitsubishi Rayon Co., Ltd., begun in 1907, when the Asahi Glass Company was established in the Amagasaki, Hyogo Prefecture, Japan. In 1909 the company registered its diamond-shaped logo and started to make Belgian-type hand-blown sheet glass, the first such manufacturing process ever in Japan. Its headquarters moved to Tokyo in 1917, when it first produced soda ash by the ammonium method at its Kitakyushu manufacturing facility. Mitsubishi Chemical Industries divided in 1950 to form Asahi Glass, Nippon Kasei Kogyo, now Mitsubishi Chemical Corp., and Shinko Rayon, now Mitsubishi Rayon Co., Ltd. That year, Shinko Rayon produced fertilizer-grade ammonium chloride for the first time.

A simple feedback loop has been driving Japanese companies to manufacture outside Japan. Since the 1950s, with Japan still recovering from WW2, the better Japanese companies performed the better their national currency performed. But the better Japan's national currency performed, the more difficult it became for its companies to export their products. The higher the yen, the more expensive and, therefore, less competitive Japan's exports were becoming. This loop explains the lineage from Amagasaki, Hyogo, to Clear Lake, Texas.

But the transition process behind this lineage is not that simple. As Mitsubishi Rayon managers try to secure and to maintain control of strategic resources within the chemical industry, they know and understand their barriers intimately. Their mature giant conglomerate does not usually lack resources but sometimes they lack control over its resources. Their challenge often lies in Mitsubishi Rayon's capacity to anticipate the emergence of future barriers. The managers on our modeling team often praised Texas Instruments because it consistently used experience curve effects to create barriers for other entrants, even in the Japanese market.

When entry barriers are low, emerging inertial barriers help Mitsubishi Rayon improve judgments as to what is the most appropriate timing for contemplated tactical moves. In addition, Mitsubishi Rayon can estimate the time lag required before rival defenders start responding in sufficient numbers. Strategic timing frequently emerged as a burning issue during Citibank’s new product introductions in the 1960s and 1970s.

It has become axiomatic that strategic planning starts with some form of environmental analysis of managerial economics. Increased rivalry among firms in an industry and Porter’s (1991) emphasis on the bargaining power of buyers and suppliers, as well as on the threats of new entrants and substitutes, strongly support this axiom. In effect, environmental analysis is often reduced in practice to industry analysis. Yet, changes in the environment beyond the chemical industry’s boundaries almost always significantly affect, and sometimes largely determine, what happens within the industry and its entry, exit and inertia barriers.

To bypass them, Mitsubishi Rayon builds strategic scenarios, which are not new in the chemical industry (Zentner 1987). Scenario-driven planning (Georgantzas & Acar 1995) is helping Mitsubishi Rayon integrate its competitive intelligence efforts with strategy design, not as a narrow specialty, but as an admission of limitations and environmental complexity. Analyzing the firm's strategic situation has lead into a comprehensive inquiry into the environmental causalities and equivocalities that dictate its competitive actions. Computed strategic and tactical scenarios probe the combined consequences of environmental trends, changes in the firm's own strategy, as well as the moves of its current and future competitors.

Computed from custom-built system dynamics (Forrester 1961, Sterman 2000) models, scenarios help Mitsubishi Rayon managers understand what they do not know, enabling strategy design and implementation through the coalignment of the right tactics to improve long-term performance. Through its judicious use of corporate resources, scenario-driven planning makes the tactics required for implementation clear (Georgantzas 1995). Also, it can reveal the required coalignment of tactics over time, so a firm can become both flexible and efficient, and save time!

The system dynamics model this essay presents reveals a lot about this Japanese giant conglomerate's strategy design and implementation tactics. The model shows a tiny fragment of Mitsubishi Rayon's gigantic effort to re-perceive itself. It wants to see its Keiretsu infrastructure transform into an agile *virtual enterprise network* (VEN) of active agents that collaborate to achieve their transnational business goals (Georgantzas 2001).

Although still flying low under the media's collective radar screen, VENs receive increased attention by strategic managers (Ahuja & Carley 1998, Anon. 1993, Davidow & Malone 1992, Drucker 1988). By becoming a VEN, Mitsubishi Rayon is poised to bring the necessary people and production processes together to form *autopoietic*, i.e. self-organizing (Zeleny 2000), customer-centric value chains in the specialty chemicals industry. Many of its rivals are still fighting the last war over what they and executives at 3M, Bristol-Myers Squibb, Hewlett-Packard and P&G call the *bullwhip effect* (Hau, Padmanabhan & Whang 1997).

Sterman (2000, Ch. 17 and 18) presents a generic value-chain management (VCM) structure that can unearth what VENs are up to. His system dynamics simulation model explains the sources of oscillation, amplification and phase lag seen in customer-supplier value chains. Locally rational policies that create smooth and stable adjustment of individual business units can, through their interaction with other functions and firms, cause oscillation and instability. The model incorporates policy parameters pertinent to decision making and timing that allow testing the sensitivity of VCM to customer-supplier value chain changes. The results reveal policies that VENs use to improve their VCM performance.

Similarly, Mitsubishi Rayon computes scenarios with system dynamics to design efficient processes that satisfy the peculiar needs of particular customers in specific marketspaces or niches within its industry. The model this essay presents shows how Mitsubishi Rayon's strategy of balanced marketing and production aims at sustainable profitability through superior performance that goes beyond the cross-shareholding of equity.

The following section gives a brief account of the strategic modeling content and process at Mitsubishi Rayon. Then, the description of how the firm plans to implement its strategy of balanced marketing and production takes the form of a system dynamics simulation model, which precedes the interpretation of its behavior. It is perhaps its capacity to reintegrate the content and process perspectives of strategy that has turn system dynamics into a new paradigm for competitive advantage (Istvan 1992), and simulation modeling in general into a critical fifth tool in addition to the four tools used in science: observation, logical/mathematical analysis, hypothesis testing and experiment (Turner 1997).

Strategic modeling content and process at Mitsubishi Rayon

The content

Much like Citibank and Shell, Mitsubishi Rayon too is a successful cosmopolitan firm that anticipates changes in the global environment as opportunities. Its managers see clearly how competitive dynamics has decisively shifted from the local industry environment to the global environment, as it has decisively shifted from the national economy to the world economy.

The managers on our modeling team accept the idea that their strategy design at the local industry level will succeed if and only if it strengthens, or at least does not impair, Mitsubishi Rayon's global strategic posture. They also seem to have accepted the necessity of selecting the relevant milieu of important variables and relations to be mapped on a case-by-case basis. Simply going down the categories of a pre-established checklist may not best capture these. Environmental scanning, mapping, and modeling are worthwhile, value-adding, but demanding business activities. And Mitsubishi Rayon managers are... *diamond*-clear about that. The conventional perspective of copycat strategy shows linear thinking at best and clumsy benchmarking—also known as *shadow marketing*—at worst (Hatten & Hatten 1987). Unlike Mitsubishi, shadow marketing proponents assume that they can improve long-term performance incrementally, with disconnected tactical moves alone, when improvements in strategy design should be their primary concern.

Piecemeal tactics can undermine strategy, but they are secondary. It may be possible to improve performance through efficient tactics, but it is better to design an efficient strategy that will expel counterproductive tactics. Examples of counterproductive tactics are those coercive moves that increase rivalry among competitors, without a real payoff, either direct or indirect, for the industry incumbent who initiates such moves. It is atypical of an industry or market leader to initiate such moves (Georgantzas 1995). In strategy, superior implementation demands superior design (Georgantzas & Acar 1995).

According to the design school led by Ansoff, Channon, Hofer, McMillan, Porter, Schendel, Thomas and others, logical incrementalism may help implementation, but it becomes a prescription for failure when the environment is shifting. Examples of such failures and reversals are abundantly documented in the business press. Rapid changes in information technology, global competition, family structure and other facets of our global society's culture systems are foisting metamorphoses on the business environment. To some, changes in the environment resemble tornado like forces, cutting a swath of destruction through corporate landscapes. They are forces that leave a litter of torn organizational charts and broken traditions in their wake. To others, environmental change represents a more beneficent maelstrom, a dynamic force that animates vibrant opportunities and infuses new life into tired organizational structures. But no matter how it is perceived, environmental change is a force that managers must deal with.

Transnational firms like Mitsubishi Rayon have a striking capability of institutionalizing change; they never stand still. Yet, even these masters of innovation sometimes refrain from taking a bold step toward complete renewal when a major change, for which they have not analytically or at least conceptually prepared, occurs in the environment (Sherman, 1984).

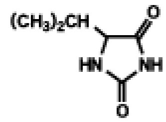
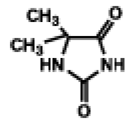
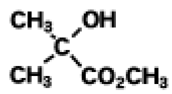
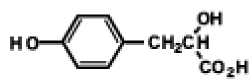
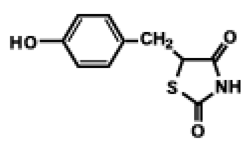
This is what Gluck, Kaufman & Walleck (1980) described as the "unspoken problem". When industry forces change or new market opportunities open up, only a few companies are able to rethink from ground zero the way they do business. The challenge, as our Mitsubishi Rayon modeling participants see it, is learning to recognize the permanence of change and to act proactively.

The overarching goal permeating their thoughts and actions aims at nothing less than transforming Mitsubishi's Keiretsu into an efficient VEN system. Ahuja & Carley (1998) define *virtual enterprise network* as a geographically distributed organization where members, bound by a long-term common interest or goal, communicate and coordinate their work through information and communication technology. But Georgantzas (2001) shows that, despite the considerable progress in developing static models of competitive success, far less developed is our understanding of the dynamic process by which firms attain superior performance.

Consequently, it has become Mitsubishi's objective to convey its Keiretsu system into an efficient VEN structure by re-perceiving its own dynamic business processes through system dynamics modeling intervention such as this, in order to maintain superior performance that goes beyond cross-shareholding of equity. In this context, the purpose of our modeling intervention was to refine and to operationalize Mitsubishi Rayon's strategic decision to set up a production plant in the United States of America that will serve its customer base locally instead of importing its fine specialty chemicals from Asia (Table 1).

Mitsubishi decided to build its own plant in USA because the net present value (NPV) of the combined cash flow resulting from a merger with other specialty-chemicals manufacturers in USA was less then the sum of the NPVs of the cash flows of the firms acting independently. Moreover, Mitsubishi's own technology transfer cost is so low that the internalization cost associated with a merger would far exceed supplier charges plus market transaction costs. To remain competitive (Porter 1991), Mitsubishi will not integrate the activity but offshoot it as a branch of its VEN-becoming Keiretsu infrastructure. The plant will be fully operational in January 2004. In order to maximize the combined accounting-profit NPV (net present value) of its new USA plant and the existing one in Asia, Mitsubishi wishes to improve its sales revenue before production starts in USA.

Table 1 A sample of Mitsubishi Rayon's fine specialty chemicals

Name	Structural Formula	CAS No.	ENCS No.	Stage
5-Isopropylhydantoin		16935-34-5	9-2190	C
5,5-Dimethylhydantoin		77-71-4	5-441	C
α-Hydroxyisobutyric acid methyl ester		2110-78-3	2-1404 2-1430	D
3-(4-Hydroxyphenyl)-lactic acid		6482-98-0	—	D
N-tert-Butylglycine	t-$BuNHCH_2CO_2H$	58482-93-2	95 ≤	D
Glycine tert-butyl ester	$H_2NCH_2CO_2$t-Bu	27535-96-3	97 ≤	D
5-(4-Hydroxybenzyl)-thiazolidine-2,4-dione		6482-98-0	—	D

C = Commercial, D = Development

Figure 1 shows a schematic representation of Mitsubishi Rayon's strategic situation. Its pre-production marketing tactic entails building a salesforce to increase the sales of Mitsubishi Rayon's fine chemicals in USA. Until the completion of the new plant in December 2003, Mitsubishi Rayon will be importing these chemicals from its Asian production plant.

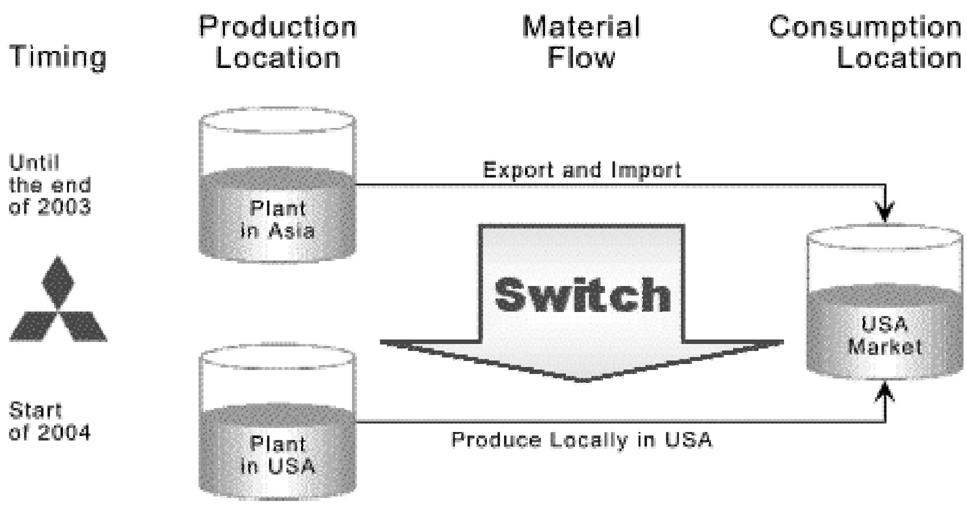
The process

In the early phases of modeling a managerial decision situation, it may be helpful to try modeling a business or social *process* than a business or social system. Generally, it is more productive to identify a social process and ask about its cause than to slice a chunk of the real world and ask what kind of dynamic behavior pattern it will generate. Distinguishing between a social system and a social process is roughly equivalent to distinguishing between a system's underlying structure and its *dynamics*, i.e. behavior patterns through time.

Randers (1980, p. 120) defines a *social system* as a set of cause and effect relationships, with its model structure being a causal diagram, a map of the real-world chunk chosen for study.

A social *process* is a dynamic behavior pattern of events evolving over time. The simulation results of full-fledged system dynamics models usually portray such chains of events as they might occur in the real world. An example of a social system (structure) is the set of rules and practices that an organization might enact when dealing with swift changes in demand, along with the communication channels used for transmitting information and managerial decisions. A corresponding social process (behavior pattern) might be the stop-and-go pattern of capital investment caused by a conservative bias in the organization's culture. Forrester incorporates such a conservative facet of corporate culture in his model of a firm's fast growing new product line. Causing sales to stagnate, considerable back orders had to accumulate to justify expansion because the firm's president insisted on personally controlling the approval of all capital expenditures (Richmond et al. 2001).

Figure 1
Mitsubishi Rayon's strategic situation and goal: A smooth and profitable switch



The common tendency is to begin by describing system structure; it seems to arise from its tangible nature as opposed to the elusive character of its dynamic behavior. Also, modelers usually present model structure before model behavior in their final reports. Ultimately, the goal in modeling a managerial decision situation is to link system structure and behavior. Yet, in the early stages of modeling is preferable to start with a description of a system's behavior patterns and *then* proceed with the identification of underlying causes.

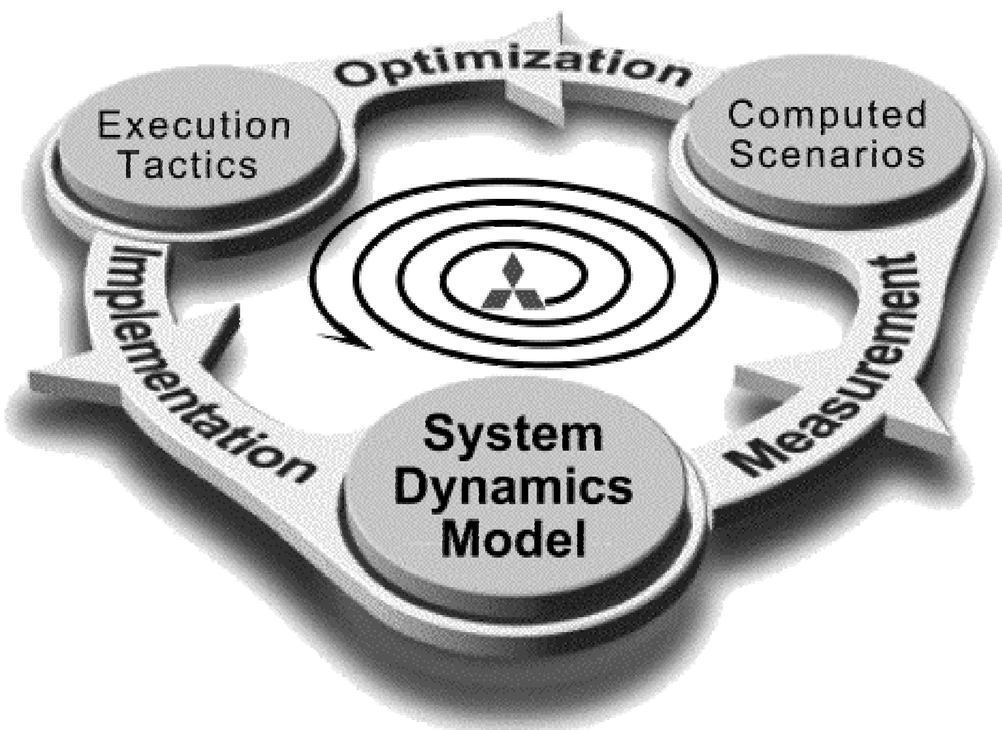
The modeling process itself is recursive in nature. The path from real-world events, trends and negligible externalities to an effective formal model usually resembles the expanding spiral of Fig. 2. An effective model can only be produced through effective conceptualization, focusing the modeling effort by establishing both the time horizon and the perspective from which a managerial decision situation will be framed. Typically, managerial decision models require adopting a long-term horizon, over which the likely effects of changes in strategy and in the environment are assessed by computed scenarios.

Effective formulation is another requirement to effective modeling. Casting the chosen policy perspective into a formal representation entails postulating a detailed structure, a diagramming description precise enough to propagate images of alternative futures, i.e., scenarios, "though not necessarily accurate" (Randers 1980, p. 118).

The modeling process must never downplay the managers' mental database and its information content. Effective modeling always draws on the mental database (Forrester 1961).

The expanding spiral of Fig. 2 suggest that the insight required for decisive action increases as the quantity of information may decrease, by orders of magnitude, while the required quantification of the relationships among variables pertinent to a business decision situation changes the character of the information content as one moves from mental to written to numerical information (Table 2). Perceptibly, a smaller quantity of information remains, but much more pertinent to the nature and structure of the situation. That is, clarity rules in the end.

Figure 2
The system dynamics modeling process at Mitsubishi Rayon



Mental, written and numerical information played different roles in shaping the formal model of Mitsubishi Rayon decision situation. The dominant role that the mental database plays in modeling can be appreciated if we visualize what would happen if a firm's managers let written policies and numerical information alone guide their actions. This 'going strictly by the book' might be perceived as a strike in some parts of the world. The mental database provided the raw material for modeling. In turn, the art in modeling expanded, refined and thereby improved the mental database. This is the fine art of simulation modeling—a prelude to true organizational learning and systems thinking at Mitsubishi Rayon.

The modeling process enabled Mitsubishi Rayon to frame the decision situation of Fig. 1 into the cyclical pattern that Fig. 2 shows. The system dynamics model incorporates both measurement data (Table 2) and econometric sales forecast functions that make it possible for computed scenarios to answer a very specific, *generalist*, i.e. multi-functional, optimization question. To design execution tactics for implementation, Mitsubishi Rayon's top management wanted to know what size of a USA salesforce would ensure a smooth switch in sales (marketing function) and production (operations function) in January 2004, and also maximize the combined accounting-profit NPV (accounting/finance function) of the new plant in USA and the existing one in Asia, from now through 2008, i.e. 5 years after the completion of the plant in USA. Simple, right?

Out of curiosity, one of our team members asked the manager who presented this concern to us in what specific function did he work for. "I am a Mitsubishi Rayon manager," the manager said politely with a smile. Sterman (2000) frequently points out that building system dynamics models does not mean excluding other modeling methods. On the contrary, combining system dynamics with other disciplines, such as this model's econometric sales forecast functions, for example, shows how flexibly adaptive system dynamics is in solving real business problems.

Table 2 Price trends in Asia and USA (ICIS Report) and Mitsubishi Rayon's **disguised** data

	Asia CFR, $/MT	USA CTS, $/MT	Date refered
1999 Q1	1,000	992	1999/1/7
1999 Q2	1,000	948	1999/4/8
1999 Q3	950	948	1999/7/6
1999 Q4	1,000	948	1999/10/6
2000 Q1	1,000	948	2000/1/8
2000 Q2	1,050	1,014	2000/4/7
2000 Q3	1,100	1,014	2000/7/7
2000 Q4	1,250	1,058	2000/10/6
2001 Q1	1,300	1,146	2001/1/5
2001 Q2	1,250	1,146	2001/4/6
2001 Q3	1,130	1,146	2001/7/6
Average ($/MT)	1,094	1,028	
Average ($/lb)	0.50	0.47	

*(Asia) SE ASIA 500mt or more lowest
(USA) Railcar lowest

Import Duty of the Chemical	5%

Company's Data (Disguised)

	Unit		
Asia			
Production Capacity	mmlbs/m	13	
Tank Capacity	mmlbs	13	
Production Cost	$/lb	0.3	
Number of Sales People		10	until the end of 2003
		20	from the beginning of 200
Sales Cost per Salesperson	$/mo	20,000	
USA			
Production Capacity	mmlbs/m	18	
Tank Capacity	mmlbs	18	
Total Fixed Cost	$/mo	300,00	
Variable Cost	$/lb	0.2	
Freight	$/lb	0.07	
Sales Cost per Salesperson	$/mo	40,000	
Sales Volume per Salesperson	mmlbs/m	0.4	
Discount Rate	%	6	

Empirical Data

Annual Sales Growth in USA	10% until 20
	15% from 20
Customer Acquisition Factor[1]	1-1/(time+0.
Sales Force Deminishing Factor[2]	0.98

1: factor that describes how a new salespers acquires sales at the beginning (the new salesperson reachs the average sales volume about one year.)
2: factor that describes the diminishing effec the number of sales people

Model description

The model consists of five sectors, four of them dealing with accounting and finance data and calculations. Figure 3 shows the production and sales sector and Table 2 the corresponding algebra. While Mitsubishi Rayon is building its new Clear Lake factory in Bayport, Texas, its factory in Asia manufactures and sells all the specialty chemicals the USA market will not (yet) absorb. This is what the feed forward link between the production in Asia (3.3) and sales in Asia (3.4) flow shows. The surplus demand in Asia for Mitsubishi Rayon's fine chemicals accounts for this rather unorthodox structure. This surplus demand in Asia is the model's enabling *safety valve*, i.e. a major strategic assumption, which makes tactical implementation feasible.

With the plant in Asia producing at full capacity, the sales in USA before (the switch) flow (3.5) both depletes the Tank in Asia stock (3.1) and reduces Mitsubishi Rayon's sales in Asia. The sales in USA flow depends on the USA Salesforce (3.13) that builds and maintains a customer base in USA. But the size of this decision variable is just one single determinant of sales in USA. Sales productivity depends on many parameters, such as the annual growth before (the switch) rate (1.1) of specialty chemicals in USA, the average expected volume a salesperson can sell per month (3.14) and the diminishing returns (3.1) sales people experience after the first successful calls they make on their industrial customers. B2B (business to business), i.e. industrial marketing, can sometimes be a tough as B2C (business to customer), i.e. selling retail.

Figure 3
The production and sales sector

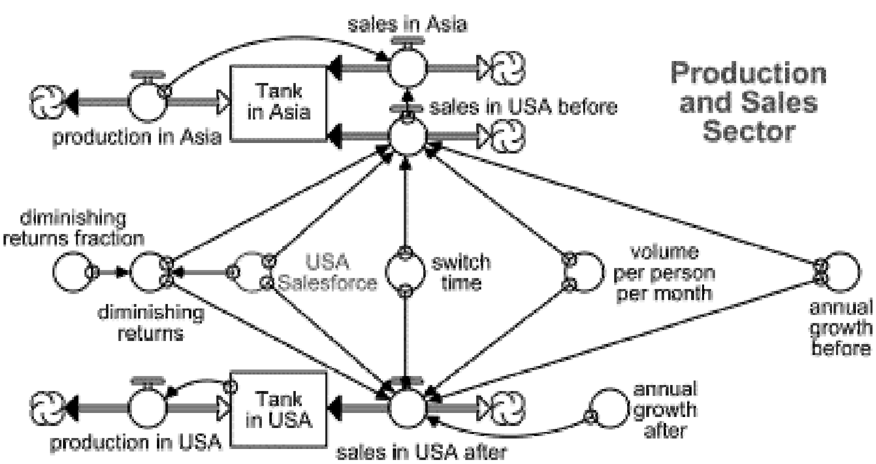


Table 3 Production and sales sector equations

Level or state variables (stocks) {·} = {**units**}	*Eq. #*
Tank in Asia(t) = Tank in Asia(t - dt) + (production in Asia - sales in Asia - sales in USA before) * dt	(3.1)
INIT Tank in Asia = production in Asia {lbs}	(3.1.1)
Tank in USA(t) = Tank in USA(t-dt) + (production in USA - sales in USA after) * dt	(3.2)
INIT Tank in USA = 0 {lbs}	(3.2.1)
Rate variables (flows)	
production in Asia = 13e+6 {lbs/month}	(3.3)
sales in Asia = MAX(0, production in Asia - sales in USA before) {lbs/month}	(3.4)
sales in USA before = IF(TIME < switch time) THEN (MAX(0, (volume per person per month * USA Salesforce * (1-1/(TIME + 0.1)) * diminishing returns * (annual growth before^(TIME / 12))))) ELSE (0) {lbs/month}	(3.5)
production in USA = IF(TIME < 30) OR (Tank in USA >= 18e+6) THEN (0) ELSE (18e+6 - Tank in USA) {lbs/month}	(3.6)
sales in USA after = IF (TIME < switch time) THEN (0) ELSE ((volume per person per month * (1 - 1 / (switch time + 0.1)) * (annual growth before^(switch time / 12)) * USA Salesforce * diminishing returns) * (annual growth after^((TIME - switch time) / 12))) {lbs/month}	(3.7)
Auxiliary variables and constants (converters)	
annual growth after = 1.15 {dimensionless}	(3.8)
annual growth before = 1.1 {dimensionless}	(3.9)
diminishing returns = diminishing returns fraction^USA Salesforce {dimensionless^people}	(3.10)
diminishing returns fraction = 0.98 {dimensionless}	(3.11)
switch time = 30 {months}	(3.12)
USA Salesforce = 2 {people}	(3.13)
volume per person per month = 0.4e+6 {lbs/person/month}	(3.14)

Time t = 30 months corresponds to January 2004, when the switch time (3.12) converter cuts off the supply of Mitsubishi Rayon chemicals from its plant in Asia. Ready since December

2003, the firm's Texan factory now can supply the entire customer base that Mitsubishi Rayon's USA Salesforce have been building for 30 months. The sales in USA before flow stops draining the Tank in Asia, sales in Asia resume their mission to fulfill the fine-chemicals surplus demand and production in USA (3.6) starts. Acting both as a production flow and as a continuous-review inventory order point, after January 2004, production in USA feeds the Tank in USA (3.2) stock of rudimentary VCM (value-chain management) structure on the lower panel of Fig. 3.

In system dynamics models, rectangles represent stocks, i.e. state variables that accumulate through time, such as the Tank in USA stock of Fig. 3. The double-line, pipe-and-valve-like icons that fill and drain the stocks, often emanating from cloud-like sources and ebbing into cloud-like sinks, represent material flows that cause the stocks to change. The production in USA rate of Fig. 3, for example, shows the fine chemicals' flow into the Tank in USA stock. The single-line arrows represent information flows, while the circular icons depict auxiliary constants, behavioral relations or decision points that convert information into decisions. Changes in the Tank in USA stock, for example, depend on sales in USA after (3.7) shipments, adjusted by the annual growth after (3.8) and other parameters. Both the diagram of Fig. 3 and Table 3 are reproduced from the actual simulation model built on the glass of a computer screen using the diagramming interface of *iThink® Analyst* 7 (Richmond et al. 2001).

Value chains entail a stock and flow structure for the acquisition, storage and conversion of inputs into outputs, and decision rules governing the flows. The jet ski value chain, for example, includes the stock and flow networks of material such as hulls and bows pulled out of jet ski molds. The hulls and bows travel down monorail assembly paths prior to shipment to dealers. At each stage in the process, there is a stock of parts buffering production activities, e.g. an inventory of fiberglass laminate between hull and bow acquisition and usage, an inventory of hulls and bows for the lower and upper structure of the jet ski, and an inventory of jet skis between dealer acquisition and sales. The decision rules governing the flows entail policies for ordering fiberglass laminate from suppliers, scheduling the spraying of preformed molds with three to five layers of fiberglass laminate before assembly, shipping new jet skis to dealers, and customer demand.

A typical firm's or VEN's customer-supplier value chain consists of cascades of supply chains, which often extend beyond a single firm's boundaries. Effective VCM models must incorporate different agents and firms, including suppliers, the firm, distribution channels and customers. System dynamics is well suited for VCM modeling and policy design because the customer-supplier value chain involves multiple chains of stocks and flows, with time lags and delays, and because the decision rules governing the flows create feedback loops among VEN members or value- and supply-chain partners (Sterman 2000).

The Tank in USA stock, for example, feeds information about its level back to production in USA. Acting first as a decision point, production in USA compares the Tank in USA level to the tank's capacity of 18e+6 lbs. If the tank is less than full, then production in USA places an order to itseld and, since Mitsubishi Rayon's USA factory has the requisite capacity (Table 2), production in USA refills the Tank in USA stock at a rate of 18e+6 lbs per month (3.6). But that is only until the sales in USA after (the switch) outflow (3.7) drains the tank again and the cycle begins all over again.

Meanwhile the profit in Asia (Fig. 4 and Table 4), profit in USA before (Fig. 5 and Table 5) and profit in USA after (Fig. 6 and Table 6) sectors perform all the financial accounting necessary to keep track of the individual transactions that take place in the VCM production and sales sector of Fig. 3 and Table 3. It is amazing how the simple generic structure of these three accounting and finance sectors that ships as modeling template on the of *iThink® Analyst* 7 CD (Richmond et al. 2001) can perform so much bean counting so efficiently.

Figure 4
The profit in Asia sector

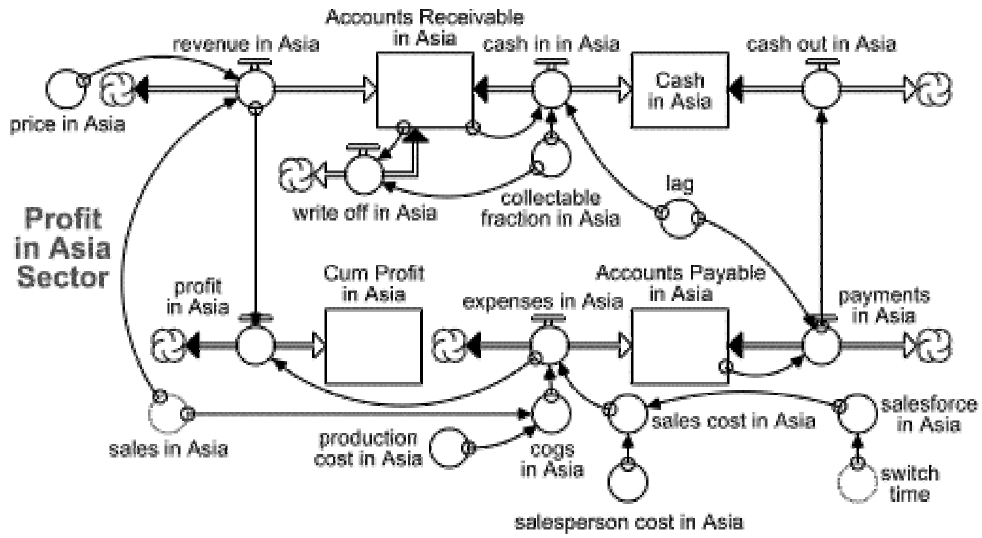


Table 4 Profit in Asia sector equations

Level or state variables (stocks) {·} = {**units**}	*Eq. #*
Accounts Payable in Asia(t) = Accounts Payable in Asia(t-dt) + (expenses in Asia - payments in Asia)*dt	(4.1)
INIT Accounts Payable in Asia = expenses in Asia {$}	(4.1.1)
Accounts Receivable in Asia(t) = Accounts Receivable in Asia(t - dt) + (revenue in Asia - cash in in Asia - write off in Asia) * dt	(4.2)
INIT Accounts Receivable in Asia = revenue in Asia {$}	(4.2.1)
Cash in Asia(t) = Cash in Asia(t - dt) + (cash in in Asia - cash out in Asia) * dt	(4.3)
INIT Cash in Asia = cash in in Asia {$}	(4.3.1)
Cum Profit in Asia(t) = Cum Profit in Asia(t - dt) + (profit in Asia) * dt	(4.4)
INIT Cum Profit in Asia = profit in Asia	(4.4.1)
Rate variables (flows)	
expenses in Asia = cogs in Asia + sales cost in Asia {$/month}	(4.5)
payments in Asia = Accounts Payable in Asia / lag {$/month}	(4.6)
revenue in Asia = price in Asia * sales in Asia {$/month}	(4.7)
cash in in Asia = MAX(0, collectable fraction in Asia * Accounts Receivable in Asia / lag) {$/month}	(4.8)
write off in Asia = (1 - collectable fraction in Asia) * Accounts Receivable in Asia {$/month}	(4.9)
cash in in Asia = MAX(0, collectable fraction in Asia * Accounts Receivable in Asia / lag) {$/month}	(4.10)
cash out in Asia = payments in Asia {$/month}	(4.11)
profit in Asia = revenue in Asia - expenses in Asia {$/month}	(4.12)
Auxiliary variables and constants (converters)	
cogs in Asia = sales in Asia * production cost in Asia {$/month}	(4.13)
collectable fraction in Asia = 1 {dimensionless}	(4.14)
lag = 1 {months}	(4.15)
price in Asia = .50 {$/lb}	(4.16)
production cost in Asia = 0.30 {$/lb}	(4.17)
salesforce in Asia = IF (TIME < switch time) THEN (10) ELSE (20) {people}	(4.18)
salesperson cost in Asia = 20000 {$/person/month}	(4.19)
sales cost in Asia = salesperson cost in Asia * salesforce in Asia {$/month}	(4.20)

Figure 5
The profit in USA before sector (before the switch)

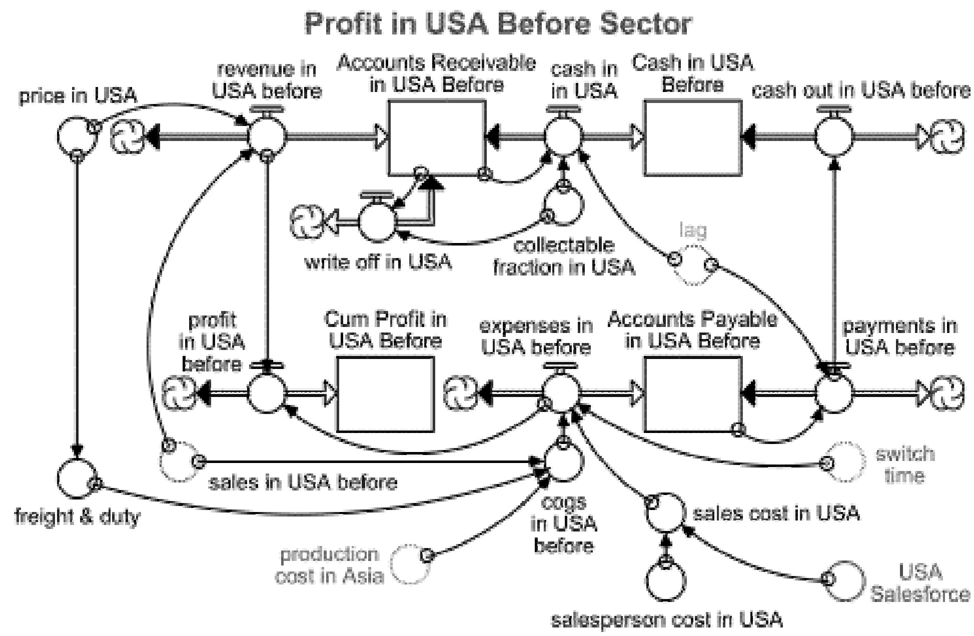


Table 5 Profit in USA before (the switch) sector equations

Level or state variables (stocks)	{·} = {**units**}	*Eq. #*
Accounts Payable in USA Before(t) = Accounts Payable in USA Before(t - dt) + (expenses in USA before - payments in USA before) * dt		(5.1)
INIT Accounts Payable in USA Before = expenses in USA before {$}		(5.1.1)
Accounts Receivable in USA Before(t) = Accounts Receivable in USA Before(t - dt) + (revenue in USA before - cash in in USA - write off in USA) * dt		(5.2)
INIT Accounts Receivable in USA Before = revenue in USA before {$}		(5.2.1)
Cash in USA Before(t) = Cash in USA Before(t - dt) + (cash in in USA - cash out in USA before) * dt		(5.3)
INIT Cash in USA Before = cash in in USA {$}		(5.3.1)
Cum Profit in USA Before(t) = Cum Profit in USA Before(t - dt) + (profit in USA before) * dt		(5.4)
INIT Cum Profit in USA Before = profit in USA before {$}		(5.4.1)
Rate variables (flows)		
expenses in USA before = IF (TIME < switch time) THEN (cogs in USA before + sales cost in USA) ELSE (0) {$/month}		(5.5)
payments in USA before = Accounts Payable in USA Before / lag {$/month}		(5.6)
revenue in USA before = price in USA * sales in USA before {$/month}		(5.7)
cash in in USA = MAX(0, collectable fraction in USA*Accounts Receivable in USA Before / lag) {$/m}		(5.8)
write off in USA = (1 - collectable fraction in USA) * Accounts Receivable in USA Before {$/month}		(5.9)
cash in in USA = MAX(0, collectable fraction in USA*Accounts Receivable in USA Before / lag) {$/m}		(5.10)
cash out in USA before = payments in USA before {$/month}		(5.11)
profit in USA before = IF (TIME < 30) THEN (revenue in USA before - expenses in USA before) ELSE(0) {$/month}		(5.12)
Auxiliary variables and constants (converters)		
cogs in USA before = sales in USA before * (freight & duty + production cost in Asia) {$/month}		(5.13)
collectable fraction in USA = 1 {dimensionless}		(5.14)
freight & duty = (price in USA * 0.05) + 0.07 {$/lb}		(5.15)
price in USA = 0.47 {$/lb}		(5.16)
salesperson cost in USA = 40000 {$/person/month}		(5.17)
sales cost in USA = USA Salesforce * salesperson cost in USA {$/month}		(5.18)

Figure 6
The profit in USA after sector (after the switch)

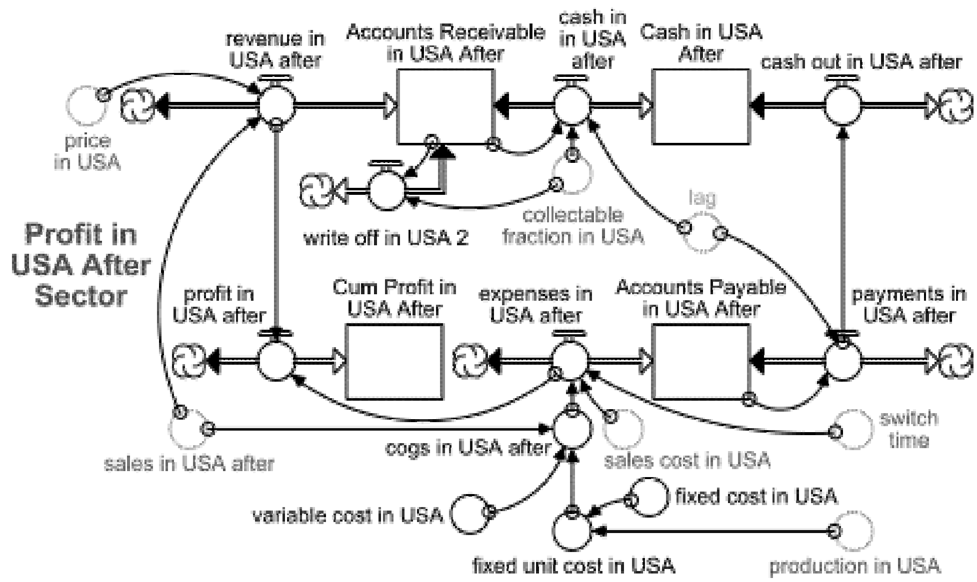


Table 6 Profit in USA after (the switch) sector equations

Level or state variables (stocks) {·} = {**units**}	*Eq. #*
Accounts Payable in USA After(t) = Accounts Payable in USA After(t - dt) + (expenses in USA after - payments in USA after) * dt	(6.1)
INIT Accounts Payable in USA After = expenses in USA after {$}	(6.1.1)
Accounts Receivable in USA After(t) = Accounts Receivable in USA After(t - dt) + (revenue in USA after - cash in in USA after - write off in USA 2) * dt	(6.2)
INIT Accounts Receivable in USA After = revenue in USA after {$}	(6.2.1)
Cash in USA After(t) = Cash in USA After(t - dt) + (cash in in USA after - cash out in USA after) * dt	(6.3)
INIT Cash in USA After = cash in in USA after {$}	(6.3.1)
Cum Profit in USA After(t) = Cum Profit in USA After(t - dt) + (profit in USA after) * dt	(6.4)
INIT Cum Profit in USA After = profit in USA after {$}	(6.4.1)
Rate variables (flows)	
expenses in USA after = IF (TIME < switch time) THEN (0) ELSE (cogs in USA after + sales cost in USA) {$/month}	(6.5)
payments in USA after = Accounts Payable in USA After / lag {$/month}	(6.6)
revenue in USA after = price in USA * sales in USA after {$/month}	(6.7)
cash in in USA after = collectable fraction in USA * Accounts Receivable in USA After / lag {$/month}	(6.8)
write off in USA 2 = (1 - collectable fraction in USA) * Accounts Receivable in USA After {$/month}	(6.9)
cash in in USA after = collectable fraction in USA * Accounts Receivable in USA After / lag {$/month}	(6.10)
cash out in USA after = payments in USA after {$/month}	(6.11)
profit in USA after = revenue in USA after - expenses in USA after {$/month}	(6.12)
Auxiliary variables and constants (converters)	
cogs in USA after = (fixed unit cost in USA + variable cost in USA) * sales in USA after {$/month}	(6.13)
fixed cost in USA = 3e+5 {$/month}	(6.14)
fixed unit cost in USA = IF (TIME<30) THEN (0) ELSE (fixed cost in USA / production in USA) {$/lb}	(6.15)
variable cost in USA = 0.20 {$/lb}	(6.16)

While each simulation runs, the computed accounting profit in Asia (Fig. 4 and Eq. 4.12), USA before (Fig. 5 and Eq. 5.12) and USA (Fig. 6 and Eq. 6.12) results feed the corresponding change in net present value (NPV) flows (Eqs 7.4, 7.5 and 7.6) of the model's grand total NPV sector (Fig. 7 and Table 7). By financially adjusting each sector's accounting profit according to the discount (7.7) rate (7.9) of Fig. 7 and Table 7, these change in NPV flows (Eqs 7.4, 7.5 and 7.6) flows help compute the Grand Total NPV of the combined acountin profit both in Asia and in USA, both before and after Mitsubishi Rayon's January 2004 fine-chemicals supply switch.

Figure 7
The grand total NPV (net present value) sector

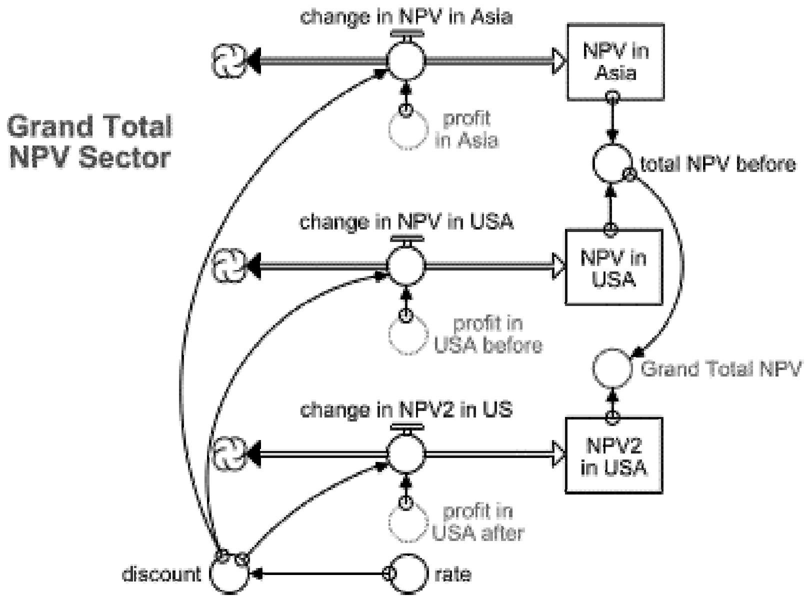


Table 7 Grand total NPV (net present value) sector equations

Level or state variables (stocks)	{·} = {**units**}	*Eq. #*
NPV2 in USA(t) = NPV2 in USA(t - dt) + (change in NPV2 in USA) * dt		(7.1)
INIT NPV2 in USA = 0 {$}		(7.1.1)
NPV in Asia(t) = NPV in Asia(t - dt) + (change in NPV in Asia) * dt		(7.2)
INIT NPV in Asia = 0 {$}		(7.2.1)
NPV in USA(t) = NPV in USA(t - dt) + (change in NPV in USA) * dt		(7.3)
INIT NPV in USA = 0 {$}		(7.3.1)
Rate variables (flows)		
change in NPV2 in USA = discount * profit in USA after {$/month}		(7.4)
change in NPV in Asia = discount * profit in Asia {$/month}		(7.5)
change in NPV in USA = discount * profit in USA before {$/month}		(7.6)
Auxiliary variables and constants (converters)		
discount = 1 / (1 + rate) ^ (TIME - STARTTIME) {dimensionless}		(7.7)
Grand Total NPV = NPV2 in USA + total NPV before		(7.8)
rate = 0.005 {dimensionless/month}		(7.9)
total NPV before = NPV in Asia + NPV in USA		(7.10)

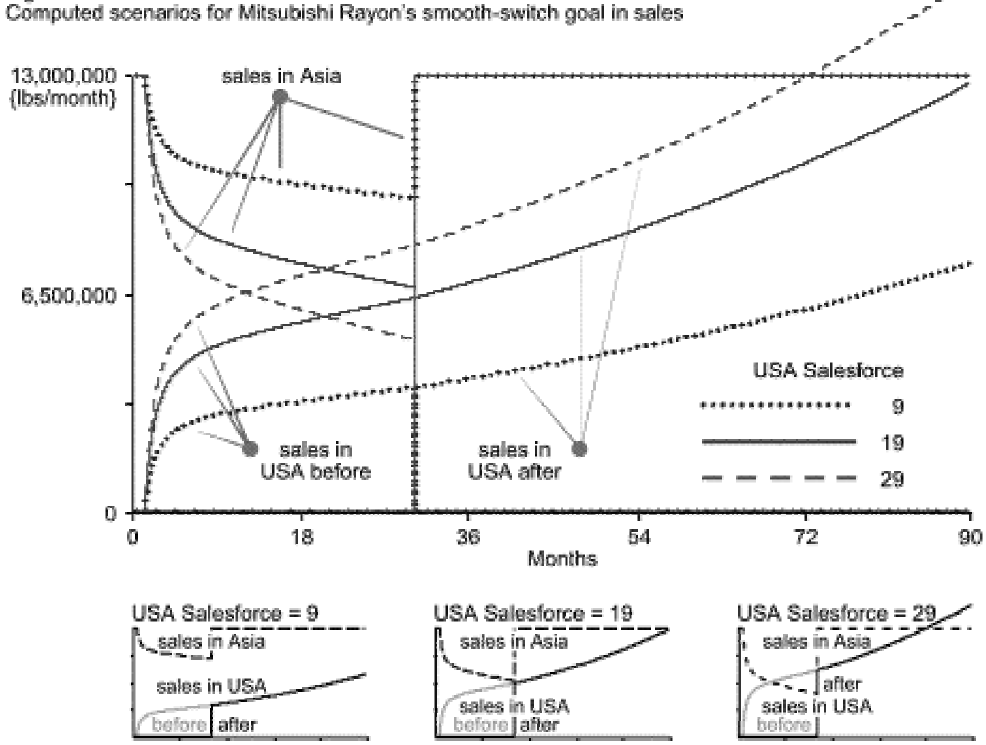
Simulation Results

Recall that the system-dynamics modeling-process spiral enabled our team at Mitsubishi Rayon to crystallize the firm's strategic situation (Fig. 1) into the cyclical pattern that Fig. 2 shows. Although heavily disguised, Mitsubishi Rayon's measurement data (Table 2) and econometric sales forecast functions (Eqs 3.5 and 3.7) helped our system dynamics model compute scenarios to answer that razor-sharp generalist/multi-functional optimization question that polite Mitsubishi Rayon executive so calmly asked:

What size must our USA salesforce be to give us a smooth switch both in sales and in production in January 2004, and also to maximize our combined accounting-profit NPV at our two plants in Asia and USA from now through 2008?

Treating the USA Salesforce (Eq. 3.13) decision variable as a parameter in the *Sensi Specs...* menu item of *iThink® Analyst* 7 (Richmond et al. 2001) established its requisite characteristics for a set of 30 computed scenarios. Each one of these 30 scenario corresponds to Mitsubishi Rayon's hiring from one to 30 sales people, respectively, to sell specialty chemicals to manufacturing companies in USA both before and after the January 2004 switch. Figure shows the simulation results for three of the 30 scenarios, corresponding to USA Salesforce of 9, 19 and 29 people, respectively.

Figure 8
Computed scenarios for Mitsubishi Rayon's smooth-switch goal in sales



The three variables Fig. 8 shows are: sales in Asia, sales in USA before and sales in USA after the switch at time t = 30 months. Under all three scenarios (USA Salesforce = 9, 19 and 29 people), sales in Asia resumes its mission of fulfilling the Asian specialty-chemicals demand surplus in January 2004, with Mitsubishi Rayon's sales people in Asia selling all their factory can make at a production in Asia rate of 13e+6 lbs per month. The model's two precalibrated exogenous econometric sales forecast functions (Eqs 3.5 and 3.7) dictate how smoothly the sales in USA before and sales in USA after the 30-month switch variables behave. In January 2004, sales in USA before steps down to zero while, concurrently, sales in USA after steps up as if it were to resume the behavior pattern of sales in USA before, before the latter dropped to zero.

Among the three scenarios Fig. 8 shows, the one corresponding to Mitsubishi Rayon's building a USA Salesforce of 19 people achieves a smooth balance between sales in Asia and in USA. Under this scenario, at time t = 30 (January 2004), the number of pounds of fine chemicals sold in Asia in January 2004 is roughly equal to the number of pounds of fine chemicals sold in USA. So hiring 19 sales people now meets Mitsubishi Rayon's smooth switch in sales objective. But what of production? Does producing and selling in USA at a rate roughly equal to the rate of depleting production and sales in Asia in January 2004 constitute a fair response to Mitsubishi Rayon's smooth switch both in sales and in production performance objective? Even if that were acceptable by our client at face value, our team had to further expose the dynamics of Mitsubishi Rayon's rudimentary USA value-chain management (VCM) structure (Fig. 3), to unearth what the USA memebr of this VEN becoming Keiretsu might be up to.

Although simple, the VCM segment of the production and sales sector on the lower panel of Fig. 3 can show the same amplification symptoms seen in much more elaborate customer-supplier value chains when they fall pray to the common bullwhip effect. Locally rational policies that create smooth and stable adjustment of individual business units can, through their interaction with other functions and firms, cause value chain amplification and instability.

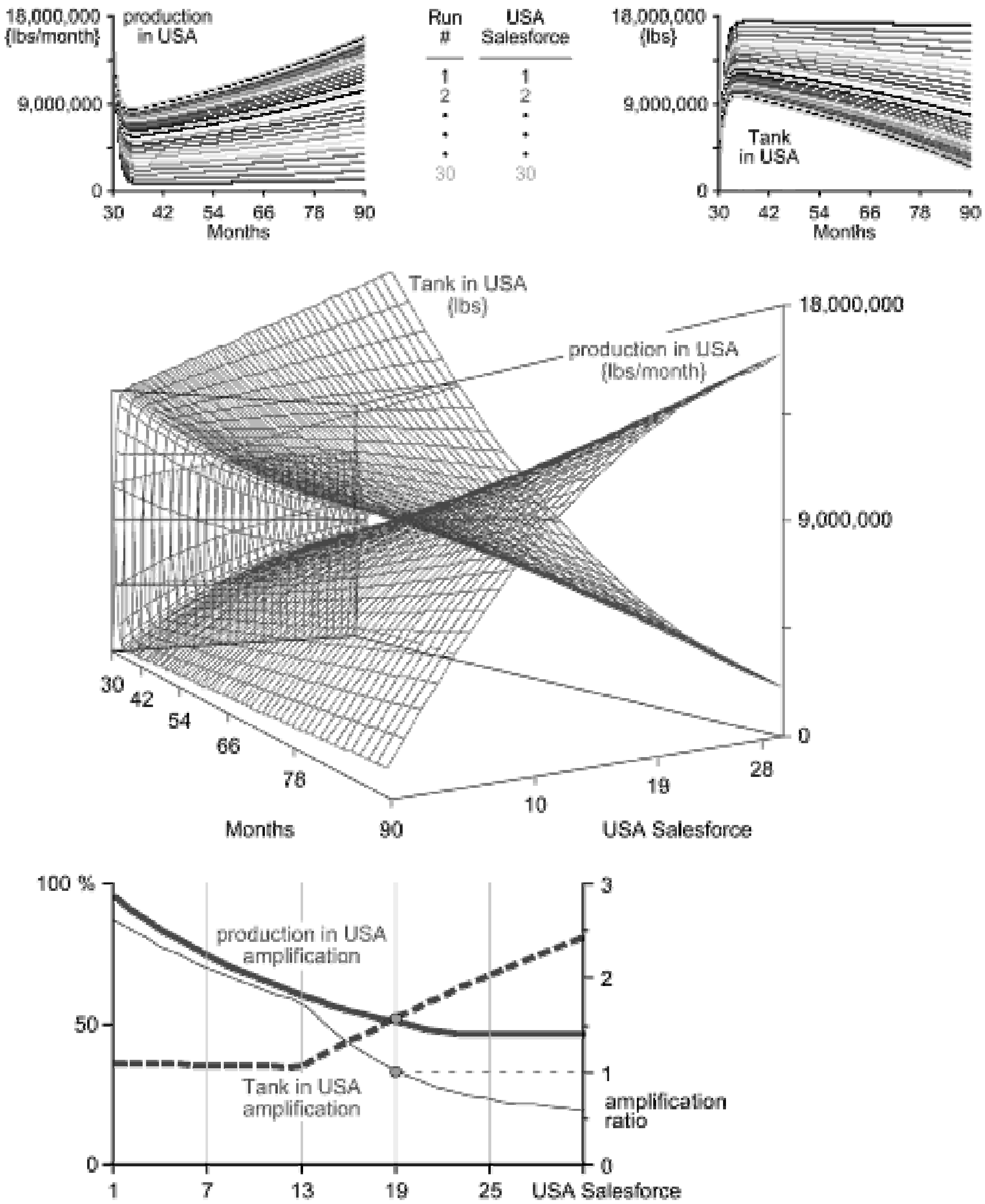
The top panel of Fig. 9 shows the profound consequences of Mitsubishi Rayon's January 2004 switch for its VCM in USA. *First*, the Tank in USA stock adjustment process creates significant amplification in the production in USA rate. Though the Tank in USA stock's relative amplification is 36.18 percent under the USA Salesforce = 2 scenario, for example, the production in USA (top left of Fig. 9) rate's relative amplification increases by a maximum of more than 90 percent (the peak production in USA rate, after t = 30 months, divided by the minimum production in USA rate = 11,766,430.01 / 1,026,107.64 = 91.28 percent). The *amplification ratio*, i.e., the ratio of the maximum change in the output to the maximum change in the input, is therefore 91.28%/36.18% = 2.52. A one-percent increase in demand for Mitsubishi Rayon's specialty chemicals causes a 2.52- percent surge in demand at the firm's Texas plant. While the amplification ratio magnitude depends on the stock adjustment times and delivery lags, its existence does not (Sterman 2000, p. 673).

Second, amplification is temporary. In the long run, a one-percent increase in sales in USA after leads to a one-percent increase in the production in USA rate. After two-adjustment times, i.e., 2 months, production in USA after gradually drops. During the disequilibrium adjustment, however, production in USA after overshoots its new equilibrium, an inevitable consequence of the stock and flow structure of customer-supplier value chains, no matter how tiny or simple they look. The only way the Tank in USA stock can increase is for its inflow production in USA after rate (order rate) to exceed its outflow rate sales in USA after. Within a VEN's or Keiretsu's customer-supplier value chain, supply agents face much larger changes in demand than finished-goods inventory managers and the surge in demand is temporary.

The surface plot of Fig. 9 shows the response surfaces the production in USA rate and Tank in USA stock form after January 2004 in response to the 30 computed scenarios of Mitsubishi Rayon's hiring 1 through 30 sales people in USA. Because of the specialty chemicals' supply switch in January 2004, these scenarios cause 30 sudden step changes. Both variables' adjustment rates increase, but the Tank in USA stock's amplification remains almost constant below 50 percent (lower panel of Fig. 9). As customer demand steps up because of a larger USA Salesforce, so do both variables' new equilibrium points, but in direct proportion to the step increase in customer demand in USA for Mitsubishi Rayon's products. This scenario set confirms Sterman's argument that, while amplification magnitude depends on stock adjustment times and delivery lags, its existence does not. A direct implication is that no matter how drastically customers and firms downstream in the customer-supplier value chain change an orders' magnitude, they simply cannot affect their value chain's supply-chain amplification. VCM must never blame customers and downstream firms or their forecasts for bullwhip effects.

The production in USA rate's amplification is almost double the Tank in USA stock's for a small USA Salesforce, suggesting that Mitsubishi Rayon's Texas factory faces much larger changes in demand than its sales people do. Although temporary, during its disequilibrium adjustment, the production in USA rate consistently overshoots its new equilibrium points, an inevitable consequence of the stock and flow structure. Customers are innocent, but Mitsubishi Rayon's VCM structure is not.

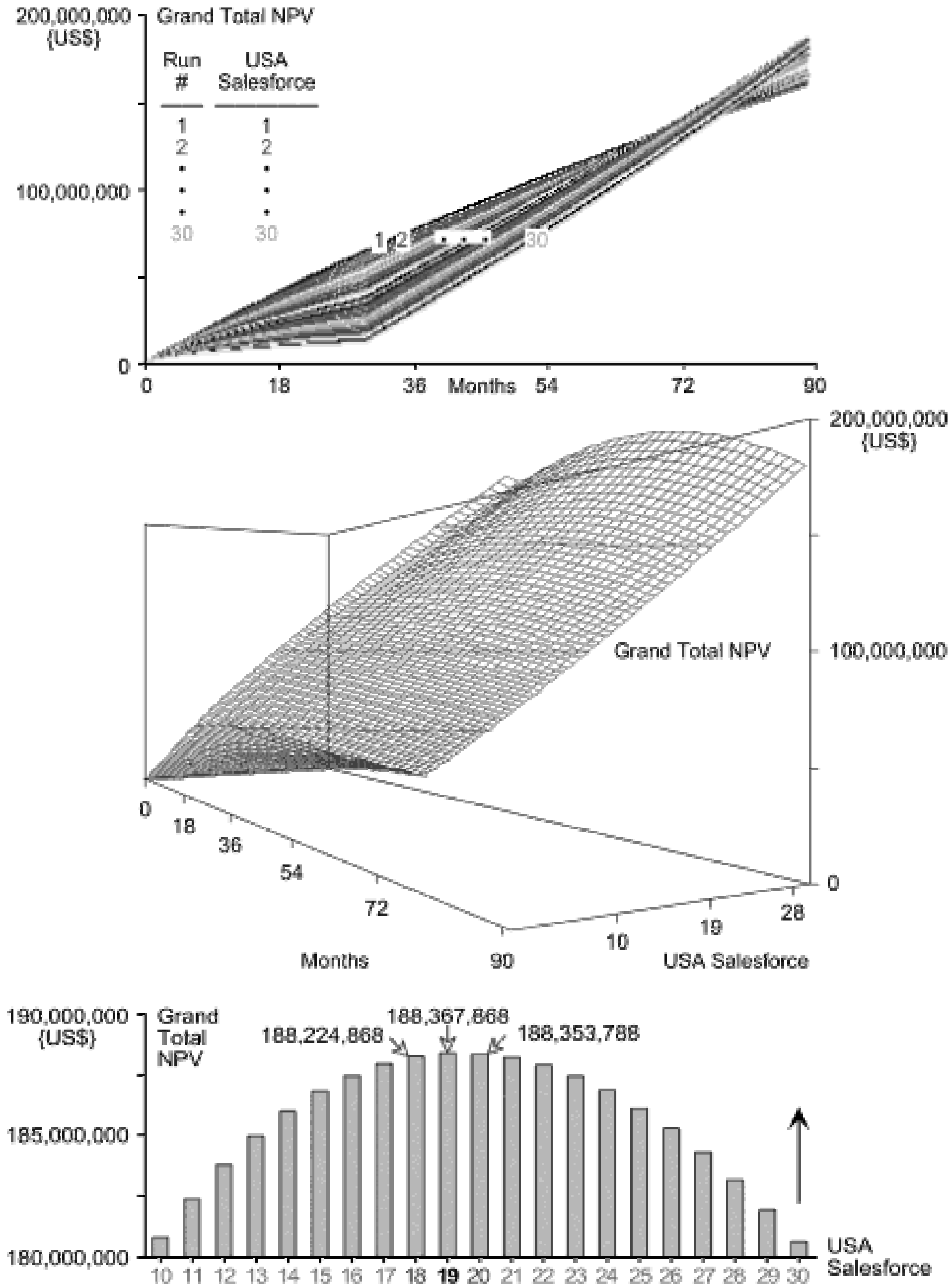
Figure 9
Computed scenarios for Mitsubishi Rayon's smooth-switch goal in production



The computed scenarios show that as the USA Salesforce increases, the production in USA rate's amplification declines because its new long-term equilibrium point is closer to its initial jump in January 2004. Conversely, as the Tank in USA stock's long-term equilibrium point remains consistently high because of the larger USA Salesforce, its relative amplification begins to rise. Since the two variables' relative amplification moves in opposite directions, eventually, they meet. What a coinsidence! The meet above USA Salesforce = 19 people. Now, isn't this a much better interpretation of the word 'smooth' in fair response to Mitsubishi Rayon's smooth switch both in sales and in production performance objective? The answer to our client is now pertinent to Mitsubishi Rayon's balancing its VCM in USA. With a USA Salesforce = 19, Mitsubishi Rayon's VCM components show equal relative amplification to suddent changes in demand, attaining a nothing less than magnificent amplification ratio = 1. Now that's smooth!

But what of profitability? The polite executive said: "maximize... combined... NPV". In the time domain (top of Fig. 10), Grand Total NPV creates an interesting pattern that hides the USA Salesforce dimension. But the surface plot of Fig. 10 crearly and cleanly shows a concave down behavior along USA Salesforce at time t = 90 months. And the phase plot of Fig 10 shows that USA Salesforce = 19 maximizes the two plants' accounting-profit Grand Total NPV.

Figure 10
Computed scenarios for Mitsubishi Rayon's profitable switch goal



Discussion and Conclusion

Inventory models teach us that to maximize profit, a firm must balance its ordering and holding cost. This essay's model shows that, in the VCM context, the same value of a parameter (e.g. USA Salesforce = 19) that balances value-chain components' relative amplification, i.e. rendering their amplification ratio = 1, also maximizes accounting profit's NPV. Can we draw an analogy between inventory models and VCM models? Or are this essay's simulation results just coincidental? Perhaps there is a hidden research adventure here but, nonetheless, Mitsubishi® Rayon's penetration strategy case intervention shows that seeking balance and profitability might be more broadly pertinent and readily applicable to value-chain model analysis, multi-functional policy design and strategy development.

Can a company ever, for example, really resolve any serious strategic issue within a single one of its functions? The way Japanese generalists deal with multi-functional strategic issues renders system dynamics most appropriate for strategy design and implementation tactics.

All models are wrong, some models are useful but it is always the modeling process that helps clarity rule in our clients' mental models. Like all models, this too relies on assumptions that make our calculation and recommendations possible. In this vein, let's mentally engage in the strategic assumption surfacing and testing (SAST) process (Mason & Mitroff 1981).

To calculate the best sales force mix for a maximum NPV, we assume that the Texas plant would be fully operational in January 2004. It is Mitsubishi Rayon's target date but, if any delay or early completion is significant, it may affect the optimal USA Salesforce headcount. Another crucial assumption is stable foreign exchange rate. Our modeling team assumed a stable rate for the purposes of our study. Along with foreign exchange rates go export tariffs and shipping charges. Will they remain stable? Again, this assumption hides thousands of possible outcomes. For the purpose of this study we are keeping rates and tariffs stable and focus on the USA Salesforce decision variable.

The ultimate safety valve for the model's computed scenarios to play is sufficient demand surplus in Asia so that the Asian plant will be able to immediately recoup lost sales to US through increased sales to Asia. According to Mitsubishi Rayon, its existing customers in Asia are interested in increasing their orders. Furthermore, the overall growth of the market by 2004 will leave plenty of sales opportunities in Asia. Given that real exports to clients in USA will be a small portion of overall production, we again assume that Asia sales will recoup lost sales when the US plant in Texas becomes operational.

Another vital assumption is that Mitsubishi Rayon's USA Salesforce of 19 will be able to sell all the fine chemicals its USA plant produces. There is already a market in USA with existing competitors. Will Mitsubishi Rayon's sales take away market share from competitors provided enough of a selling effort is made? Also, will our ‘declining marginal returns’ in sales computations hold? Only time can tell.

But even the time horizon is telling on our accounting-profit NPV calculations. Clearly if the time horizon changes, it can greatly affect the NPV calculations. Like most Japanese companies, Mitsubishi Rayon uses accelerated depreciation for its fixed assets. The result is that, on paper at least, the plant in Texas will have a useful life of five years. Understandably then, Mitsubishi Rayon's management wants to maximize NPV using this time horizon. Although the actual life of the plant may be longer, for the purposes of our model, we had to assume a 5-year life span for the plant in USA.

In light of these qualifications, all we can hope for is that this essay described a useful model. If the above assumptions hold, then we have given our client more than just valuable insight and clarity about its strategic situation. But aren't insight and clarity what the system dynamics modeling process is all about?

References

Ackoff, R.L. (1981) *Creating the Corporate Future*. New York, NY: Wiley.

Ahuja, M.K. & K.M. Carley (1998) 'Network structure in virtual organizations', *Journal of Computer-Mediated Communication* 3 (4): Special Issue on Virtual Organizations.

Anon. (1993) 'The virtual corporation', *Business Week* (February 8): 98-103.

Davidow, W.H. & M.S. Malone (1992) *The virtual corporation: Structuring and revitalizing the corporation for the 21st century*. New York, NY: Edward Burlingame Books/Harper Business Press.

Drucker, P. (1988) 'The coming of the new organization', *Harvard Business Review* (Jan-Feb): 45-53.

Forrester, J.W. (1961) *Industrial Dynamics*. Cambridge, MA: MIT Press.

Georgantzas, N.C. (1995) 'Strategy design tradeoffs-free', *Human Systems Management* 14(2): 149-161.

Georgantzas, N.C. (2001) 'Virtual enterprise networks: The fifth element of corporate governance', *Human Systems Management* 20(3): 171-188.

Georgantzas, N. C. & W. Acar (1995) *Scenario-driven planning: Learning to manage strategic uncertainty*. Westport, CT: Greenwood.

Gluck, F.W., S. Kaufman & A.S. Walleck (1980) 'Strategic management for competitive advantage', *Harvard Business Review* 58 (4): 154-161.

Hatten, K.J. & M.L. Hatten (1987) *Strategic Management: Analysis and Action*. Englewood Cliffs, NJ: Prentice-Hall.

Hau, L.L., V. Padmanabhan & S. Whang (1997) 'The bullwhip effect in supply chains', *Sloan Management Review* (Spring): 93-102.

Hodgin, R.F. (2001) *Clear Lake Area Industry and Projections 2001*. Houston, TX: Center for Economic Development and Research, University of Houston-Clear Lake.

Istvan, R.L. (1992) 'A new productivity paradigm for competitive advantage', *Strategic Management Journal* 13 (7): 525-537.

Mason, R.O. & I.I. Mitroff (1981) *Challenging Strategic Planning Assumptions*. New York, NY: Wiley.

Porter, M.E. (1991) 'Towards a dynamic theory of strategy', *Strategic Management Journal* 12 (Winter Special Issue): 95-117.

Randers, J. (1980) 'Guidelines for model conceptualization', in J. Randers, Ed. *Elements of the System Dynamics Method*. Cambridge, MA: MIT Press, pp. 117-139.

Richmond, B. et al. (2001) *iThink Analyst* 7: *The power to understand!* Hanover, NH: High Performance Systems, Inc.

Sherman, S. (1984) 'Eight big masters of innovation', *Fortune* (Oct. 16).

Sterman, J.D. (2000) *Business dynamics: Systems thinking and modeling for a complex world*. Boston, MA: Irwin McGraw-Hill.

Turner, F. (1997) 'Foreword: Chaos and social science', in R.A. Eve, S. Horsfall & M.E. Lee, Eds. *Chaos, complexity and sociology*. Thousand Oaks, CA: Sage, pp. xi-xxvii.

Zeleny, M. (2000) 'New economy of networks', *Human Systems Management* 19(1): 1-5.

Zentner, R.D. (1987) 'Scenarios and the chemical industry', *Chemical Marketing & Management* (Spring): 21-25.

Back to the Top