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The New Era in Managing Supply Chains- Lessons from Industrial Dynamics

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The New Era in Managing Supply Chains- Lessons from Industrial Dynamics

Outline

Developments in technology have led to a revolution in how we can conceive and manage supply chains. Despite the success of companies like Dell, and the availability of an extensive literature and of consulting services etc, the performance of many supply chains has not improved.

System Dynamics in its earlier guise as Industrial Dynamics has much to offer in understanding this apparent dilemma. Evidence suggests the lessons of the Beer Game are as relevant today as they were 40 or 50 years ago!

This paper outlines recent developments in supply chain thinking and demonstrates the important contribution that System Dynamics can make to resolve a number of current supply chain debates.

Key Words

Supply chain management; beer game effects; system dynamics; action learning; 6-Sigma; knowledge management.

Introduction

I recently had my bathroom renovated necessitating the installation of a new shower screen. After considerable search across a bewildering number of options of designs and price etc, I settled on a reasonable quality screen from what seemed to be a reputable company.

Following a call to the screen company, a salesman visited to do a "measure and quote". Following this visit a deposit was paid and the company contracted to make and install the screen within 7 to 10 working days from the receipt of the deposit. However, before anything could proceed a person from the screen manufacturer had to visit to make exact measurements. This occurred two days after the visit from the salesman. Unfortunately the measurer found a problem in the design the salesman had set out (the screen needed to be 10 cm higher!), so we had to contact the salesman to have the order specifications changed. This didn't present any problems and the salesman agreed to organise the change with the manufacturer. Several days passed and on the last day of the contract period the installer arrived to install the screen. The only trouble was that the screen was made to the original (smaller) specifications! Following the refusal of a generous offer from the factory manager to supply this screen at half the quoted price, plus a supply of cotton wool to help ease the impact every time I struck my head on the top of the screen, we were informed it would take a week for the manufacturer to obtain the new sheets of plate glass required to make the screen. Perhaps foolishly, I agreed and a week later a new screen arrived. The trouble this time was that the two screens had got mixed up and so this delivery had two panels from the original specification and one panel from the revised order. The next day the correct panels were finally assembled and installed to our satisfaction, albeit eight days outside the contract period of10 days.

Now, it will be obvious to most that there was a problem with communication between each of the individuals involved in this saga- the salesman, the manufacturer, the glass supplier, and the installer. Furthermore, you may have also guessed that they were all individual contractors attempting to integrate their contributions to the supply chain. One can only wonder on the variability of successful installation times or some other performance measure. But it seems likely that it will be much greater than what seems reasonable.

On the surface this supply chain should operate very efficiently, and effectively- it is based on the "demand pull" principle as distinct from "supply push", largely eliminating the need for inventories; it uses market competition to select from a large number of contractors; given the lead times on house construction approvals and renovations, market demand for screens is probably fairly predictable; screen technology is relatively stable; raw materials and supplies are locally available; simple computer systems are exist to track orders etc; and in general terms, this market situation could be described as being reasonable mature.

In fact this story highlights a number of characteristics of many supply chains as illustrated by recent examples from industries as diverse as automotive manufacturing, telecommunications, and agriculture- see Figure 1.

Anecdotal evidence suggests that typical industry reactions to these types of supply chain problems include:

- A demand for improved forecasts resulting in the application of increasingly sophisticated time series and econometric methods.
- Setting targets for both levels of performance and variability that are beyond the capability of the existing supply chain system and then driving short term increases in performance under the threat of sackings
- Increased attempts to centralise the control of the supply chain, despite the availability of technologies to facilitate more decentralised and flexible supply chains.
- Attempts to optimise parts of the supply chain without due consideration of the whole.
- Increased collection of data and publication of largely unrelated statistical reports.

In fact, these responses are largely maladaptive and exacerbate the situation. This outcome is confirmed by, Marshall L. Fisher (1997), who, following ten years of supply chain research observes that:

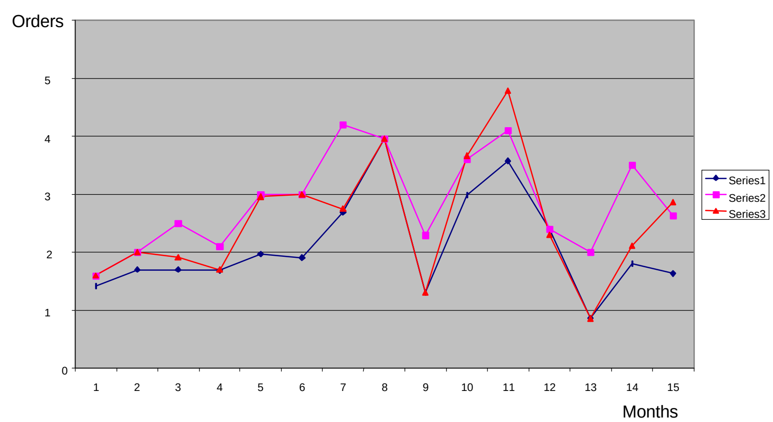
> *"Never has so much technology and brainpower been applied to improving supply chain performance. Point-of-scale scanners allow companies to*

capture the customer's voice. Electronic data interchange lets all stages of the supply chain hear that voice and react to it by using flexible manufacturing, automated warehousing, and rapid logistics. And new concepts such as quick response, efficient consumer response, accurate response, mass customisation, lean manufacturing, and agile manufacturing offer models for applying the new technology to improve performance.

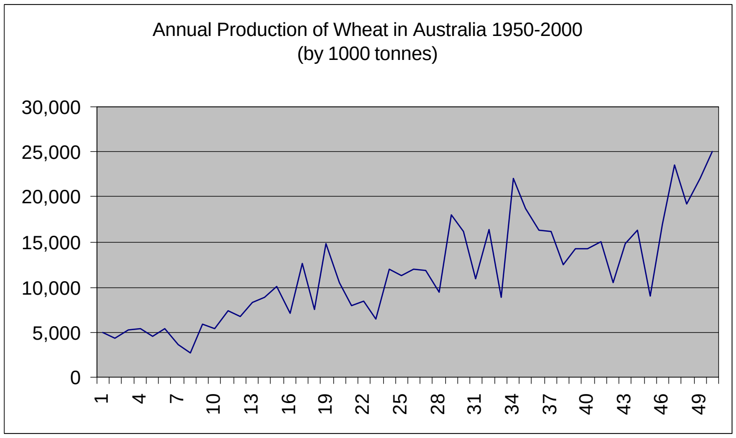
Nonetheless, the performance of many supply chains has never been worse. In some cases, costs have risen to unprecedented levels because of adversarial relations between supply partners as well as dysfunctional industry practices such as the over reliance on price promotions".

So we can conclude that the circumstances of the "Beer Game" are alive and well![1]. So what goes wrong and can System Dynamics help?

Bullwhip Effects: Motor Industry



[1] Also see Lee, Padmanabhan, and Whang, 1997



Mobile Phone Sales

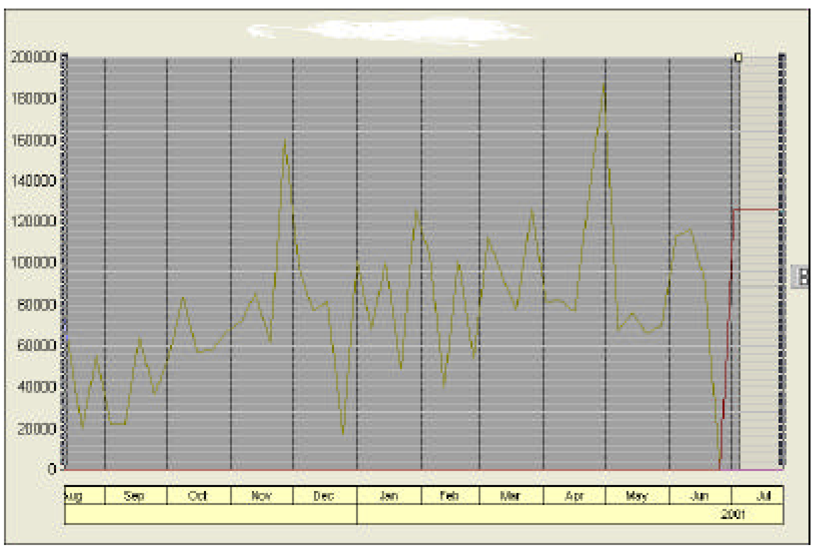


Figure 1.

Recent Developments in Supply Chain Thinking

Supply chain management has a great strategic importance. For example, in the motor vehicle industry, the urgency to better manage supply chains is being driven by the factors including:

1. Competitive pressures arising from a global reorganisation of the industry arising largely from a current over-investment in the industry. A 1998 estimate sets excess global capacity at nearly 30%.
2. A trend towards mergers and globalisation of suppliers and a shift towards modularisation of components.
3. A perception of a changing manufacturing industry dynamic that involves a cycle of shifts between vertically integrated businesses and horizontally/ modularised businesses.
4. Increasing speed of product and supply chain cycle times
5. Technological changes in information technology and communications.
6. Technology changes in the motor industry, particularly relating to telematics and engine design. (US estimates indicate that telematic equipment installed in new cars sold will rise from 18% in 1999, to 90% in 2004 (nearly 15 million cars).
7. The effects of changing energy prices and environmental concerns, for example, greenhouse gases.

These types of forces demand a re-think on how we approach supply chain management.

The concept of a supply chain has changed from the simple sequential view in which the various stakeholders add value along the supply chain, to a more contemporary view that supply chains are *value constellations* or *networks* centred around the consumer. Furthermore, it is now realised that *total* supply chains extend well past the supplier and customer boundaries, into supplier markets and the secondary after-markets for goods. See Figure 2.

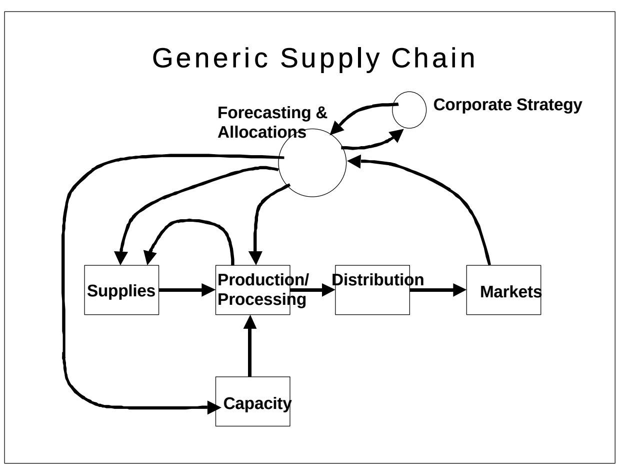


Figure 2. The Traditional Supply Chain

Accordingly, the supply chain can be defined as the *network* of organisations that develop new ideas, source raw materials, manufacture products (or develop services), store and distribute goods, and ultimately deliver the products and services to customers and consumers.

The objective of supply chain management is to achieve a customer outcome from the supply chain that is greater than that possible from just managing the individual parts- we want the whole to be greater than the sum of the parts.

Clearly, supply chain management is not only about the operational logistics of manufacture and distribution, a perspective recognised by the established logistics industry- for example, a prominent logistics research group from Michigan State University identify ten “Megatrends that will revolutionise Supply Chain Logistics”:

1. Customer service to relationship management
2. Adversarial to collaborative (alliances etc)
3. Forecast to endcast
4. Experience to transition strategy (moving past experience curves)
5. Absolute to relative value
6. Functional to process integration
7. Vertical to horizontal integration
8. Information hoarding to information sharing
9. Training to knowledge-based learning
10. Managerial accounting to value-based management.

Consequently, organisations that have traditionally structured along functional lines such as operations, distribution, marketing, finance and human resources- the “functional silos”- are being forced to shift much more towards organising around their supply chains. For many organisations this is clearly a difficult task because power structures, operating systems and reward systems have evolved that are centred on the traditional functions. This is less of a problem for newer organisations that have self-organised around supply chain projects to start with. This is the case in the information technology industries. Consequently, many of the lessons to be learned come from this sector.

Poirier (1999) identifies four stages of change organizations need to move through to improve supply chain management:

1. The improvement of individual process along the supply chain. The emphasis is on sourcing and logistics.
2. Coordinating the individual improvements to improve the chain as a whole. The emphasis is on internal excellence.
3. Developing a network and emphasising the management of alliances and partnerships.
4. Establishing an industry leadership role and being in a better position to leverage off the information structures that reside in the network.

The movement through these stages is closely associated with the degree of uptake of information technologies and the adoption of e-business and e-commerce technologies.

Two recent contributions to supply chain management are of particular significance to this discussion because the first emphasises the importance of thinking about a single design principle for the whole supply chain, and the second emphasises supply chain dynamics and the role of knowledge management:

1. Fisher (op cit) conclusion that the problems of supply chains are associated with mismatches between the types of supply chain- demand-pull (requiring product effectiveness) Vs supply-push (requiring logistical efficiency)- with the wrong type of product.

   Consequently, Fisher advocates strategies based on classifying products as being either functional or innovative. Functional products are products like groceries that have stable, predictable demand and long lead-times. They usually incur low margins and are subject to intense competition driving suppliers into various forms of differentiation (Fisher quotes 26 types of toothpaste from one supplier). Innovative products require consumers to change some aspect of their lifestyle and are associated with short life-cycles.

   Most problems arise when suppliers emphasise logistical efficiency when attempting to supply innovative products. Consequently, they need to decide whether to simplify the product back to a functional level, or adopt strategies that reduce uncertainty, cut lead times and improve flexibility, and/or develop better hedging policies.

2. Fine’s emphasis on supply chain dynamics based on his concept of “clockspeed”. (Fine, 1999; Fine, Vardan and El-Hout, 2002). Fine et al argue that, given the speed with which competitive advantage is won and lost in today’s markets, “on-going value chain assessment and design at the corporate level have become a necessity”.

   Fine applies the concept of “clockspeed”, that is, the rate of evolution of products, processes and customer requirements to argue that “the faster the industry clockspeed, the shorter the half-life of any given competitive advantage. A company’s real core capability- perhaps its only sustainable one- is its ability to design and redesign its value chain in order to continually find sources of maximum, albeit temporary, advantage”.

   Fine et al then develop a “Strategic Value Assessment (SVA) model” to help identify (qualitative) contributions to customer value along the supply chain and, by correlating these to an economic performance measure, establishes a decision criteria for decisions such as outsourcing/in sourcing supply chain processes. Importantly, the SVA model distinguishes between knowledge assets- “those related to the design and engineering of products, processes and services- and supply assets relating to "manufacturing and delivery capabilities".

By advocating the adoption of different internal structures depending on the nature of customer demand, Fisher's strategy provides an example of the application of the endogenous principle advocated in system dynamics- supply chains can be made more robust by adopting appropriate internal structures and policies. But, on his own admission, Fisher's somewhat static framework tends to break down in the dynamics of product innovation, competition and product differentiation. These issues are addressed by Fine's clockspeed dynamics and his SVA tool, and lead directly to the need for simulation modelling.

Fisher also identifies the very real problem of "the adversarial relations between supply chain partners". This points to the need for the adoption of an appropriate action learning framework within which to manage supply chain relationships: an essential aspect of the System Dynamics method.

Lessons from Industrial Dynamics.

In his preface to Industrial Dynamics, Forrester (Forrester 1961)[2] describes Industrial Dynamics as:

"…*a way of studying the behaviour of industrial systems to show how policies, decisions, structure, and delays are interrelated to influence growth and stability. It integrates the separate functional areas of management- marketing, investment, research, personnel, production, and accounting. Each of these functions is reduced to a common basis by recognizing that any economic or corporate activity consists of flows of money, orders, materials, personnel, and capital equipment. These five flows are integrated by an information network. Industrial dynamics recognises the critical importance of this information network in giving the system its own dynamic characteristics".*

After establishing the basic philosophies and tools of Industrial Dynamics, Forrester demonstrates his approach using two models:

- a simple distribution system involving inventories and flows of orders and goods, extended to include "a simple aspect of the market and sales effort" (Ch 2, 15 and 16)
- a model that explores the interaction between a customer-supplier loop and a supplier-labour loop, inclusive of money flows (Ch 17,18),

[2] This is not to suggest that current versions of System Dynamics are not important, but to recognise that Forrester's early work was essentially stimulated by what we now identify as supply chain problems. It is possible that Industrial Dynamics contains a number of insights that have been past over by the broader applications of System Dynamics. One example is the explicit articulation by way of alternate symbols for each of the five flows. But fundamentally, there is a certain irony in pointing out that an arguably superior approach to managing supply chains has been available for over 40 years.

Possible extensions are discussed in Ch 19 to include consideration of market dynamics, growth, commodities, research and development, top management structure, money and accounting, competition, forecasting and long-range planning, and industry models[3].

Of particular interest on this occasion[4] is Forrester's treatment of information. While obviously stimulated to look in this direction from his background in servo-mechanism theory, Forrester is careful to make the distinctions between an economic/industrial system and a purely mechanical system: "..our economic systems have a "distributed error function" represented by the individual goals of many participating persons". (as compared to a servomechanism that is often treated as having a single "error function", ie, the difference between actual and desired results. "The control function is likewise dispersed, so that it exists in part at each decision point in the system" (p61).[5]

Elsewhere Forrester makes the distinction between numerical data/information, written information, and mental information, and, pre-empting a key aspect of knowledge management, stresses the importance of using mental information. He stresses the information feedback nature of economic and industrial systems and the need for models to preserve closed–loop structures. It is this feature that gives rise to "the instability that is the counterpart of "hunting" in mechanical servomechanisms". He goes on to discuss the importance of time relationships (delays), amplification and information distortion.

In Appendix J, Forrester discusses the value of information and demonstrates the way in which a changed information flow can affect the system. He points out that inefficiencies can occur when random-noise variation in market data is "imposed directly on the production system" encouraging managers to stress short-term decisions- note Fisher's comment about point of sale scanning. His models indicated that system improvements "did not result so much from changing the type of information available or its quality nearly as much from changing the sources of information used and the nature of the decision based on the information"(p427). This is demonstrated in explicit terms by using his Ch15 model to show that when data on retail sales is available at the factory level, less than expected improvements are achieved[6]. He suggests that a "detailed study of such a system might lead to the conclusion that the solution to better system behaviour lies not in more information at the factory but rather in a change in the operating policies of the distribution system" (p429).

These observations can be further understood in knowledge management terms by reference to Figure 3 which shows the relationships between data, information, knowledge and decisions, and their interdependence with mental

[3] A research students dream section!
[4] See later discussion of knowledge management.
[5] This suggests some form of Agent Based Modelling.
[6] This point can be validated when playing the Beer Game by giving participants customer order data from week 30 onwards.

models (world views). Most importantly, System Dynamics models make "world views" explicit and clarify decision assumptions.

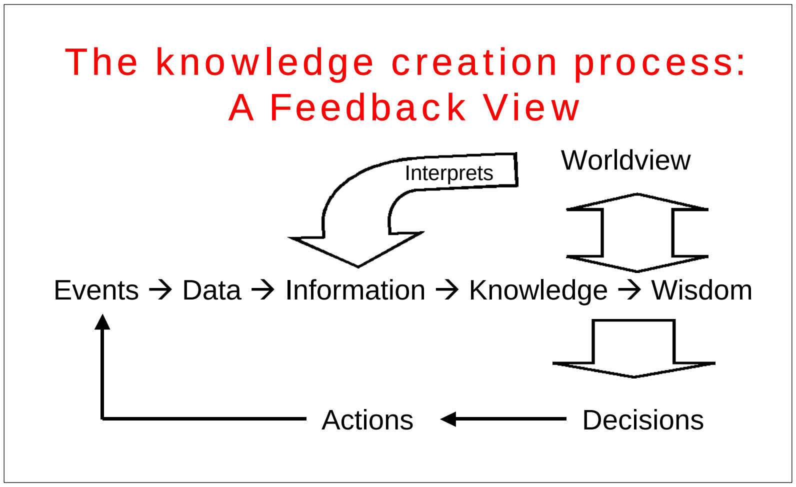


Figure 3.

When compared to one of the better researched studies of "value stream management" (Hines, Lamming, Jones, Cousins & Rich, 2000), Industrial Dynamics provides at least two distinct advantages- an integrated framework and a dynamic framework.[7] In fact Hines et al propose the use of System Dynamics as a tool for studying demand amplification, but fail to recognise the wider implications of the method. In particular:

- Mapping supply chains using the stock-flow structure provides a superior means of representation than either the often-used data flow diagrams associated with information systems, or the schematics and time-delay diagrams used in lean manufacturing. The reason for this is that System Dynamic's diagrams identify material and resource flows as well as information and decision structures. Consequently, they more clearly capture the economics of the supply chain as well as logistics etc.
- Simulation modelling addresses supply chain logistical problems of balancing inventories etc and understanding the impacts of delays and policies in a much more holistic way.

[7] Hines et al define seven value mapping tools- Process activity mapping; supply chain response matrix; production variety funnel quality filter mapping; demand amplification mapping; decision point analysis; and physical structure by volume and value. These tools are then correlated with seven forms of waste identified with Toyota's lean manufacturing system- overproduction; waiting; transportation; inappropriate processing; unnecessary inventory; unnecessary motion; defects.

- The system dynamics action learning structure (see Figure 4) helps address the problems of stakeholder communication and information sharing. Indeed, some of the biggest improvements in supply chain management have resulted from learning and growth relating to improved communication processes and knowledge management[8].

A SYSTEM DYNAMICS ROADMAP WITH 4 LEARNING CYCLES

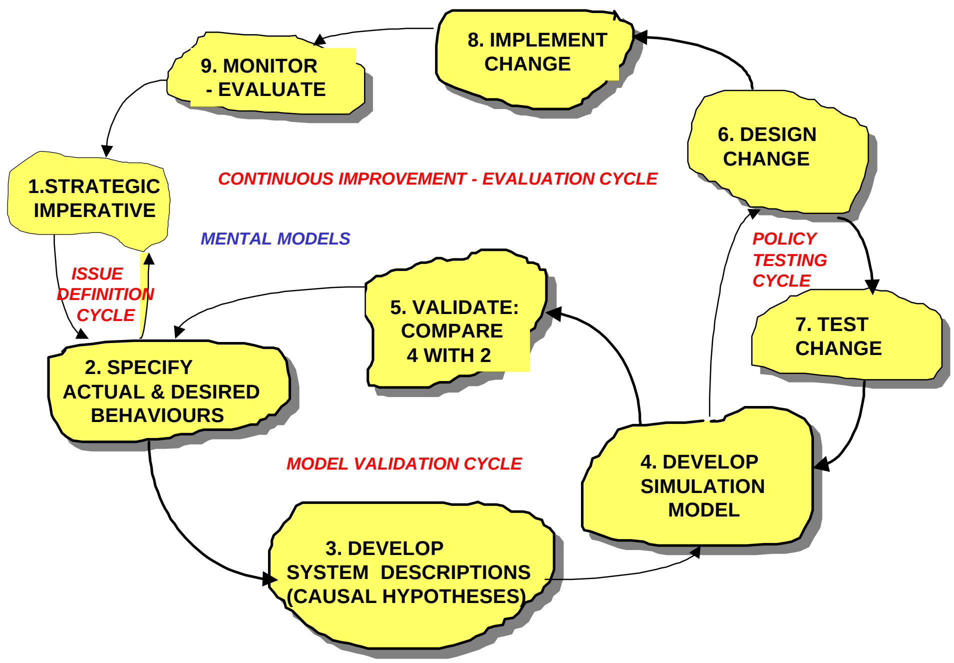


Figure 4.

In summary, Table 1 correlates recent developments in supply chain thinking with Industrial Dynamics method.

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[8] The learning structure inherent in the Toyota production system has been described as the "DNA" of the Toyota system- see Spear and Bowen, *Decoding the DNA of the Toyota Production System*. HBR Sept-Oct 1999.

Table 1.

Supply Chain Development	Industrial Dynamics Response
Recognition of strategic importance	Industrial Dynamics and its extent forms in System Dynamics and Strategy Dynamics etc, complement the "What, How, & For Whom" questions of traditional (static) strategic thinking by adding the "When" question using its dynamic framework .
The value constellation concept.	Clearly Industrial Dynamics maps material flows in an episodic manner, so to this extent it reinforces the "linear view" of supply chains. But a little reflection shows that the feedback structure rapidly breaks down this perception and, as becomes more graphically apparent, quickly adopts the persona of a value constellation when causal maps are developed.
Extension past the traditional logistics view of supply chains with an emphasis on procurement, production and distribution to include research and development, tertiary suppliers, customer relations and after market activities.	Forrester and subsequent work by Roberts demonstrate an early concern with aspects such as research and development and customer dynamics. The methodology of Industrial Dynamics is flexible as to what part of the industrial system is included and provides for exogenous effects for what is excluded. Eg, compare the exogenous effects of customer decisions in the Beer Game with models that make customer effects endogenous. Forrester's work is one of the most dramatic attacks on the silo mentality of functional management.
Poirier's four stage change process	These stages can be considered as action learning cycles as described in Figure 3.
Fisher's model based on the distinction between supply-push and demand-pull	This provides an example of the "endogenous view" in which system structure is designed for robustness.
Fine's concept of "clockspeed"	As Fine acknowledges, System Dynamics in an ideal framework within which to understand the dynamic implications of clockspeed.
Fine's articulation of knowledge and supply, and the resulting construction of SVA.	Forrester pre-empts much of the current discussion of knowledge management by emphasing the importance of tacit knowledge and by providing a framework and learning process for making tacit knowledge explicit. His use of an information networks to integrate flows of money, orders, materials, personnel, and capital is central to the Industrial Dynamics method.

Can We Help Our Shower Screen Supplier? Yes We Can![9]

Applying the method of Industrial Dynamics to the case of the shower screen supply chain, possibly complemented with some of the summary charts advocated by Hines et al and Fine etc, provides a comprehensive framework for better managing this supply chain. As an indication of the method, only the first couple of stages of the System Dynamics roadmap will be applied.

Stage 1. Formation of an action learning team[10] and definition of problem. This stage involves getting to key stakeholders together and discussing key performance measures for the supply chain. This may be based on Balanced Scorecard thinking, but in the first instance may concentrate on meeting contracted delivery times, quality measures and financial performance. Consideration of related reference modes and competitive performance can then provide the basis for establishing gaps between actual and desired performance.

Stage 2. Mapping the existing supply chain.

Figure 5 describes a first attempt to map the supply chain. In auditing this map, inclusion of money, orders, materials, personnel, and capital flows need to be checked. Clearly this map is deficient in this respect- only order and material flows are included. Cash flows will be critical to this system and need to be included. Capital and personnel flows may be less significant at least in the short run.

Similarly, delays and their possible variability should be carefully measured and cumulative delays graphed against project time elapsed.

To more clearly articulate stakeholder accountabilities it may be worth colour coding key decisions for which particular stakeholders are accountable, This has the further advantage of making individual stakeholders aware of the required information flows relevant to their decision making.

At the conclusion of this stage, a basic framework for on-going communication has been established. The ground is now set for applying tools such as Fine's SVA framework, and moving towards completing the simulation model ready for starting Stage 3.

Conclusions.

The problem of improving the management of supply chains has been presented and recent developments in supply chain thinking presented. After reviewing key elements of the Industrial Dynamics method developed by Forrester in the 1950s and 60s, a case is made that this methodology

[9] The model and further discussion in this section are still to be completed.
[10] If the language of "action learning" seems inappropriate, the DMAIC problem solving process related to the 6-Sigma approach should be considered.

provides both a dynamic and integrated approach to supply chain management.

This contrasts with the problems of the reductionist approach to managing supply chains with its emphasis on optimisation of parts, static analysis, and inflexible centralised control aimed at trying to keep the parts together but with an inadequate requisite variety to succeed in the long run[11].

The Industrial Dynamics/ System Dynamics approach has the additional advantage that it establishes the foundation for a knowledge management approach to managing supply chains.

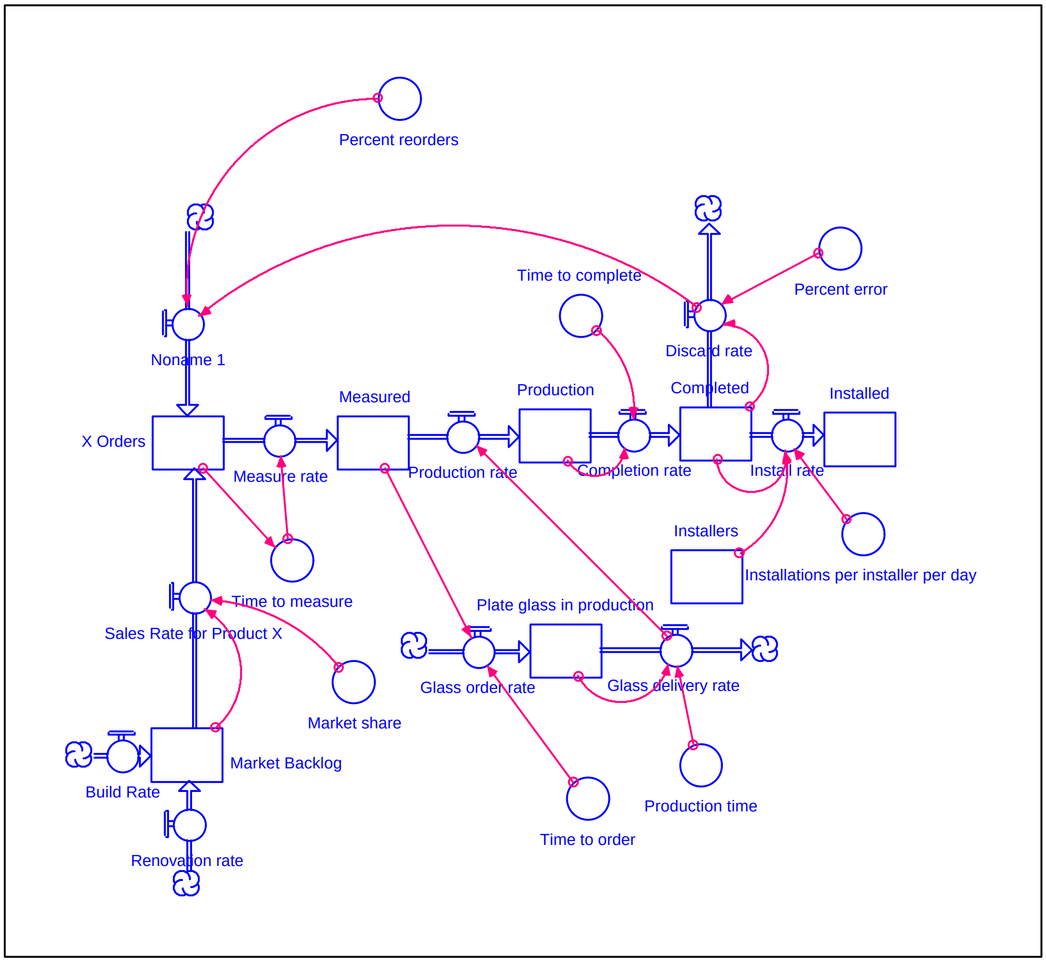

Figure 5. Initial Stock-Flow Diagram

[11] Walmart is possibly one organization that has been successful in centralising control.

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