

# SHRINKING THE SUPPLY CHAIN UNCERTAINTY CIRCLE

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## ABSTRACT

Any business operating within a product delivery supply chain is faced with an Uncertainty Circle. This is a major problem area and has four segments associated with: the supply side, the manufacturing process, the control systems and the demand side. Whereas uncertainty caused by the first two processes may be considerably reduced via the application of lean thinking principles, the last two require an understanding of total systems behaviour. In particular the availability of un-distorted market place data throughout the chain plus proven Decision Support Systems will shrink the Uncertainty Circle dramatically. The methodology is illustrated with simulation results and improved business performance observed in a real-world supply chain.

## INTRODUCTION

We believe that those companies which cope best with uncertainty, are most likely to produce internationally competitive bottom-line performance. Thus a business strategy which acknowledges uncertainty and provides a mechanism for pro-actively tackling it is rewarded by an opportunity to enable best practice way ahead of those competitors whose response is always reactive. Furthermore, *it is our experience that the best way to cope with uncertainty is to work hard to reduce it rather than to expect to solve the problem by acquiring even more sophisticated forecasting soft-ware.* Fortunately, in the case of supply chains there already exists a route-map for improving performance which inherently reduces uncertainty throughout the chain to the benefit of all 'players' therein. The ultimate goal in our approach is the Seamless Supply Chain (SSC) wherein all players 'think and act as one' [Towill 1].

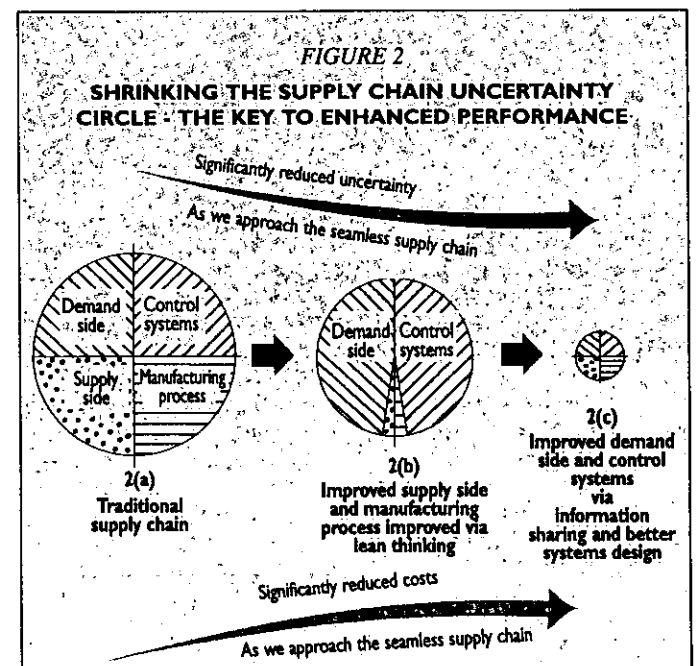
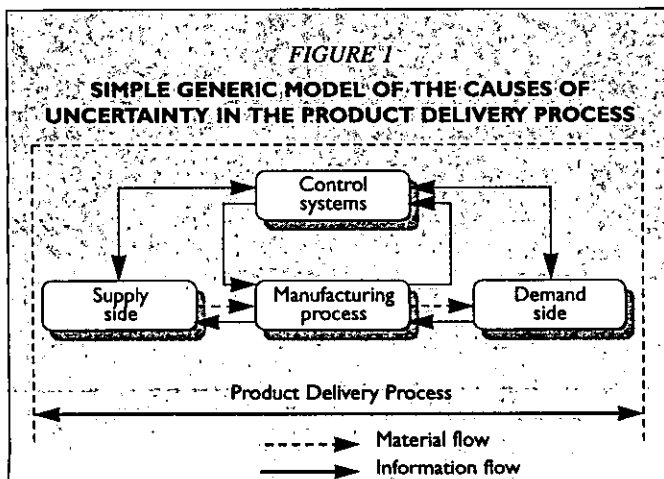
To understand the problems posed by uncertainty, let us consider the operation of a typical company engaged in the Product Delivery Process (PDP) in which goods are supplied in response to an order from our immediate customer. But who our immediate customer actually is depends on our position within the chain. For example, if we are an OEM, our immediate customer is usually a dealer, but if we are a PCB manufacturer our customer is usually an electronic products sub-assembler. As we shall see later, in the 'traditional' supply chain, PDP uncertainty will be a function of how far upstream we are from the ultimate market place. Typically, demands placed on a second-tier supplier will be twice as volatile as those experienced by the first tier vendor.

However, regardless of our position within the chain, the PDP uncertainty problem facing our business may be simplified and put into the generic format of Figure 1. Here a single echelon PDP is shown in which the primary manufacturing process (which may be composed of many individual tasks) is directed by our control systems. The company responds to our immediate customer (the 'Demand' side). In turn our stocks are replenished with materials, components, and sub-assemblies by various vendors (the 'supply' side). Reducing uncertainty is achieved by understanding and tackling the root causes inherent in each of the four areas and, equally importantly, how they interact with each other. The purpose of this paper is to demonstrate that an holistic approach to Supply Chain Management (SCM) has a great deal to offer in achieving these goals.

## SHRINKING THE UNCERTAINTY CIRCLE

It is useful to represent the total uncertainty facing our PDP as the area of a circle with four fundamental constituent segments due to Manufacturing: Supply Side: Control Systems: and Demand Side. In Figure 2 (a) we show a typical traditional situation in which all four are significant and approximately equal in importance. What does management then do to reduce uncertainty which is usually transparent from alternating high stocks followed by stock-outs? In response to this disaster two actions are normally taken, sometimes sequentially, but nowadays often concurrently.

Firstly, we strive to improve the performance of the manufacturing process by reducing lead times and greatly improving quality levels via the application of waste elimination principles known as 'Lean Thinking' [Womack and Jones 2]. Secondly, we work more closely with our suppliers, preferably via a Partnership Sourcing Programme to spread the 'Lean Thinking' approach upstream. We thereby expect to considerably improve supplier quality, reduce supplier lead times and experience much more consistent delivery patterns so that JIT production may be enabled as appropriate. When properly engineered, such a programme will also result in much better ownership of all aspects of the PDP [Parnaby 3].



Unfortunately, companies which have taken these actions (usually with external consultant guidance, and often at considerable cost in money, time, and hassle) are often perplexed to find that much uncertainty still persists within the PDP. The reason is quite obvious as can be seen from Figure 2 (b), since we have only reduced two of the sources of uncertainty, leaving the process controls and demand side problems untouched. Furthermore, management has also to understand that the law of diminishing returns applies here. There is little point in continuing to hammer our suppliers and our shop floor for even better performance, particularly when the really big gains are to be made elsewhere in the system.

But of course we have so far concentrated on the easy actions. It is manifestly much simpler to tackle problems wholly within our remit and to re-engineer the shop floor and chase/change our suppliers compared to the difficult task of attempting to persuade all players in the chain to seriously practice SCM! It is thus obvious that to deliver the further improvements shown via the Seamless Supply Chain in Figure 2 (c) that we must amply demonstrate the benefits accruing from successful SCM. This we shall do using both simulation and real-world supply chain results which show the benefit to all players when properly engineered.

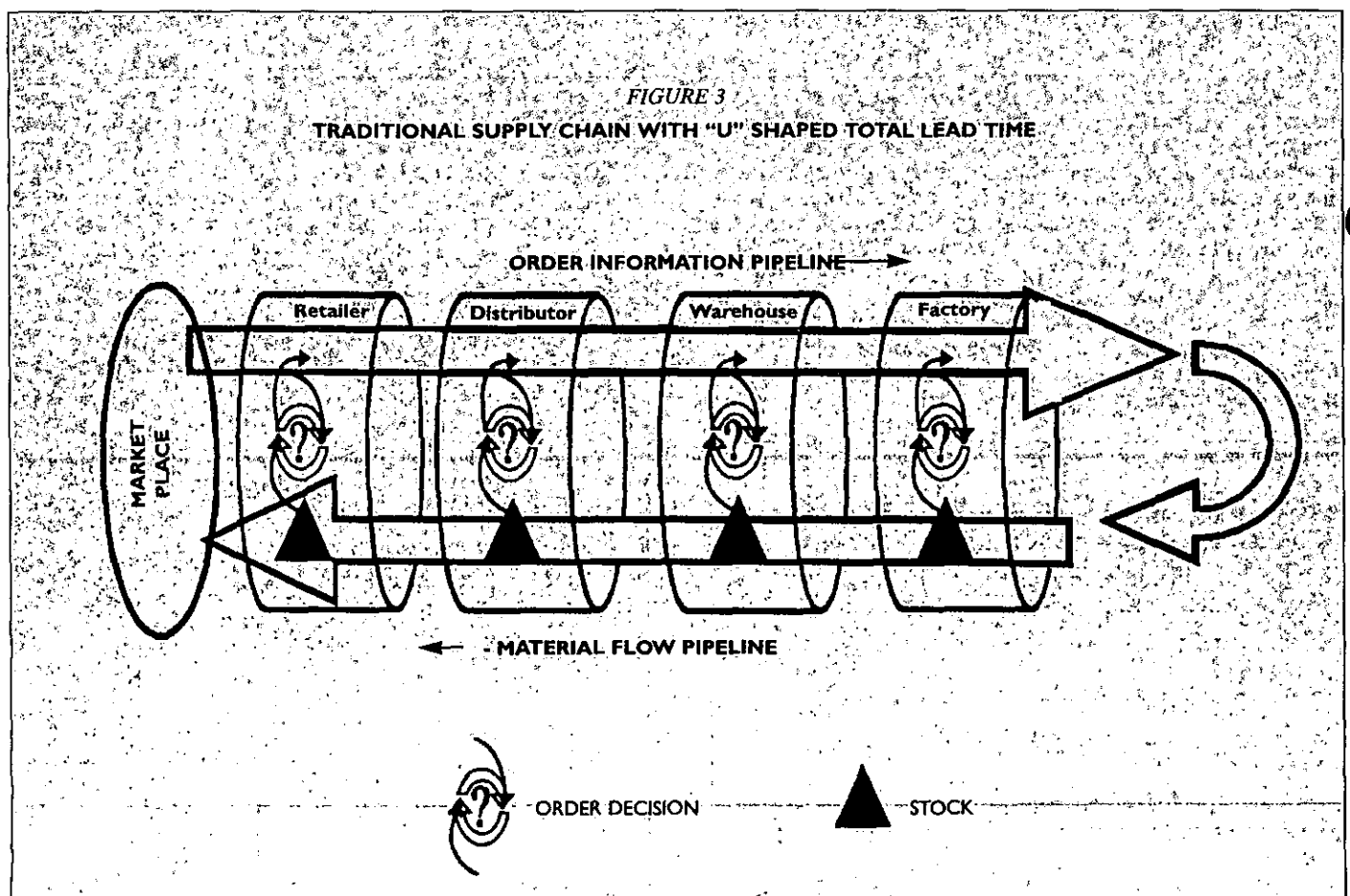
### PIPELINE MANAGEMENT IN TRADITIONAL SUPPLY CHAINS

Jay Forrester first coined the phrase 'pipeline management' to describe the continuing controlled flow of goods on demand using the analogy with the behaviour of a hydraulic system. This embraced the view that there is a continuous flow of materials throughout the supply chain rather than via a series of unconnected operations. Supply chain lead times from raw materials to customer can often be very long and can run into months. However, in achieving better control we must remember that all supply chains have two distinct lead time pipelines.

The first is the sales/order information transfer pipeline, from point of sale to raw material supplier; and the second is the product transfer from raw material to customer. As shown in Figure 3, in practice there is a tendency towards a characteristic supply chain U-shape configuration from end consumer demand to goods delivery into the market place. Orders therefore flow upstream and as a direct consequence products flow downstream. In this traditional mode information only flows between successive echelons or 'players' with individual businesses having no direct visibility of what is happening anywhere else in the chain.

So at each echelon order information is subject to delay, bias, and noise, or indeed may be totally absent. Far from cancelling each other out, our experience is that these various distortions of true market place demand is at best additive and at worst multiplicative in their effect. Hence any genuine market place uncertainty in the market place is greatly magnified as orders are transmitted upstream in the supply chain. Frequently this is compounded by players 'double guessing' the true order pattern. Unfortunately, their actions are usually out-of-phase with what is actually required to damp down excess magnification of the order waveform. Hence despite their best efforts, demand volatility is made worse, not better.

The product pipeline is activated by the information pipeline, therefore speed of information transference is crucial to an effective supply chain. Unlike production delays, which are frequently reliant on technological innovations for faster material flow the order information pipeline can in theory be instantaneous. Not surprisingly, EDI has become essential to enable a competitive market position in many industries. This is to such an extent that it is frequently stated that 'information technology is the key enabler for Business Process Re-engineering (BPR)'. Speed of information transfer has therefore been recognised as a key commodity that can, if handled properly, become a competitive advantage.



However, it is *the quality* of the information *not the quantity* of data which is *the* key enabler. This is evident from our real world examples shown in Table 1. The attitudes adopted by the various players in these particular supply chains guarantee that considerable and wasteful uncertainty is induced into the upstream businesses. Yet some of these same players are known to wrongly feel that they represent best-practice in supply chain management. As [MacBeth and Ferguson [4] have pointed out, their behaviour is so adversarial as to suggest that they regard fellow players in their own supply chain as being 'the real enemy'!

**TABLE 1**

**TYPICAL INFORMATION FLOW PROBLEMS ENCOUNTERED IN REAL WORLD SUPPLY CHAINS**

SYNDROME	CHARACTERISTICS
'Over to you' (Information withheld)	Supplier wins a year's contract to supply 10,000 widgets, but customer refuses to forecast a weekly breakdown - customer says 'just deliver what we want, when we want it'.
'Badging' (Information withheld)	Supplier of finished goods has no view of market and delivers blindly on demand to an intermediary, who 'badges' before passing on to retailer, so has little opportunity for forward planning.
'We know best' (Information distorted)	OEM provides detailed forecast throughout the chain but an intermediate player places cyclical demands on his upstream supplier even though customer forecast proves to be quite accurate.

### DYNAMIC BEHAVIOUR IN TRADITIONAL SUPPLY CHAINS

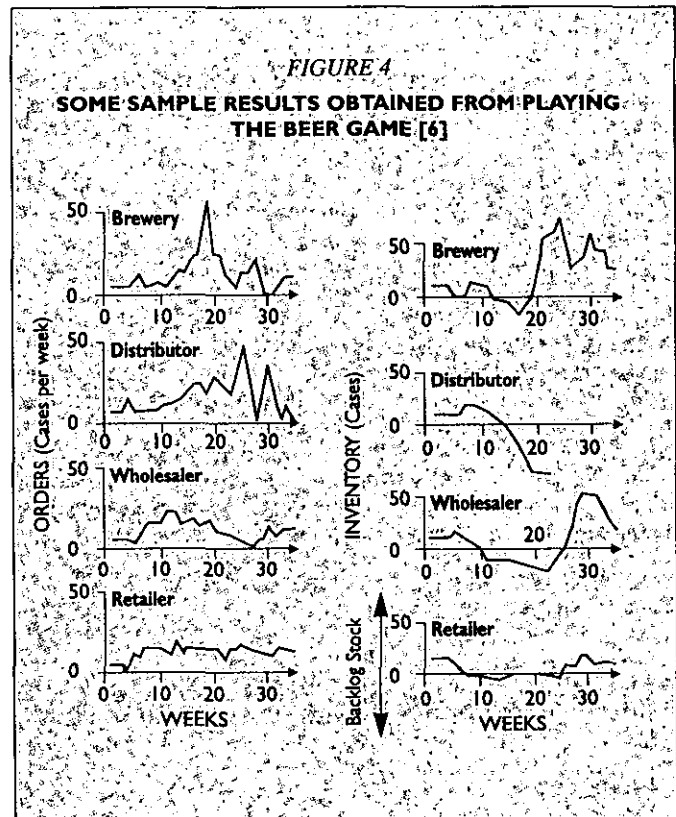
Each echelon in the traditional supply chain receives an order from its customer from which the business makes a decision on what it needs to produce to satisfy its stock targets (which of course may well be zero). The decision process normally involves a certain amount of judgement to forecast what is thought to be happening within the market place in order to try and ensure the company stays ahead of the game. So in theory trends in consumer demand such as seasonality will be monitored via general trade reports etc, but in practice this is often extremely difficult when denied direct access to market place data. If we restrict the transferring information through a supply chain in such a traditional sequenced manner then this gives rise to the Burbidge 'Law of Industrial Dynamics' which may be stated as:

*"If demand for products is transmitted along a series of inventories using stock control ordering, then the demand variation will increase with each transfer"*.

This phenomenon, which is a major generator of uncertainty, has been widely observed and researched to discover opportunities for avoidance via good supply chain design. The practical consensus is that if there is any possible way in which demand can multiply then it will, [Towill 5]. So, the further away from the consumer a 'player' is in the supply chain, the less he is aware of the true consumer demand and the more likely he is to be misled especially as there is usually geographical as well as time separation between events. In a traditional supply chain the raw materials supply will respond to an increase in consumer demand may be weeks, months or even years after the buying practice first showed itself in the market place. By this time the product may well be obsolete with vast quantities of stock written off at various points in the chain. (For example, a well known UK machine tool manufacturer went bankrupt scrapping four years stock of lathe beds dispersed throughout the supply chain). Unfortunately, high stocks are not necessarily

'right stocks'. Experience suggests that high stocks are much more likely to be 'wrong stocks'!

One of the most researched and useful supply chain models is the MIT Beer Game [Sternan 6]. The Game is representative of a four level supply chain (ie. four 'players') and clearly shows the difficulties in matching product flow with consumer demand, especially when played in the 'traditional' mode, ie. withholding market place information. Some sample results are shown in Figure 4, in which the four 'players' represent the Retailer, Warehouse, Distributor and Brewery. The dynamics of uncertainty induced by the players responding to a simple step demand at the market place is both remarkable and realistic. The demand amplification across the supply chain is greater than 10 - 1. This corresponds reasonably well with our rule-of-thumb suggesting a 2 - 1 amplification across each business interface [Towill 5].



As stated by the 'Law of Industrial Dynamics' although the driving force in a supply chain is the need to meet its customer demand very few players within the traditional supply chain are in a position to respond directly to the market place. Although the actual consumer demand variation in the Beer Game is in this case very simple the wildly varying responses observable is due to each level trying (often in vain) to anticipate what the true demand is, meet its immediate customers' demand and simultaneously keep control of its own stock level. The demand magnification phenomenon is unmistakable. The difficulties faced by the 'players' are lack of communication within the chain, lack of knowledge of the actual consumer demand, and a delay in information transfer (for example the factory experiences a four week delay).

The basis of most of the problems within the Beer Game can be associated with the lack of good quality market demand information being made available to the whole supply chain (the demand segment of the Uncertainty Circle) usually made worse by poor decision making (the control systems segment of the Uncertainty Circle). It should be noted that at de-briefing sessions, many 'players', including some very experienced decision makers, are very reluctant to accept that such uncertainty is generated within the chain rather than externally. They tend to blame the 'environment' rather than their own inadequate decision-making capability.

In one sense it may be argued that the Beer Game is an extremely simplistic representation of a supply chain with only one decision point at each level (and in this particular scenario only one change in consumer demand). But even when presented with just these few variables it appears to be very difficult for human operators to adequately control ordering procedures and stock levels. It is thus hardly surprising that organisations have difficulties meeting demand effectively, especially when considering the distortion and delays to which market sales information is subjected in the real world. We therefore argue that reducing the size of the Uncertainty Circle depends partly upon enhancing our control systems by selecting a good Decision Support System (DSS) and more significantly upon having transparent information flow throughout the supply chain.

## THE INFORMATION ENRICHED SUPPLY CHAIN

[Stalk and Hout 7] neatly sum up the difficulties associated with information delays when they state

*"The underlying problem here is that once information ages, it loses value...old data caused amplifications, delay and overhead... The only way out of this disjointed supply system between companies is to compress information flow time so that the information circulating through the system is fresh and meaningful."*

So the key to gaining control of the whole supply chain and hence meeting consumer demand more efficiently is to directly access end sales and hence re-design the way the chain uses this market place information. Managers have the power to design their business using established tools such as BPR, systems thinking and simulation via a holistic approach to change. Business Systems Engineering [Towill 8] brings these tools together in a suitable integrated methodology. In this

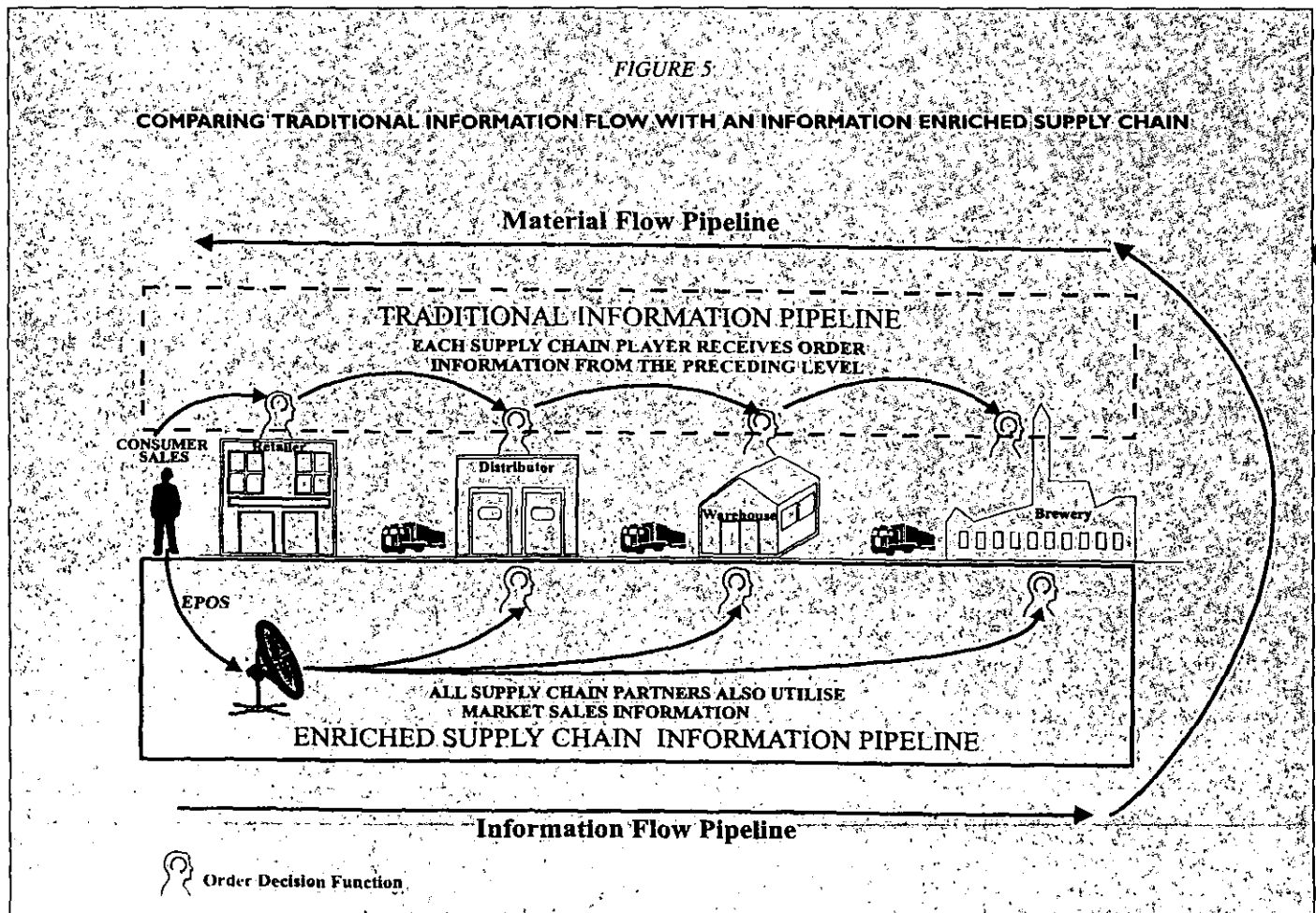
paper we provide the evidence (based on simulation and practical experience) as to why in supply chains this should be especially re-engineered via improved information flow.

The importance of information has long been recognised in the change process, and is championed by [Hammer and Champy 9] as a key enabler for BPR. Not surprisingly therefore many BPR projects and associated literature have an IT bias and much work has been carried out and presented that analyses and optimises information flow. We believe the aim of such research should include the investigation of the benefits of re-designing the supply chain around the flow of market sales information.

*The two main issues on the system re-design brief are then to limit order magnification as the information moves up the supply chain (leading to uncertainty) and to reduce the time delay in receiving information (leading to the loss of information value).*

Both factors greatly compound the controls process which timeliness and transparency can help alleviate.






Market sales data provides catalyst information for the whole supply chain, since it holds undistorted data of the consumer demand pattern. Therefore the best way to ensure everyone in the supply chain gets the most up-to-date and useful information is to directly feed each level of the supply chain with the market sales data. Figure 5 shows a representation of the information enriched supply chain in which each echelon receives the data directly rather than via the traditional mode where the information flows through each level (and is usually distorted therein) before it gets passed on. This enrichment is achievable with a point of sales link at each level in the supply chain. So rather than each link making an order decision based purely on the internal chain sales data it can now make an informed judgement based on what the end consumer is actually buying.



A good real-world example of market sales information being utilised within the consumer goods sector is the business link between Wal-Mart Stores (USA) and Procter & Gamble, one of its main suppliers. Basically Wal-Mart broke down the barriers to information sharing and opened its consumer information to all their suppliers for both tactical and strategic usage. This was a revolutionary step resulting from the new Wal-Mart ideology that it did not matter what competitors might thereby learn about the business so long as the Wal-Mart relationship with their suppliers grew stronger thus resulting in a better service for customers and hence greater profits for the chain, [Johansson et al 10].

approach adopted is to make a preliminary selection of the best strategy on the basis of the step response and then to verify the choice by simulating random and seasonal disturbances [Mason-Jones et al 13]. One benchmarked output from such a simulation study is shown in Table 2. It is based on a set of measures of performance responding to a 'shock' demand at the market place. For this particular supply chain configuration it is clearly advantageous to reduce all material flow lead times and operate an information enrichment policy. The latter will help 'shrink' both the 'demand side' segment and the 'process controls' segment in the move towards the SSC which is good for customers and suppliers alike.

TABLE 2.  
SUPPLY CHAIN PERFORMANCE IMPROVEMENT BENCHMARKING

Supply Chain Design Strategy	Dynamic Performance Measures					Overall Dynamic Performance Benchmark
	Peak value 	Peak Time 	Order Recovery 	Stock depletion 	Stock recovery 	
Datum Design	**	**	*	*	*	*
Information pipeline time compression only	****	**	*	***	***	***
Material flow pipeline time compression only	*	****	**	**	****	***
Total Cycle Time compression	****	****	****	****	***	****

\*\*\*\* = Best, \* = Worst.

The current situation is that Procter & Gamble now take the consumer information from Wal-Mart at point of sale and decide how much stock to deliver to the stores so as to ensure consumer demands are satisfied. *It is Procter & Gambles' responsibility to keep shelves full.* This strategy has a double benefit in terms of shrinking the size of the Uncertainty Circle. Firstly it reduces uncertainty by eliminating both material and information flow delays; secondly it reduces uncertainty yet further by eliminating a decision point within the chain.

### DEMONSTRATING THE BENEFITS OF THE 'INFORMATION ENRICHED' SUPPLY CHAIN

A standard way of establishing benchmarks for judging the effectiveness of competitive supply chain re-designs is via the use of simulation models [Van Ackere et al 11]. We use a generic model for this purpose, which is a tried and tested representation of much industrial practice. Each echelon is represented by a DSS which takes account of orders received, WIP, stock policy, and any forecasts available. The echelons are then coupled together in the way which best describes current supply chain strategy. One example of such a generic model depicting the behaviour of an electronic products supply chain is described by [Berry et al 12] and which was subsequently used to benchmark various real world strategies against the baseline case.

We have found that for synthesis purposes it is realistic in the first phase of system design to use a step demand to simulate a shock event at the market place. The waveform propagation upstream is then observed, thus generating displays broadly equivalent to those previously met in Figure 4. The reason for this choice is that the step response provides an extremely 'rich picture' of the supply chain dynamics. Hence the

### REDUCING THE UNCERTAINTY CIRCLE IN THE REAL WORLD

A real world supply chain application of the principles of shrinking the Uncertainty Circle has been reported by [McCullen et al 14]. It concerns the re-engineering achieved by Edwards High Vacuum International (EHVI) via their company wide 'rapid response' and 'IT integration' programmes. Actions taken and implemented by EHVI (which impact on all four areas of the Uncertainty Circle) include manufacturing lead time reduction; linking factories directly to customer demand data; more frequent and more rapid planning; streamlined physical distribution; and a new DSS to fully exploit the reduced time delays.

TABLE 3  
IMPROVED DYNAMIC PERFORMANCE OBSERVED IN RE-ENGINEERED EHVI SUPPLY [14]

SUPPLY CHAIN PERFORMANCE METRIC	EHVI PRODUCT CODE					
	E2M1.5	E2M2	E2M5	E2M8	E2M12	E2M18
Reduction in production demand amplification variability	-45%	-26%	-18%	-25%	-14%	-46%
Reduction in central warehouse stock variability	-34%	-31%	-35%	+15%	-27%	-36%
<b>(b) Improvement in global inventory of vacuum components</b>						
YEAR	1	2	3	4	5	
% TOTAL CHANGE	0	-17%	-29%	-35%	-45%	

The recorded results are summarised in Table 3 and emphasise the continuing beneficial trend in global inventory of vacuum components (down 45% in 5 years) and plus reduction in production demand amplification for the sampled product ranges by up to 46%. Unfortunately, the data does not enable the credit for performance improvement to be apportioned between 'rapid response' effects and 'IT integration' effects, but the combined benefits from these concurrent programmes are indeed impressive. They also confirm the effectiveness of our approach to shrinking the Uncertainty Circle concept as a means to improving competitiveness.

## CONCLUSION

The Uncertainty Circle is a useful concept as an aid to greatly improving the performance of real world supply chains to the benefit of all players therein. Whereas the Supply Side and Manufacturing Process segments are essentially under the direct control of the business and may be tackled using lean thinking principles, the Process Control Systems and Demand Side require action to be taken externally if significant improvements are to be achieved. Both the Control Systems and Demand Side uncertainties in product delivery may be substantially shrunk via the ready and transparent availability of undistorted market place data. To obtain the necessary collaboration businesses may find that the genuinely shared and properly led Partnership Programmes are good enabling mechanisms. Our approach to the practical shrinking of the Uncertainty Circle has been demonstrated via simulation modelling and real world BPR experiences.

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