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Int. J. Production Economics 62 (1999) 61–73

international journal of
**production
economics**

www.elsevier.com/locate/dsw

Total cycle time compression and the agile supply chain

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Abstract

Agility is herein interpreted as using market knowledge and a virtual corporation to exploit profitable opportunities in a volatile market place. This requires the slashing of process lead times throughout the chain. However, as we demonstrate in the paper such action is simply not enough to enable agility. Similar steps must also be taken to reduce information lead times, resulting in the concept of the “information enriched” supply chain. Simulation results obtained on realistic models of fashion trade supply chains confirm the superior agility resulting from information enrichment. The paper concludes with a Route-Map indicating the steps to be taken in achieving supply chain agility in real world scenarios. © 1999 Elsevier Science B.V. All rights reserved.

Keywords: Agile; Supply chain; Information; Competitive advantage; Speed of response

1. Introduction

A balanced supply chain requires workable trade-offs within the value stream. Following Gattorna and Walters [1] the five necessary basic functional activities are:

- procurement (maximum purchasing discounts),
- inbound logistics (low transportation costs),
- operations (low production costs),
- marketing and sales (wide product range/high availability),
- outbound logistics (low transportation costs).

Furthermore the development of an integrated supply chain requires the management of material and

information flows at three levels: strategic, tactical, and operational. Whilst the stages of supply chain integration described by Stevens [2] apply to some degree to all supply chains, in agile supply chains there is an especial need for a clear focus on strategy. This is because in the demand classification adopted by Gattorna and Walters [1], agile supply chains are usually dominated by surge flows rather than wave flows or base flows. Surge flows result from demand uncertainty [3]. Hence an agile supply chain has to be engineered to cope with uncertainty yet still profitably satisfy customer demand.

The definition of agility used in this paper takes the following form:

“Agility means using market knowledge and a virtual corporation to exploit profitable opportunities in a *volatile* marketplace [4]”.

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This in turn implies that the businesses must work together to form an integrated supply chain focusing on meeting the demands of the end-user irrespective of what performance improvement paradigm is adopted by individual companies. Thus the goal in achieving agility is to establish a Seamless Supply Chain (SSC) in which all “players” think and act as one [5]. All functional and territorial boundaries are thereby removed so as to ease the rapid flow of material, cash, resources, and information.

Because of the emphasis on integration, the principles of Business Systems Engineering (BSE) in the design of agile supply chains is reviewed and related to current thoughts on Lean Thinking. Since Naylor et al. [4] have already shown the necessity for lead time reduction as a pre-requisite to agility, the Total Cycle Time (TCT) Compression Paradigm is described, and applied to an automotive supply chain. We conclude the description of traditional supply chains with a reference to a fashion supply chain. The resulting TCT is of many months duration so it is no surprise to hear of companies in this market sector such as Benetton re-engineering their supply chain to achieve reductions of more than 4:1 [6].

To date the emphasis on TCT reduction has focused on slashing material flow lead times. This is a necessary, but not sufficient condition to enable an agile supply chain. As many companies have found via the experiential route, there is a second necessary condition to be met. This is that information lead time must be similarly reduced, leading to the concept of the “information enriched” supply chain. This conclusion is supported by experiments on simulation models representing “traditional” and “information enriched” supply chains typical of the fashion sector. Finally, we review the barriers opposing agility. This results in a route map for change which must be followed to ensure end customer satisfaction.

2. Business systems engineering of supply chain

The concept advanced here is that any organisation which operates using a systems approach delivers better engineering throughout *all* its activities

[7]. When the systems approach is used to “engineer” business processes the focus is on the design and operation of the most effective means by which customer need is transformed into customer satisfaction. The resulting methodology is known as Business Systems Engineering (BSE), as described in detail by Watson [8]. It provides a structured way of simultaneously maximising both customer value *and* the performance of the total supply chain to the benefit of all the stakeholders therein. In this paper the Business Process of particular interest is the Product Delivery Process (PDP), i.e. the control of material flow from identification of customer need to satisfaction of that need [9].

A system is an integrated combination of components and activities designed to follow a common purpose. A systems philosophy demands that an uncoordinated approach is replaced by a framework in which the identity of the separate elements are subsumed by the identity of the total systems. Systems engineering is an art: it is based in part on control engineering principles and in part on industrial engineering principles [10]. Via the systems approach the individual elements and subsystems are designed and fitted together to achieve an overall system purpose in the most effective way, at the lowest cost, with minimum complexity. *Specifically, the hallmark of systems thinking is that it considers the connections between the elements to be as important as the elements themselves* [11]. *It is therefore the ideal way to approach the problem of designing “agile” supply chains.*

As has been shown elsewhere [9] BSE conveniently integrates and subsumes many ideas (such as “Lean Thinking”, [12]) which have been proposed (and very effectively used) to improve individual company competitiveness. It is however quite wrong and unnecessarily restrictive to think of BSE as being applicable only to large scale mechanical engineering artefacts, i.e. traditional manufacturing industry, where the scale of perceived improvement may be gauged from the typical results shown in Table 1. In the real world it has been found to be equally applicable to such apparently different market sectors as automotive, aerospace, electronic products, banking and insurance. Also as systems thinking is as much concerned with the connections as with the elements, we would

Table 1

Typical results quoted of John Parnaby [7] following the successful application of a BSE programme within an aerospace actuator company

Benchmark	Improvement
Leadtime	Down 75%
Manufacturing costs	Down 75%
Material movements	Down 90%
Inventories	Down 75%
Work in progress	Down 75%
Adherence to schedule	Up 30%
Product “ownership”	Much improved

expect BSE to be a suitable methodology for the analysis, modelling, and design of supply chains. This is indeed the case, and the roots of the “systems movement” applied to supply chains can be traced as far back as Jay Forrester [13].

The essence of BSE is encapsulated in the *Understand – Document – Simplify – Optimise* routine which starts with process mapping and then engineers the system via a set of tools which includes Industrial Engineering, Information Technology, Production Engineering, and Operations Engineering [14]. BSE may also be seen as engineering a formal attack on *muda* or waste [15]. Thus there is a concerted effort in “Pursuit of the Zeros” as follows:

\$ Zero Waste Time,
 \$ Zero Waste Materials,
 \$ Zero Waste Labour,
 \$ Zero Waste Capacity,
 \$ Zero Waste Computing Power,
 \$ Zero Waste Management Effort.

Such a checklist is invaluable in the re-engineering of individual companies [12]. However, as we shall see later, the Agile Supply Chain concentrates on:

\$ Zero Waste Total Cycle Time

and additionally, since slashing information lead times lead times is a necessary prerequisite to enabling agility:

\$ Zero Waste Information Flow.

This leads to an augmented set of goals for the Agile Supply Chain.

3. The time compression paradigm

Lead time has long been recognised as an important metric for assessing the performance of a business process [10]. However, there is considerable industrial evidence that time may be used in an even wider context in Business Systems Engineering Programmes. Specifically, *Total Cycle Time (TCT)*, which is defined by Philip Thomas [16] as *the elapsed time between customer enquiry and customer need being met is shown to be a fundamental driver in achieving enhanced business performance*. He quotes the range of results shown in Fig. 1 as typical of those to be expected from successful TCT targeted BSE Programmes across a range of industries. Note that *all* of the important business metrics listed have been significantly bettered. Consequently we may have considerable confidence in ranking the effectiveness of BSE proposals by estimating the expected reduction in TCT, especially with regard to the Agile Supply Chain (ASC) wherein time compression is a key enabler [4].

So powerful is this approach that it has become known as the Time Compression Paradigm (dictionary definition of paradigm: an example or pattern, especially an outstandingly clear or archetypal one). The important consequence of this paradigm is that by concentrating on reducing the TCT

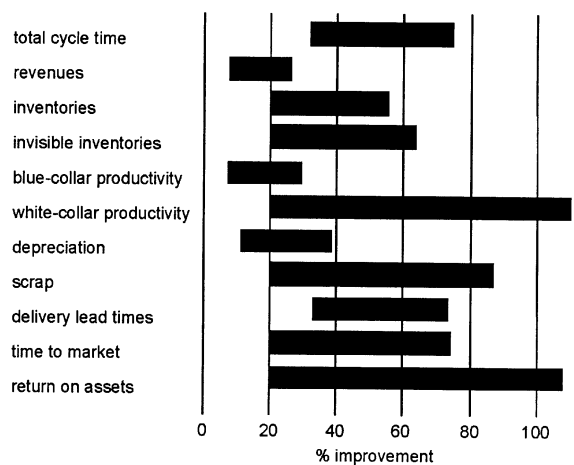


Fig. 1. How reducing total cycle time leverages the company “bottom line”; a range of industrial results reported by Philip Thomas [16].

required to perform a business process we have a guarantee of leveraging total performance in such a way that the “bottom line” will be greatly improved. Also, we need not perform complex calculations in order to project exact financial benefits: we simply need to predict, monitor, and systematically seek to reduce total cycle times. As an initial strategy it is enough to target TCT reduction via BSE knowing that if done properly substantial business benefit will ensue.

The TCT compression paradigm is now widespread and because of its universal appeal and strategic leverage is sometimes known by the alternative name of Time Based Management (TBM) as coined by the Boston Consulting Group. The generality of these conclusions is supported by the results of three large sample surveys undertaken by Schmenner [17]. Table 2 lists both the significant and insignificant factors established by statistical testing of the survey data. *The crucial conclusion reached is that the only significant factor in improving productivity is to properly re-engineer operations so as to reduce TCT.* Thus we may find both good and poor productivity in new plants, old plants, high tech plants, low tech plants, and with examples of “best practice” across a wide range of industries.

The crucial fact is that the Time Compression Paradigm works at all levels from individual work processes up through business processes to total supply chains. Consequently TCT is a fundamental business lever to be exploited within a BSE framework. This is clearly illustrated in the results of an ELA survey of replenishment lead times summarised in Table 3. It is manifest that there is continuous and market sector independent pressure to reduce lead times often by success factors which would have been impossible to comprehend back in 1987. *An important consequence of the use of TCT as a performance driver is that it is unambiguous and simple to measure. The only question to be answered is “how long did it take between customer request and for that need to be satisfied?”* In itself this lead time is a direct measure of business performance but even more importantly it significantly leverages the “bottom line” metrics. It is therefore no surprise to find that a survey of five major management consultancies has established that

Table 2

TCT Reduction is the significant productivity improvement driver (based on large-scale industrial surveys undertaken by Schmenner [17])

Factors tested for statistical significance	Significant?
Investment in high technology	No
Setting up gain sharing plans	No
Investment in Class A MPR II systems	No
Operator focused industrial engineering	No
Age of plant	No
Size of plant	No
Global location of plant	No
Degree of union activity	No
Process/nonprocess industries	No
Total cycle time reduction	Yes

Table 3

The progressive reduction in replenishment leadtimes is independent of the market sector (based in part on an ELA study)

Market sector	Leadtime (days) in a year		
	1987	1992	1997 (Estimated)
Food and beverages	5	4	3
Fast moving consumer goods	9	6	4
Petrochemicals	16	11	6
Automotive	28	20	12
Building materials	42	18	7

lead time is a prime metric for planning and executing BPR programmes in all cases, [18]. This is despite the wide historical differences between these consultancies.

4. Time compression in supply chains

Table 4 lists the four basic ways (i.e. the “what”) of achieving cycle time compression [19]. Which approach(es) are top priority in engineering a given supply chain can only be identified once a process flow chart has been compiled and which is agreed by all the players as being a realistic description of what is to happen [10]. The reason why flow chart fidelity with the real world is so important is because there are often process elements which are

Table 4
Strategies for cycle time reduction, Towill [19]

Tactics adopted	Engineering procedure
Elimination	Remove a process
Compression	Remove time within a process
Integration	Re-engineering interfaces between successive processes
Concurrency	Operate processes in parallel

“hidden” from normal view, and which are frequently prime candidates for elimination or concurrence [16]. It is also a fact that few executives have a full picture of the supply chain until an agreed process flow chart is drawn up. Hence supply chain re-engineering is essentially a feature of a “learning” organisation. Once the windows of opportunity have been identified, the “how” of time compression can be readily achieved via specific technologies. The latter can be broadly categorised into industrial engineering, production engineering, information technology, and operations engineering. A full description of these techniques together with typical TCT engineering examples is given in Evans et al. [14] and Scott and Westbrook [20] and need not be repeated here.

An industrial example of the application of the TCT paradigm is re-engineering the supply of automotive seat covers manufactured via a four-echelon demand chain [6]. Fig. 2 shows the bar chart resulting from the mapping of the original process. The Boston Consultancy Group undertaking this BSE project found that the delivery cycle time was 71 days but only 19 days were actually spent adding value to the product. The ultimate goal set by the OEM is seen as achieving a 20 day TCT. The BSE methodology has already removed 28 days from the cycle by adopting a better system for information flow resulting in the transparency of the OEM schedule throughout the chain, plus parallel action to reduce raw material vendor lead times. At the time of reporting these results the BSE Task-Force estimated that a further 10 days remain to be removed by cutting non-value added lead times via reduction in set-up times, etc. Most importantly this TCT reduction programme is visibly on track to achieve the 20 day target. Proper application of

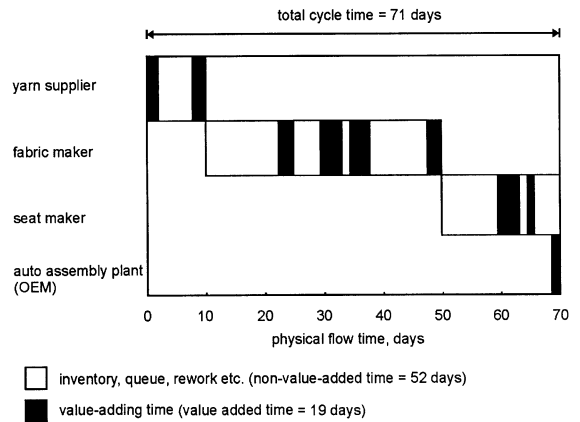


Fig. 2. Bar chart showing distribution of value-added and non-value-added time recorded by the Boston Consultancy Group when analysing a four-echelon automotive seat supply chain.

BSE has already resulted in a TCT improvement of 1.65:1 when dealing with problems spanning across three business interfaces.

5. The world of “traditional” supply chains

Before discussing the structure of agile supply chains, it is helpful to outline the behaviour of “traditional” chains. A particularly good description of the guessing game which typically distorts real-world PDP is given by Stalk and Hout [6]. A much abbreviated summary of the principles involved is as follows:

“In a very simple clothing chain (shown in schematic format in Fig. 3), the top level is a retailer, the second level is an apparel maker, the third is a fabric maker and the fourth is a yarn maker. The retailer places orders, say for blue jeans, to a blue jean maker, which in turn places orders to a denim fabric maker, which orders from a yarn maker with shipments going in the reverse order. All of these activities go on continuously, driven by the following forces: *demand in the market, inventory levels at each of the four tiers in the chain, and the rules governing production lot sizes that each player uses to run its business.*

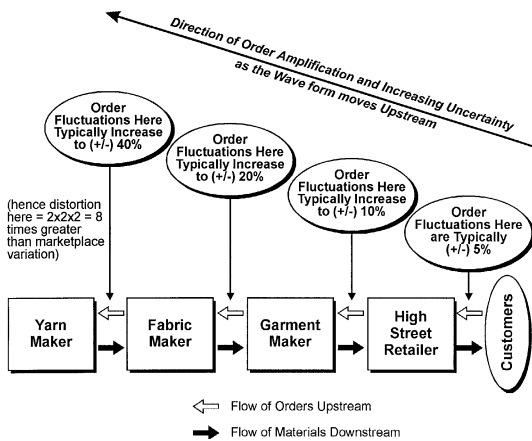


Fig. 3. Basic structure of a “traditional” clothing supply chain (based on a description by Stalk and Hout [6]).

Consumer demand at the marketplace obviously varies and cycles month-to-month, and the changes may be up or down 10–15%. But back in the supply chain, the changes in order get larger and larger as each supplier further upstream from the marketplace struggles in order to catch up from the last rippling of the demand curve. Weeks or months may pass between the first sign of a retail demand rise and the time an upstream supplier finally hears about it in the form of an order that is up, say 30–35% over the last order, and so on, and so on!”

As Stalk and Hout point out, in this scenario (which is typical of the “traditional” supply chain) the retailer has passed no information upstream to her suppliers about the rise in the market place sales for nearly three months. After this long delay she has sent a discontinuously large order which represented a mixture to satisfy the greater “real” demand and also to achieve replenishment of already depleted inventory. She may also have added further cover in the expectancy of yet further increases in the demand. But the jean maker, while he may well have read in the press that there is a general sales rise in jeans, does not know about this particular retail customer’s increased sales for nearly three months. So, when this very large and very late order arrives, he does not know how much of the order volume represents a

sales increase and how much represents a one-time inventory replenishment (separating out the order flow in the supply chain following the recommendations by Wikner et al. [21] would have made this distinction obvious). But in this case the unfortunate jean maker gets information that is both late, distorted, and difficult, if not impossible to interpret. In fact it is a good example of the usual boom-and-bust scenario in which poor deliveries to customers are coupled with excess capacity requirements!

6. Traditional supply chain which has failed to deliver

A good example of a major company that has fallen on hard times through poor supply chain design and operation has recently hit the headlines as reported in the business section of “The Times”. In the Autumn of 1997, the Chief Executive of the UK Fashion House, Laura Ashley plc, departed abruptly from that troubled company. This followed a period of poor trading performance and associated loss of confidence by the Stock Market. A consultant appointed to establish the root causes of this situation found the following problems:

- frequent stock-outs of fast-selling goods,
- gross overstocking of slow moving goods,
- absence of a tracking system to locate goods within the supply chain,
- absence of an accounting system to properly evaluate the true cost of goods.

But these are typical logistics problems which are important to solve in both Lean and Agile Supply Chains. Their existence within a supply chain pulled by what was a relatively successful Fashion House is surprising. The wonder is how Laura Ashley survived so long whilst clinging to such outmoded operating principles especially since there had been previous disturbing reports of supply chain problems involving that company [22]. This case is a timely reminder that although the best retailers are expert at designing supply chains, there is a “long tail” within the industry which requires extensive re-engineering. Hence the

relevance of the description of the “Blue Jeans” supply chain which detailed many of the underlying reasons for poor control and poor response [6]. In the case of Laura Ashley plc it is no surprise that the consultant performing the most recent diagnosis soon became a Senior Executive within the company.

The inherent dangers resulting from overstocking (rather than re-designing the supply chain to achieve the necessary agility) are also manifest. Uncertainty in demand is not, however, restricted to fashion goods. For example, in electronic goods supply chains, demand forecast errors over a three months planning horizon are in the region of $\pm 50\%$ [8]. So there has to be a better way of staying in such a business than operating a traditional supply chain. This is to achieve an agile response, which in the fashion trade is best exemplified by Benetton [1]. Half of Benetton’s sales are shipped by air to 7000 stores in 100 countries world-wide by air with an eight day order cycle. *The reasoning is that the cost of airfreight is not nearly as important as the savings in inventory plus the increased sales from having products in store when customers want them.*

7. The importance of the lead-time factor in the agile supply chain.

The essence of an agile supply chain is its ability to respond quickly and efficiently to a volatile marketplace. In order to satisfy consumer demand instantaneously one approach has been to build large stock points throughout the supply chain. However this policy is unsatisfactory when delivering to a volatile marketplace because it leads to a sluggish response. This makes the chain unable to respond quickly to the kind of changing demands so indicative of a fashion product resulting in both stock-outs and subsequent markdowns for the same items.

The key characteristic of an agile supply chain is the lead time each player has to wait between receiving a demand from his customer and delivery from his supplier. This lead-time dramatically affects the dynamic response characteristic of a supply chain. To illustrate this point Fig. 4 shows a retailer’s stock levels in response to a “shock” demand by the end consumer used to illustrate the effect of a fashion product surge in sales, so demand rises (by 100%) and drops off very quickly. The

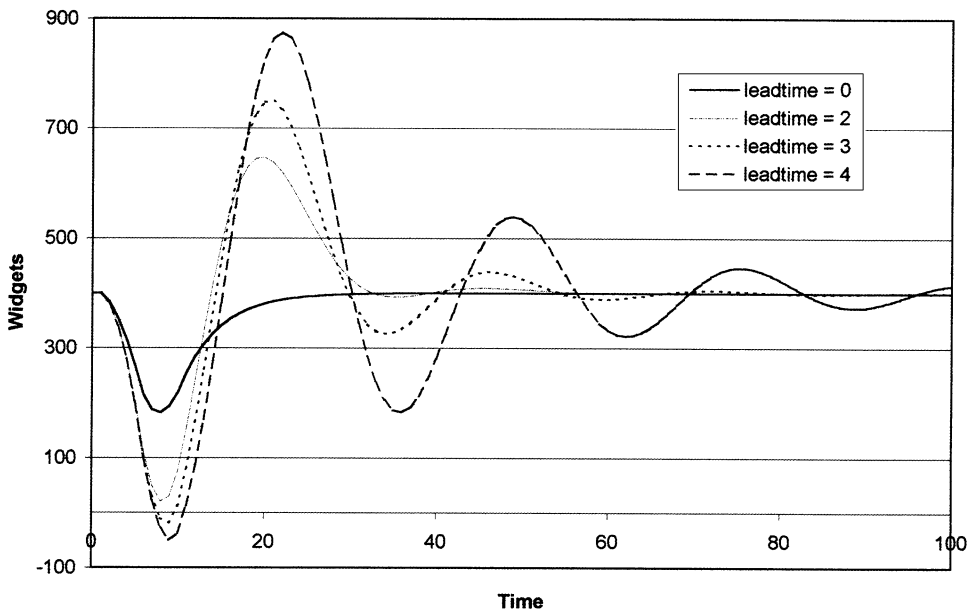


Fig. 4. Retailer stock levels for changing total cycle time.

retailer orders widgets from his supplier to ensure his stock levels are sufficient to continually meet consumer demand. Fig. 4 presents the retailers stock levels for changing time delay in delivery from his supplier. It is manifest that as the lead-time increases the stock response suffers larger and more sustained oscillations. Minimising lead-times not only enables the retailer to hold smaller stock levels but also aids stock control. The term lead-time is traditionally associated with production flow however in the supply chain it consists of two elements, hence the use of the phrase Total Cycle Time to illustrate the lead-time through the supply chain. To calculate TCT it is necessary to sum the material flow delay and the information flow delay. Thus in order to establish an agile framework both the material and information flows require analysis to establish the influence each has on the improved performance.

8. The “information enriched” supply chain

In proposing that agility can only be achieved within a supply chain by concentrating as much attention on information flow as is traditionally devoted to material flow, we are building substantially on the experiences of Stalk and Hout [6]. They specifically warn of the dangers of slow information lead-times, summing up the problems with information delays when they state “The underlying problem here is that once information ages, it loses value... old data causes amplifications, delay and overhead... The only way out of this disjointed supply system between companies is to compress information time so that the information circulating through the system is fresh and meaningful”. Overcoming these problems leads naturally to the concept of the “information enriched” supply chain [23], which contrasts with the “Traditional” supply chain previously observed.

Information flow does not have the same lead-time constraints as a production process and via IT it is possible to reduce the information transmission lead-time from one end of the chain to the other to zero. *The main constraint to enriching a supply chain with market sales data is the common attitude that information is power.* As a consequence of the tradi-

tional culture companies will often deliberately distort order information to mask their intent not only to competitors but even to their own suppliers and customers, unbelievable though this may seem [5]. In contrast, Ackere et al. [24] argue that managers can and should re-design their business processes to gain competitive advantage and must include improved information flow within their new business strategy. Market sales data is the catalyst information for the whole supply chain, holding undiluted data describing 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. Managers should therefore be challenging and questioning mechanisms within the pipeline structures which delay order transmission throughout the supply chain. In the automotive seat example discussed in Section 4 this was clearly achieved with considerable success in lead-time reduction.

Fig. 5 highlights the distinction between the “traditional” supply chain and the herein advocated “information enriched” supply chain in their approaches to information usage. In the traditional supply chain the retailer is the only player who has direct sight of the consumer demand, all other members only observe the orders from their immediate customer (i.e. the warehouse only has sight of the distributors orders). Therefore in the traditional mode the market information is distorted initially by the retailer and further distorted with each successive link in the chain. *However in the information enriched supply chain each player, no matter how far upstream, receives the marketplace data directly.*

The enrichment mechanism is an electronic point of sales link (EPOS). So rather than each player traditionally making an order decision based purely on the internal chain order data he can now make an informed judgement based on actual market demand as well. It is then but one step further to delegate the entirety of the replenishment process to the vendor, as is now done by such retailers as Wal-Mart. The suppliers are thereby directly contracted to keep shelves fully stocked rather than being contracted merely to deliver to site. This has a double benefit clearly demonstrable via systems

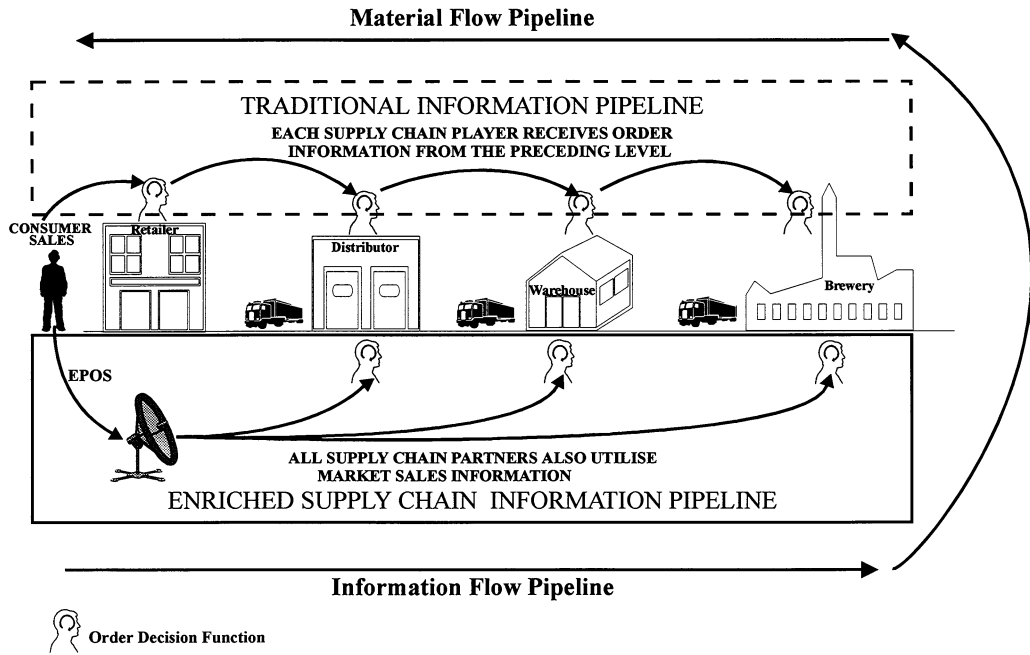


Fig. 5. Comparing traditional information flow with an information enriched supply chain.

dynamics simulations [21], since both a delay *and* a decision point are thus removed.

9. TCT and the agile supply chain

In order to fully appreciate the effect of both the material and information lead-time reduction on a retailer stock level a simulation was carried out. A two level chain is used to analyse the effects. Firstly the material lead-time is reduced by decreasing the production lead-time from 6 weeks to 4 weeks. (When analysing an improvement strategy it is the ratio of lead time reduction, rather than the absolute value, which matters.) Secondly the information lead-time is reduced via an enrichment mechanism that enables the retailers supplier to have access to the market demand and uses that knowledge to deliver products to the retailer. Finally to test the concept of the TCT both the material and information lead-times are reduced. Again a “shock” demand was utilised to mimic the kind of consumer behaviour change experienced by an agile supply chain.

To benchmark the improvements a traditional supply chain was included in the results in Table 5 which is basically a supply chain with no lead-time changes. For each benchmark the best and worst design were highlighted and were ranked accordingly as four stars (best) and one star (worst). The remaining designs were then ranked by reference to the best and worst designs observed during the simulation. This was achieved by calculating the incremental difference between each star rating and thereby designating the remaining designs, for each benchmark, by their appropriate rank. If the difference between the two designs is regarded as insignificant for practical purposes, then both designs are given the same rating.

From Table 5 it can be seen that whilst both the material flow and the information flow offer dynamic improvements to the retailer, the TCT approach offers the best overall performance judged against all the criteria. The simulation highlighted the main performance differences between optimised material flow and information flow. Reducing the material lead-time enables the retailer to bring down his overall stock level because of the

Table 5
Analysis of lead-time reductions

Stock dynamics	Supply chain approaches			
	Traditional	Material flow reduction	Information flow reduction	TCT
Max	*	***	**	****
Min	*	***	**	****
Amplitude	*	**	***	****
Settling time	*	**	***	****
Ranking	*	***	***	****

* = worst, **** = best.

reduced minimum stock level point needed to ensure he doesnot go out of stock. This is achievable because the suppliers are able to respond faster to changes in real demand. Hence the retailers do not have to hold such a large core stock to ensure customer satisfaction.

However through optimising the information lead-time the amplitude between the maximum and minimum stock levels is markedly reduced so the retailer has greater confidence in stock availability. Reducing the information delays in the supply chain additionally helpfully impacts the retailers settling time. These benefits are due to the fact that supplying upstream players with market data enables them to have an undistorted view of the demands being placed on the supply chain. Hence the classic delay and distortion factors inherent in a traditional supply chain are vastly reduced [23].

By implementing a TCT approach the retailer benefits from both the improvements available via material and information lead-time reductions. The agile supply chain must be able to respond fast but in a controlled manner to a volatile marketplace and therefore must be able to successfully manage an ever changing and relatively unpredictable demand. For an agile response the supply chain players must ensure their physical material processes are running at the optimum cycle times but information transference through the chain is equally important. Implementing an information strategy that allows all players to have access to the market sales data will enable all echelons within

a truly agile supply chain to respond almost instantly to a change in end consumer demand. Consequently players throughout the chain have every incentive to take the actions necessary to ensure consumer satisfaction.

10. Barriers to implementation

There is overwhelming evidence both from theory (such as the simulation example discussed in the previous section) and practice (such as the Wal-Mart supply chain) to suggest that information enrichment enables a powerful competitive edge. Despite this evidence there is still the attitude that “information is power”, leading to incomplete, or even distorted disclosure [5]. A reasonable halfway house is where suppliers have access to EPOS data, even though they still have to await official orders before initiating the delivery process [25]. Nevertheless in the real-world there is still a long way to go to universally implement the “information enriched” supply chain. For example Andraski [26] has stated that only about 7% of US retail supply chains operate effectively. He further argues that the main reason for this state is that supply chains are “20% technology problems, 80% people problems”.

In a separate A.T. Kearney/UMIST survey it is estimated that just (!) by improving supply performance via matching specific inventory policies to present-day best practice could save UK companies an estimated nine billion pounds per annum [27]. Yet the same report suggests that progress towards this goal remains painfully slow. This is despite the fact that individual businesses within the supply chain may well have been downsized, rightsized, and horizontally organised [28]. Table 6 illustrates the trade-offs to be expected when engineering supply chain performance improvements. The matrix is based on both simulation studies and experiential case studies in a range of industries.

Although the matrix is partly subjective, and confirms that nothing is gained without investment (of considerably management time as well as money), the improvement strategies vary considerably in the leverage exerted on supply chain

Table 6
Big picture supply chain performance improvement strategy [19]

Proposed improvement strategy		Improve “local” decision rules	Include “local” pipeline information	Remove internal echelons within business	Remove external echelons	Reduce all material flow leadtimes	Improve Supply Chain information flow
Consequential key attributes to achieve performance gain		Algorithmic	Logistical controls	Micro systems engineering	Business acquisition	Macro systems engineering	Supply chain partnerships
Likely implementation challenge	Technological	Low	High	Medium	Low	High	Medium
	Organisational	Low	Medium	High	High	Medium	Low
	Attitudinal	Low	Low	High	High	High	High
	Financial	Low	Low	Medium	High	High	Medium
Likely resulting benefit	To individual business	Low	Medium	Medium	High	High	High
	To the supply chain system	Low	Low	Low	High	High	High

performance. Reducing lead times via TCT compression is seen as a key lever. However, as we have already seen, in the agile supply chain we must improve information flow: it is not sufficient to concentrate on just the material flow. Note that the challenges to be overcome are the Technological – Organisational – Attitudinal – Financial factors present as the input drivers into the Customer Focused Business [9]. The latter clearly identifies the barriers that must be overcome in engineering the agile supply chain.

11. Enabling the agile supply chain

Stalk and Hout [6] suggested that supply chain “product champions” (usually, but not always Original Equipment Manufacturers (OEMs), or their equivalents) work with their suppliers simultaneously on the following three fronts:

1. They work to provide each company in the chain with better and more timely informa-

tion about orders, new products and special needs.

2. They help members of the chain, including themselves, to shorten work cycles by removing the obstacles to time compression that one company often unwittingly imposes on another.
3. They synchronise lead times and capacities among the levels or among tiers of the supply chain so that more work can flow in a co-ordinated fashion up and down the chain.

In establishing a suitable route map to enable agility we suggest the addition of the following six cognate actions to the product champions portfolio:

4. They select good Decision Support Systems (if process lead times are reliable and operations information of high quality, then good, robust control systems can also be simple).
5. They engineer the slashing of material flow and information flow lead times (reduction of these is within the technological and organisational remit of individual echelons).

6. They ensure the widespread provision and integrity of operations information (however, the quality and quantity of data available throughout the supply chain are a political issue).
7. They eliminate redundant echelons (this removes distortion and delay but can give rise to ownership/political problems) needing skilful resolution.
8. They ensure capacity is flexible enough to meet the true customer demand.
9. They act to reserve capacity not buy materials.

By implementing such a route map towards agility, it may then be possible in the retail fashion trade to achieve net margins three times higher than the present 5% [29]. To do this requires the lead time between the retailer buying decision and product availability on the store shelf to be slashed. Hence the best selling lines can be maximised and failures minimised, with option availability increasing from an average of 65% to the market leader benchmark of 90%. According to Gilchrist [29] such an agile supply chain has only four basic parts: create; make; move; and sell. The agile supply chain must remain simple; transparent information flow, synchronisation, and short lead times are the proven answer, and are an integral part of the recommended route map.

12. Conclusions

Agility in supply chains does not occur by a process of osmosis. It must be properly designed into the chain via good Business Systems Engineering principles aimed at eliminating eight clearly identifiable sources of waste. Two of these sources dominate the agile supply chain, namely Waste Total Cycle Time and Waste Information Flow. The paper has demonstrated the power of the TCT Compression Paradigm applied to individual businesses and complete chains. But agility is only enabled by adopting the “information enriched” supply chain in which both information and material flow lead times are slashed. The result is a structural supply chain which uses market knowledge and a virtual corporation to exploit profitable opportunities in a *volatile* marketplace.

Acknowledgements

Grateful thanks are extended to EPSRC who funded this research under Studentship Number 94315659 in association with the Ph.D. title “The Holistic Strategy of Market Information Enrichment Through the Supply Chain”. Thanks also to the support extended by the IMI Automotive Sector Research Programme.

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