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# Leagility: Integrating the lean and agile manufacturing paradigms in the total supply chain

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## Abstract

As the lean thinking and agile manufacturing paradigms have been developed there has been a tendency to view them in a progression and in isolation. This article shows that this is too simplistic a view. The use of either paradigm has to be combined with a total supply chain strategy particularly considering market knowledge and positioning of the decoupling point as agile manufacturing is best suited to satisfying a fluctuating demand and lean manufacturing requires a level schedule. This view is supported by consideration of a PC supply chain case study. © 1999 Elsevier Science B.V. All rights reserved.

*Keywords:* Agile manufacturing; Lean thinking; Supply chain management; Customer satisfaction; Time compression

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## 1. Introduction

Two current popular paradigms are lean thinking and agile manufacturing. As new paradigms are developed and promoted there is a tendency to view them in a progression and in isolation. Thus there is a view that first there was a need to adopt the lean manufacturing paradigm and now manufacturers should strive to become agile [1,2]. This article proposes that this is too simplistic a view and that the lean and agile paradigms, though distinctly different, can be and have been combined

within successfully designed and operated total supply chains. It will show how the need for agility and leanness depend upon the total supply chain strategy, particularly by considering market knowledge and positioning of the decoupling point. It will be shown that the agile manufacturing paradigm is best suited to satisfying a fluctuating demand (in terms of volume and variety) and lean manufacturing requires, and promotes, a level schedule. These key differences between the two paradigms relate them to the positioning of the decoupling point.

The need to combine the two paradigms in many real supply chains will be shown by discussing the differences between the two paradigms and when and where they should be adopted within the supply chain. A case study will be presented to

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demonstrate how agility and leanness have been combined successfully within one supply chain to meet customer requirements.

## 2. The paradigm definitions

Firstly, it is important to make some key definitions so as to ensure there is no ambiguity in further discussions. The following two definitions relate the agile and lean manufacturing paradigms to supply chain strategies. They have been developed by the authors so as to emphasise the distinguishing features of leanness and agility.

Agility means using market knowledge and a virtual corporation to exploit profitable opportunities in a *volatile* market place.

Leanness means developing a value stream to eliminate all waste, including time, and to ensure a *level* schedule.

These are both closely related to the total supply chain strategy and the positioning of the decoupling point. A supply chain is:

... a system whose constituent parts include material suppliers, production facilities, distribution services and customers linked together via a feed-forward flow of materials and feedback flow of information [3].

This should be expanded to include the flow of resources and cash through the supply chain [4].

The decoupling point separates the:

... part of the organisation [supply chain] oriented towards customer orders from the part of the organisation [supply chain] based on planning [5].

The decoupling point is also the point at which strategic stock is often held as a buffer between fluctuating customer orders and/or product variety and smooth production output. This fact is critical when considering when to adopt agile or lean manufacturing techniques. Associated with the positioning of the decoupling point is the cognate issue of postponement. The aim of postponement

is to increase the efficiency of the supply chain by moving product differentiation (at the decoupling point) closer to the end user. Postponing the decoupling point reduces the risk of being out of stock for long periods at the retailer and of holding too much stock of products that are not required. The well-known Benetton example demonstrates the use of postponement in the fashion trade [6]. Benetton delayed the dyeing of their jumpers, which is the point at which the jumpers are differentiated, until the end of the process. Postponement is also essential where products have, or are likely to have, a short life cycle as in the Benetton example or for PC manufacturers. In the Benetton case the uncertainty in demand predictions becomes critical and this uncertainty can be related directly to the prediction period as presented in Table 1 [7] which is forecast accuracy from a group of experts.

When businesses in a supply chain focus upon the end-user there are many metrics that can be considered. However, they may be aggregated as Service, Quality, Cost and Lead-time as presented in Fig. 1 [8]. This presents the total value of a product to the end-user.

Within a specific market sector the need for higher levels of service and quality or lower costs and shorter lead times will arise and the metrics will be gauged in different ways. This year's order winner will become next year's market qualifier [9]. One year a business might win more orders by providing improved service, the following year they will have to continue to provide this level of service to qualify for the market. These can be related to the agile and lean manufacturing paradigms to highlight some of their key features.

Table 1

Forecast accuracy from a group of experts in the electronics product industry [7]

Future prediction	Forecast accuracy
1 month	± 5%
2 months	± 20%
3 months	± 50%
Beyond	Toss a coin

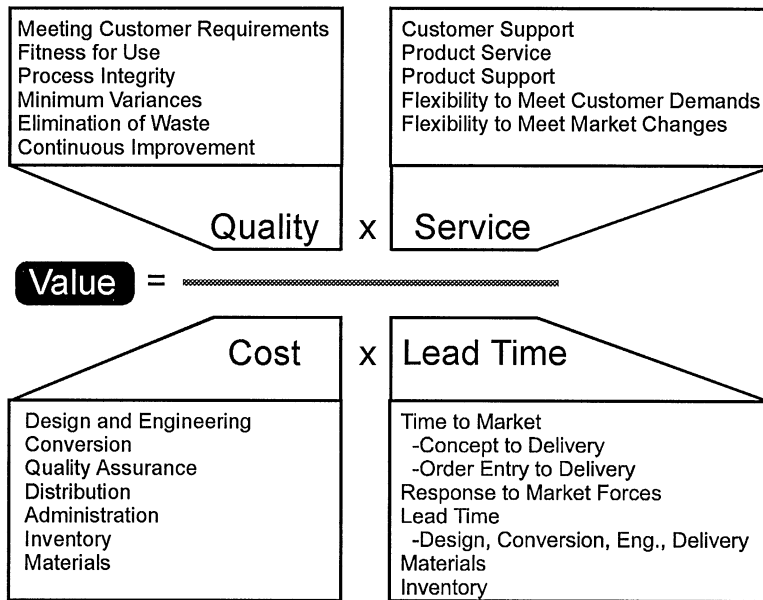


Fig. 1. Total value metric [8].

### 3. Which paradigm?

Table 2 presents some of the key characteristics of the agile and lean manufacturing paradigms as supply chain strategies. Table 2 is based upon literature regarding lean manufacturing, agile manufacturing and supply chain management and on industrial case studies. Highlighted are the prerequisite characteristics of the lean and agile paradigms. These can be regarded as essential, desirable and arbitrary for a given paradigm to be successfully implemented. The table can be broken down into the characteristics that are of the same, similar and different importance.

#### 3.1. Characteristics of equal importance

##### 3.1.1. Use of market knowledge

All businesses in any supply chain must focus on the end-user and both paradigms emphasise this point [10,11]. The nature of the end-user or market sector as a whole will have a direct impact upon which paradigm will be the most apt for any supply chain or part of a supply chain. This will become clear later in this article. If market knowledge is not

Table 2

Rating the importance of different characteristics of leanness and agility

Keyword	Lean	Agile
Use of market knowledge	○ ○ ○	○ ○ ○
Virtual corporation/Value stream/Integrated supply chain	○ ○ ○	○ ○ ○
Lead time compression	○ ○ ○	○ ○ ○
Eliminate muda	○ ○ ○	○ ○
Rapid reconfiguration	○ ○	○ ○ ○
Robustness	○	○ ○ ○
Smooth demand/Level scheduling	○ ○ ○	○

Note: ○ ○ ○ = essential. ○ ○ = desirable. ○ = arbitrary.

exploited and the supply chain is to be made more responsive then the members of the supply chain run the risk of, for example, producing too wide a variety of products at short notice when there is insufficient demand to justify the extra cost [12].

##### 3.1.2. Integrated supply chain/value stream/virtual corporation

All of these terms essentially mean the same thing [10,13]. Businesses must work together to form an

integrated supply chain focusing on meeting the demands of the end-user or final customer of the supply chain no matter what paradigm is adopted [14]. Although the terminology differs the essence is the same. The goal of an integrated supply chain is to remove all boundaries to ease the flow of material, cash, resources and information. Fig. 2 presents the progressive steps involved in moving from a supply chain constructed from functional silos to one that is fully integrated [3]. With the integrated supply chain both the information and material flows will be simplified, streamlined and optimised reducing waste and lead times. The structure of the supply chain will vary as shall be discussed in Section 4.

### 3.1.3. Lead time compression

In recent times lead time compression has become a major order winner [15]. Leanness calls for the elimination of all waste or in lean terminology “muda” [11]. This means the elimination of any-

thing that is not adding value to a process or service. By definition this includes waste time. Therefore, time compression is essential for lean manufacturing. Likewise agile manufacturing requires a responsive supply chain [10]. This also calls for lead time compression in terms of information flow as well as material flow [16].

The three characteristics listed above are the foundations for both agile and lean manufacturing, without which it will not be possible to develop either paradigm any further.

## 3.2. Characteristics of similar importance

### 3.2.1. Eliminate muda

Lean manufacturing is called lean as it uses less, or the minimum, of everything required to produce a product or perform a service [17]. Leanness achieves this by eliminating all non-value adding processes [11]. In a “pure” lean supply chain there

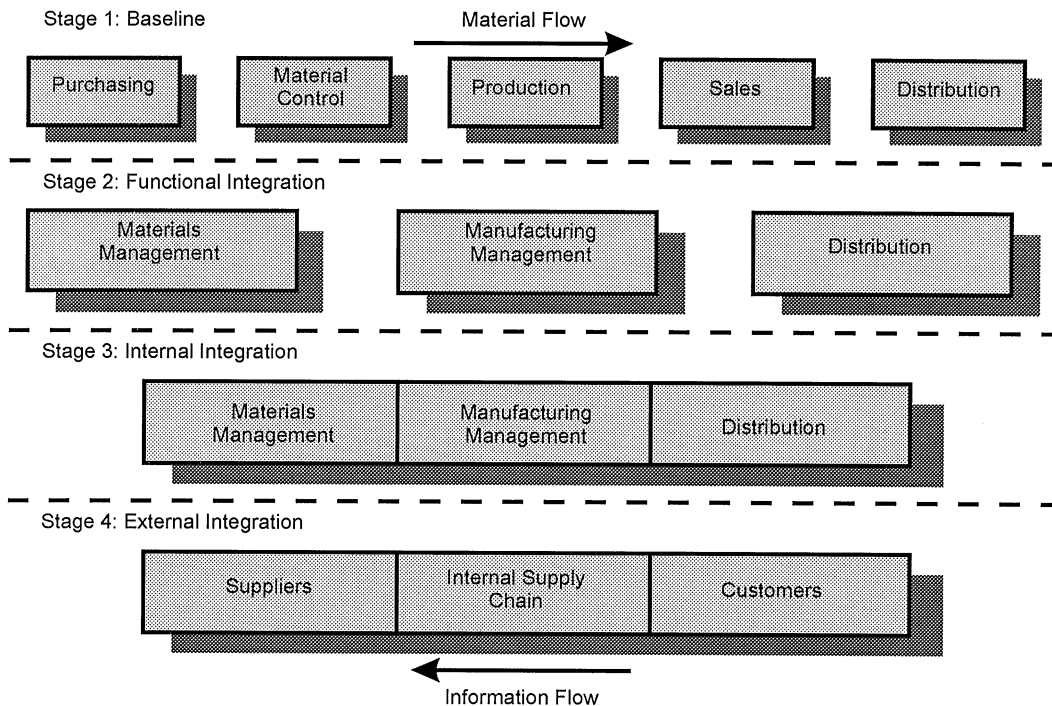


Fig. 2. Supply chain integration [3].

would be no slack and zero inventory. It would be very impressive if zero inventory throughout a total supply chain was achieved. A more realistic view would be to aim at a minimum reasonable inventory (MRI) where any further attempts to decrease stocks would not be worthwhile [18]. The appropriate MRI level may be found by using market knowledge. Quite clearly the agile manufacturer would also aim to eliminate as many non-value adding activities as possible. However, in an agile system there will have to be a careful consideration of stock and/or capacity requirements to ensure the supply chain is robust to changes in the end users' requirements. Thus the MRI may be set at a higher level than for a lean supply chain and additional activities might also be required to provide the ability to be flexible. In other words the definition of what is a value adding process will be expanded to include processes that are fundamentally non-value adding but necessary [19]. The use of an integrated supply chain is essential if elimination of waste is to be achieved [14]. The elimination of all non-value adding processes will inevitably reduce the cost of the product. This indicates that cost (referring to Fig. 1) is the way in which a supply chain employing lean manufacturing differentiates its product from one employing agility.

### 3.2.2. Rapid reconfiguration

Agile manufacturing means that the production process must be able to respond quickly to changes in information from the market [20]. This requires lead time compression in terms of flow of information and material, as indicated in Section 3.1, and the ability, at short notice, to change to a wide variety of products [10]. Therefore, the ability to “rapidly reconfigure” the production process is essential. In lean manufacturing the ability to change products quickly is also key as any time wasted in changing over to a new product is muda and therefore should be eliminated. However there must be a certain amount of leeway with respect to the production schedule and the forewarning of product changes in order to eliminate muda [21]. Thus whilst it is highly desirable to have rapid reconfiguration it is not as essential as with agile manufacturing. The ability to reconfigure quickly would have an impact upon the ability to be flexible to

meet changes in the market, which, referring to Fig. 1 again, is a component of service. These leads to the conclusion that agility focuses on service levels for product differentiation.

To summarise these two characteristics agile manufacturing calls for a high level of rapid reconfiguration and will eliminate as much waste as possible but does not emphasise the elimination of all waste as a prerequisite. Lean manufacturing states that all non-value adding activities, or muda, must be eliminated. The supply chain will be as flexible as possible but flexibility is not a prerequisite to be lean. Table 3 presents how this relates to the value metric presented in Fig. 1.

From Table 3 it can be seen that the best situation would be a supply chain that could use both of these paradigms. The final set of characteristics further differentiates the two paradigms and they will show how agility and leanness cannot be employed at the same point in any supply chain. However, by considering these last two characteristics in combination with the decoupling point and the notion of postponement the two paradigms can be combined within a supply chain as shown in the next section.

### 3.3. Characteristics of different importance

#### 3.3.1. Robustness

An agile manufacturer must be able to withstand variations and disturbances and indeed must be in a position to take advantage of these fluctuations to maximise their profits. If a manufacturer needs to be as responsive as a truly agile manufacturer must be then it is inevitable that the demand for the

Table 3  
Rating the importance of the different metrics for leanness and agility

Metric	Agile	Lean
Lead time	○ ○ ○	○ ○ ○
Service	○ ○ ○	○ ○
Costs	○ ○	○ ○ ○
Quality	○ ○ ○	○ ○ ○

Note: ○ ○ ○ = key metric. ○ ○ = secondary metric. ○ = arbitrary metric.

product will not be stable. This is in direct contradiction with the next characteristic of a supply chain.

### 3.3.2. Smooth demand/level scheduling

Lean manufacturing avoids the requirement for robustness by calling for the demand to be stable through the use of market knowledge and information, and forward planning [21]. Lean manufacturing by its very nature tends to reduce demand variation by simplifying, optimising and streamlining the supply chain [4]. However, if the end-user demand is beyond the control of the supply chain it will not be possible to implement lean manufacturing at the interface with the end-user [21]. Sudden variations in demand would lead to waste either in not producing near capacity or needing to keep larger buffer stocks as has recently occurred at Boeing [22]. Boeing pursued a lean manufacturing strategy without taking into account the variability of demand in the aerospace industry. Boeing has been able to cope with a doubling of production but this still falls far short of the market demand. Boeing's sole competitor, Airbus Industrie, has been able to exploit this and ramped up successfully to take a larger share of the market.

The paradigm that is pursued at any point in the supply chain will depend upon the requirements of the customer. Here the customer is taken to be the next direct receiver of the material in the supply chain as opposed to the ultimate end-user. The different application of agility and leanness with reference to these last two characteristics is summarised in Fig. 3.

The darker areas on Fig. 3 tend towards leanness and the lighter areas to agility. The dominant factor is whether there is a demand for variability in the production rate. If there are a wide variety of products an agile supply chain will be able to switch between the products easily. If there is a wide range of products then the demand will tend to become more variable at a disaggregate level.

## 4. The supply chain structure and the decoupling point

This section discusses the relationship between the supply chain structure and when and where to

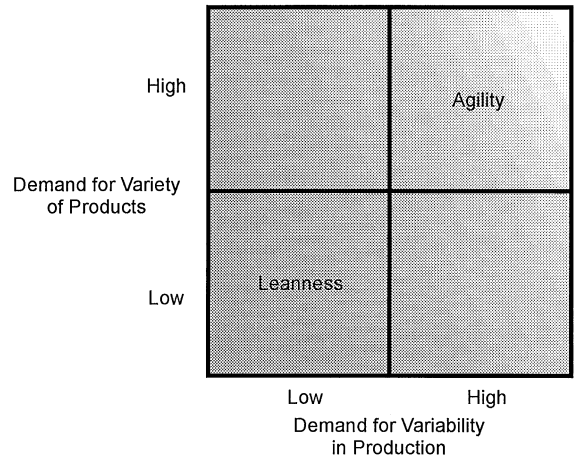


Fig. 3. Applications of leanness and agility.

adopt lean or agile manufacturing. Firstly, some simplified structures will be presented with the decoupling point in different positions along the supply chain. This will then be linked to the explanation of the two paradigms given in the previous section.

Fig. 4 presents the family of simplified supply chain structures with the decoupling point marked as a stock holding point [5,23]. The manufacturers/assemblers represent one or more members or businesses in the supply chain. There would be another stock point downstream, in terms of material flow, from the raw material supplier where the process changes from batch process to single piece flow. As this transition occurs inventory must be held to ensure the supplier does not go out of stock.

As outlined in the Section 1 the decoupling point separates the part of the supply chain that responds directly to the customer from the part of the supply chain that uses forward planning and a strategic stock to buffer against the variability in the demand of the supply chain. The positioning of the decoupling point therefore depends upon the longest lead time an end-user is prepared to tolerate and the point at which variability in product demand dominates [5,24]. Downstream from the decoupling point all products are pulled by the end-user, that is, they are market driven.

Upstream from the decoupling point the supply chain is initially forecast driven. However, with the

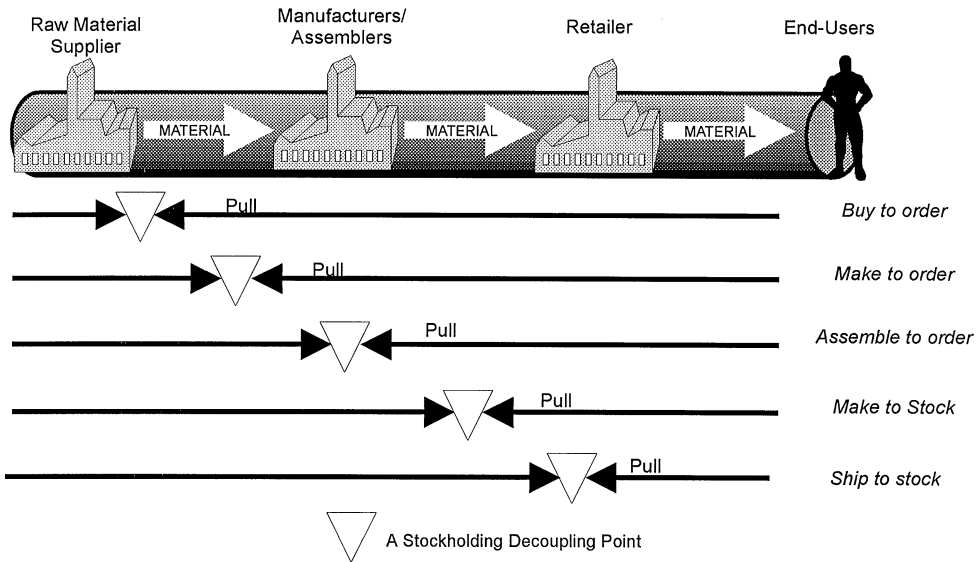


Fig. 4. Supply chain strategies [5].

advent of Kanban driven supply this has become more than simply a push system. For example in one electronics firm the forecast is calculated yearly at the strategic level, monthly at the production level but the final production schedule is calculated weekly based upon the Kanban. In other words the process is push plan and pull execution [25]. This could only take place if the demand is stable and predictable, for instance upstream, in terms of material flow, from the decoupling point.

By varying the position of the decoupling point Fig. 4 highlights five distinguishing classes of supply chains:

- The first supply chain, Buy-to-Order, would be suitable if all the products are unique and do not necessarily contain the same raw materials, where the end-user is prepared to accept long lead times and the demand for products is highly variable. If the supply chain held any stock it would run the risk of them becoming obsolete. If a particular product did not succeed in the market place then this supply chain would not have any exposure to the costs of overstocking. However the supply chain would not be able to take advantage of new markets as quickly as the next supply chain classification.
- The second supply chain, Make-to-Order, is able to change to different products as long as they are made from the same raw materials. It will also cope with varied locations, volumes and product mixes. The lead time will be reduced but the end-users might still have to accept a considerable wait to get the product they desire. The demand for the product can be variable and with a high level of customisation both in terms of numbers of different combinations and the amount of the basic model that will need to be customised. This supply chain is only exposed to the risk of holding raw materials and components as stock.
- In the third supply chain structure the decoupling point moves to within the manufacturers and assemblers in the supply chain. With an Assemble-to-Order supply chain customisation is postponed until as late as possible. With this strategy the supply chain will be able to respond to a varied product mix from within a range of products, whether customised or not. The lead time will be reduced considerably and will depend upon where in the supply chain the final assembly takes place. This slightly increases the risk of overstock or understock but the products will not be of the same value as the complete,

fully assembled product. Thus the supply chain is protected against the full risk of obsolescence. Conversely the supply chain will be in a better position to take advantage of a product ascending the growth stage of its lifecycle. The supply chain will still be able to cope with varied locations

- The final two supply chains both represent cases where a standard product is provided from a defined range. The Make-to-Stock strategy means that the supply chain can cope with demands in varied locations but calls for a steady overall demand of a standard product. The Ship-to-Stock strategy provides a standard product in fixed locations. The members of the supply chain must be able to forecast demand accurately if they adopt these two strategies. It is critical that they are aware how accurate their forecasts are and hold the correct level of stock to minimise the risk of stock-outs and overstocks [26].

The effect of the decoupling point is summarised in Fig. 5. This shows a decoupling point with the level product variety and demand variability experienced either side of the decoupling point. On the downstream side of the decoupling point is a highly variable demand with a large variety of products and upstream from the decoupling the demand is smoothed with the variety reduced. This indicates that the point of product differentiation is at or downstream from the decoupling point and the stock held at the decoupling point acting as a buffer between variable demand and a level production schedule.

Fig. 5 relates the decoupling point directly to characteristics of the lean and agile paradigms and to Fig. 3.

- The lean paradigm can be applied to the supply chain upstream of the decoupling point as the demand is smooth and standard products flow through a number of value streams. Downstream from the decoupling point a number of products flow through one value stream.
- The agile paradigm must be applied downstream from the decoupling point as demand is variable and the product variety per value stream has increased.

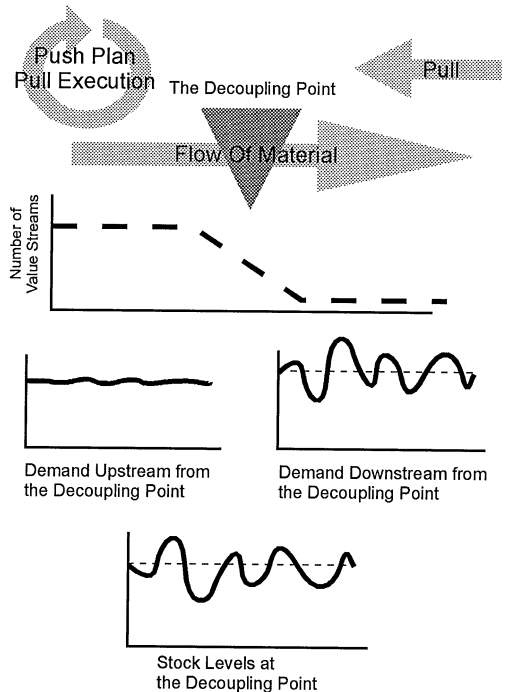


Fig. 5. Effects of the decoupling point.

Hewlett Packard redesigned their supply chain to overcome the problem of variability in demand by pursuing the technique of applying agility downstream from the decoupling point [27,28]. They achieved this by postponing the decoupling point until as late as possible and ensuring that product differentiation also occurred at that point. The US factory produced printers for the global market to an aggregate demand. However the generic printers would then have to be customised to meet national specifications and shipped to the regional distribution centres. This was a particular problem in Europe with small national markets. In the original supply chain the stockholding point would be at the distribution centres with the market specific products. Therefore, even if the aggregate forecast was accurate if the national forecasts were not then one country would find itself out of stock and another would be overstocked. The solution to this was to move differentiation to the distribution centres. In other words the generic products were sent out to the distribution centres where they were

held as the buffer stock and then differentiated for each national market as they were pulled by the end user demand. This meant that the production of the generic printers could be based on an aggregate global forecast that would be more accurate than national market forecasts. The increase in service levels compensated for the fact that the new supply chain was more expensive. The supply chain went from basically a whole lean supply chain to one that incorporated agility downstream from the decoupling point.

**5. Reengineering of a PC supply chain [25]**

Electronic product supply chains are characterised by poor supply chain dynamics with a highly variable product demand. The PC manufacturer (or the company) in this case study is involved in a wide range of large and complex supply chains. The supply chains consist of both company owned members and independent members, though the company is highly vertically integrated with plants in three of the main manufacturing echelons. Generally the operation of any member is limited to one echelon. Fig. 6 presents the sources of information used [29]. Opinion sources and publications were both particularly rich sources of information in this particular dimension, as indicated by the usage rating of three.

Since the early 1980s the company has implemented a series of supply chain reengineering strategies. Prior to reengineering the supply chain consisted of a large number of interacting but un-integrated members. The first step was to implement just in time (JIT) in the early 1980s. The primary focus of this strategy was to reduce in-plant lead times through the elimination of waste. This reduced the average manufacturing lead time from 280 to 150 days.

Next the company developed a simplified and integrated approach to materials planning. This required a change of perspective from materials planning at individual plant level, which had led to delays and demand amplification, to materials planning at the supply chain level. For the purposes of materials planning all manufacturing plants were now considered as production lines in a global

Information Sources		Usage for this modelling		
		Low → High		
		1	2	3
opinion	interviews			●
	brainstorming			●
	cross-functional groups			●
archival	accounts	●		
	procedures		●	
	minutes	●		
	publications			●
analytical	model matching			●
	statistical analysis	●		
	time series analysis	●		
empirical	questionnaires	●		
	process flow charting		●	
	activity sampling	●		

Fig. 6. Summary of information sources used in the modelling of the PC supply chain [29].

manufacturing entity. All requirements were transmitted simultaneously to the companies’ plants using electronic data interchange (EDI). The time delay for the flow of demand information has been reduced from 45 to 8 days. This meant that more of the supply chain operated in a pull mode and most of the rest of the members were push plan and pull execution as described in Section 4. The next strategy was to integrate the vendor base. This entailed connecting the vendor base directly to the rest of the supply chain via EDI primarily to pass down planning information and pull signals.

Fig. 7 presents the 1993 snap shot of the European supply chain with the members divided into echelons. The company is a highly complex global manufacturer and it is presented here with the European base and global and local suppliers [30]. It should be noted that the reengineering is a continuous process and therefore this is not the final supply chain.

In order to manage the material flow, the PC manufacturer positioned the decoupling point at the finished goods echelon. This supply chain

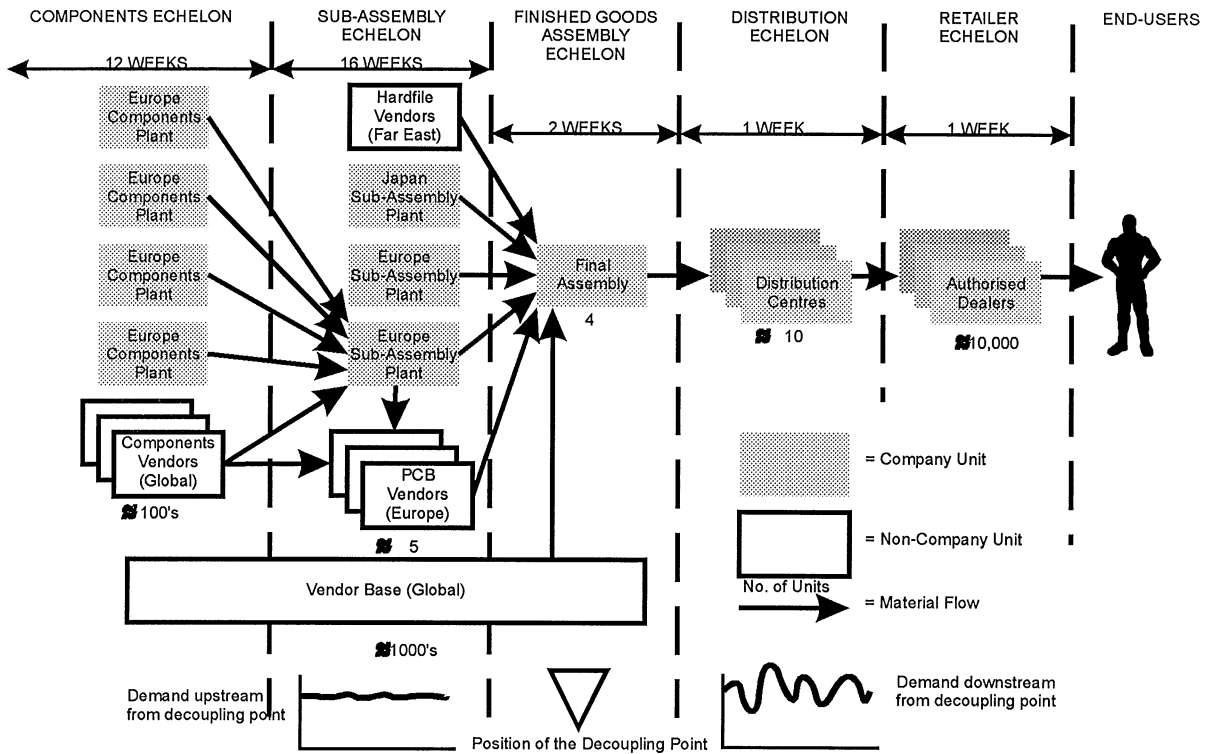


Fig. 7. Material flow through the PC supply chain [25].

follows the assemble to order supply chain strategy shown in Fig. 4. The main restraint on the location of the decoupling point was the lead time the end-user, PC purchaser, was prepared to accept. If the decoupling point was in the sub assembly echelon the end user would have to wait up to 22 weeks for an assembly to order. In the current position the lead time is 4 weeks. Another one of the main drivers for reengineering the supply chain was the ever-decreasing product life cycle. Referring to Table 1, the company would have serious problems with forecast accuracy if the decoupling point was at the sub-assembly echelon but the required total lead time was 4 weeks. This would call for a prediction of over 4 months (22 weeks less 4 weeks) and therefore the company may as well “toss a coin” [7]. It should be noted that the retailers and distributors hold some stock of standard models.

The decoupling point also operates in a similar way to the Hewlett Packard case and as presented

in Fig. 5. The variation in demand either side of the decoupling point demonstrates how the buffer stock can act to smooth the demand on the sub-assembly and components echelons. The product differentiation coincides with the decoupling point to a large extent. This allows the supply chain to assemble to order for a variety of products, volumes of products and retailer locations.

The supply chain on the upstream side of the decoupling point thus adopted the lean manufacturing paradigm with level scheduling and a Kanban system. The supply chain downstream from the decoupling point has to adopt the agile manufacturing paradigm due to demands for short lead times, product variety and demand variability from the end-users. Again this fits into the definition of the agile and lean paradigms with leanness applied upstream from the decoupling point and agility downstream from the decoupling point.

## 6. Conclusions

This paper has compared the lean and agile manufacturing paradigms, highlighting the similarities and differences. Through considering the differences between the two paradigms we have shown that they should not be considered in a progression or in isolation. Neither paradigm is better nor worse than the other, indeed they are complementary within the correct supply chain strategy. Both the Hewlett Packard case and the PC manufacturer case study clearly demonstrate the combination of the two paradigms within the same supply chain. The decoupling point acts as a buffer between the variable demand for a wide variety of products and the level production schedule for a smaller variety of components. The danger of not being agile enough to exploit change in the market demand is clearly demonstrated by the Boeing case. These cases also demonstrate the need for accurate and quick market information and hence information lead time compression as well as material lead time compression [16].

Once the need for agility and the position of the decoupling point has been identified there are further decisions to be made. The way in which an agile manufacturer differentiates its products from the lean manufacturer is through concentrating on the service levels at the expense of reducing costs. The full impact of this requires further investigation but the Hewlett Packard example shows how employing agility downstream of the decoupling point can be of great benefit to all the members of the supply chain.

This paper has shown that manufacturers should not be looking at operations in isolation from the rest of the supply chain. Whether to develop an agile capability or a lean manufacturing structure will be dependent upon where in the supply chain the members are located. This total supply chain perspective is essential and companies should be striving for “leagility” – that is carefully combining both lean and agile paradigms.

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