DESIGNING AND MANAGING MULTIPLE SUPPLY CHAINS

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Designing and Managing Multiple Supply Chains

Abstract

In this paper a perspective is taken which treats traditional supply chains and mass customisation as opposite ends of the delivery spectrum. This leads logically to a response to the emerging requirement that "One Size Does Not Fit All" by selecting, engineering, and operating multiple pipelines tailored to the needs of the marketplace. This in turn suggests a "postponement matrix" as a tool for pipeline design based on the appropriate combination of lean and agile processes. Our arguments are illustrated by reference to a case study in which the pipelines are chosen according to life cycle phase and the relevant importance of Order Winners/Market Qualifiers. Substantial bottom-line benefits are shown to accrue from this approach. Finally, embedding the case study results into the postponement literature enables a family of seven generic pipelines to be identified.

Designing and Managing Multiple Supply Chains

The general tendency in the past has been for organisations to take a ‘supply-centric’ view of supply chain design rather than a ‘customer-centric’ perspective. In other words supply chain decisions have traditionally been taken with the objective of maximising the supplying company’s efficiencies with the aim of providing an acceptable level of service at least cost. In today’s marketplace this approach is becoming less viable as customers move into the driving seat with increasing demands for a tailored logistic response (Fuller et.al., 1993).

To be successful in the challenging markets of the 21st Century, organisations need to develop the capabilities to achieve a much higher level of customised response to the different needs of different customers. Indeed it seems that to be successful in these markets companies will need not just one supply chain solution but many. The implications of this transformation are significant : designing and managing multiple supply chains will become a necessary competence in the search for competitive advantage.

This paper builds on the earlier work of Hill (1993) who emphasised the importance of recognising the Order Winners/ Market Qualifiers (OW/MQ) in specific markets in order that appropriate operations strategies can be defined. Our proposal is that once the Order Winners and Market Qualifiers are clearly understood, then appropriate supply chain solutions can be designed and implemented. It is also apparent that Order Winners and Market Qualifiers are dynamic. In other words they will change over time and hence what constitutes an appropriate supply chain strategy will also need to be revised over time (Christopher & Towill, 2000 [b]).

To support this viewpoint a case study of a real world lighting company (LightCo) is presented. The company required four pipelines to adequately service its supply chain as it developed over a four year time period. Both lean and agile operations were required in order to optimise customer service. The pipelines utilised varied according to the phase of the product life cycle so that items were switched and re-routed as their demand category changed.

For designing and implementing such a multiplicity of pipelines, a product classification schema is proposed analogous to the system proposed by Christopher and Towill (2000[b]), and provides the clustering information on which engineering judgements may be made. As Fuller et al (1993) state, some product consolidation is usually required; the classification system helps pinpoint where this is possible.

An important output from the present paper is the posited generic family of delivery pipeline strategies. The seven discrete pipelines are termed pure standardisation; compressed life cycle; compressed time-to-market; mass customisation via assembly; logistics postponement; mass customisation via processing; and pure customisation. This output results from an analysis and synthesis of the pipelines and delivery strategies proposed by Lampel and Mintzberg (1996), Pagh and Cooper (1998), Shewchuck (1998), and Childerhouse et al (2002). It is suggested that identifying this generic family of delivery pipelines greatly eases technology transfer and establishing “best practice” because it becomes much clearer how pipeline performance may be measured and compared in a meaningful way. Additionally, but recognising differences between pipelines, new and more effective costing systems may be introduced, thus avoiding undesirable cost-averaging when fixing prices charged to individual customers (Fuller et al, 1993).

The Impact of "Order Winners" and "Market Qualifiers"

Much though business managers argue that a supply chain must perform "best" across ***all*** of a set of performance metrics, the seminal work of Hill (1993) may be used to convincingly demonstrate otherwise. He sought to establish that whilst there will be a number of criteria which are considered to be important, nevertheless there is always a "first amongst equals". To make this fundamental distinction the order winner/market qualifier terminology was developed. "Market Qualifiers" are defined as those criteria which must be met in order for the customer to seriously consider buying a particular product. In other words, without the market qualifier (MQ) target being met, the product is not in contention. So there is no point in being outstanding at meeting one requirement if the product falls down on others considered important by the end customer.

Take in Figure 1 "Order Winners/Market Qualifier Matrix about here

The "Order Winner" (OW) is the criterion which will cause the end customer to buy that specific product. This concept has been further extended by Johansson et al (1993). They argue that the field for selecting order winner/market qualifiers must be small to be meaningful and can be as few as four (price; quality; lead time and service level), also that the many production factors which influence these order winners/market qualifiers are reasonably easily identified. This permits ready focus and hence control so as to gain competitiveness. Figure 1 shows how the MQ's and OW's may be helpful in determining the appropriate supply chain focus.

In Figure 1, we characterise 'Supply Chain Focus' as either 'lean' or 'agile'. Whilst these concepts are not necessarily mutually exclusive, they are different. Agility is a business-wide capability that embraces organisational structures, information systems, logistics processes and, in particular, mindsets. A key characteristic of an agile organisation is flexibility. Indeed the origins of agility as a business concept lie in flexible manufacturing systems (FMS). Initially it was thought that the route to manufacturing flexibility was through automation in order to enable rapid change. Later it was realised that reducing set-up times, i.e. the Single-Minute-Exchange of Dies (SMED) programmes provided a better way forward. This resulted in a greater responsiveness to changes in product mix or volume. The concept of manufacturing flexibility was extended into the wider business context (Nagel and Dove, 1991) and the concept of agility as an organisational orientation was born. It is our view that agility is a key requirement in delivering mass-customisation.

Whilst leanness may be an element of agility in certain circumstances, by itself it will not enable the organisation to meet the precise needs of the customer more rapidly. Webster's Dictionary makes the distinction clearly when it defines lean as "containing little fat" whereas agile is defined as "nimble". We need an interpretation of these definitions which translates into the supply chain scenario. A convenient interpretation of both paradigms is provided by Naylor et al (1999) as follows:

> ***"Agility** means using market knowledge and a virtual corporation to exploit profitable opportunities in a **volatile** marketplace."*
> *"**Leanness** means developing a value stream to eliminate all waste, including time, and to enable a **level schedule**."*

In this paper we are concerned with emphasising the role of both "Lean" and "Agile" processes in enabling customised pipelines. The particular value stream configuration in which lean processes are further upstream and are then followed by downstream agile processes has been termed "leagile" (Naylor, et al, 1999). So by having some upstream lean processes we help target cost as a market qualifier whilst simultaneously exploiting agility to enable the order winners of availability (off-the-shelf) and lead-time respectively to be delivered. Adopting the Leagile Paradigm fits well alongside the seminal idea of postponement, advocated amongst others by Bowersox and Closs (1996) and Feitzinger and Lee (1997).

The Supply Chain Migratory Model

An important idea arising from the work of Johansson et al (1993) is that the properties of order winners/market qualifiers are cyclical in nature. Hence this year's winner regresses to next year's qualifier as the opposition play "catch-up". This is demonstrated in the Supply Chain Migratory Model proposed by Christopher and Towill (2000[b]) and summarised in Table 1. As suggested by Schonberger (1996) "annual stock turns" has been added to this Table as an important business performance metric. This measures the risk to the business of excessive and usually expensive inventory becoming obsolescent, a key factor in supplying short life cycle products, an issue of increasing importance in present day value streams. The model shows that in the early 1980's the order winner was quality, which for Western industry was needed to combat Japanese imports, and was achieved within the lean internal process scenario. This was followed by the implementation of the lean supply chain impacting on cost, but still 'pushing' products into the marketplace in the sense of not responding to specific needs.

Then came the era enabled by correct positioning of the material flow de-coupling point in the particular hybrid lean-agile supply chain termed "leagile" by Naylor et al (1999). This chain is agile enough to respond to what is actually selling with availability as order winner. Finally, as instanced by present-day Dell Computers (Dell and Freedman, 1999) we have the customised leagile supply chain. Thus by further streamlining the supply chain front end, Dell aim to supply exactly what the individual customer selects. Lead time is now the order winner with a maximum of seven days allowed for pulling off the requisite sub-assemblies, finalising the PC, adding the exact peripherals, packaging, and delivery to the individual customer.

Table 1 Migratory Model Summarising the Transition from Lean Functional Silos to Customised Leagile Supply Chain, about here

Our evolutionary model of supply chain migration can be interpreted as the move from traditional (product driven) through lean (volume driven) via leagile (market driven) to customised leagile (individual customer driven) operation. These stages in supply chain evolution are best visualised by understanding how goods arrive at the marketplace. "Product driven" means, "sell what we are able to make", whereas "volume driven" means "maximise market share". In this sense "Leagile" is responsive to true market demand, but only from a finite catalogue of standard products. Because in this mode of operation availability is the order winner, fast-selling goods need to be manufactured and supplied quickly to replenish retailer's shelves. Furthermore, a supply chain usually maximises profitability by managing a bundle of value streams. Each is matched to a particular and very demanding marketplace need. So it is possible, as we shall demonstrate, to encounter lean, agile, and leagile value streams forming independent pipelines within a given supply chain (Childerhouse et al, 2002). Naturally the "order winners" will vary according to the particular pipeline utilised for that product.

The Availability Fulcrum

At its simplest the purpose of any supply chain is to balance supply and demand. Traditionally this has been achieved through forecasting ahead of demand and creating inventory against that forecast. Alternatively additional capacity might be maintained to cope if demand turned out to be greater than forecast. Either way in an ideal world demand is balanced with supply. Figure 2(a) shows a typical balanced supply chain. Now imagine that by some means or other, yet to be discussed, the fulcrum is moved closer to the demand box as in Figure 2(b). Obviously the same amount of demand can now be balanced with less inventory and/or less capacity. Clearly for many business scenarios this will be highly advantageous, but it manifestly requires both product and value stream to be appropriately engineered to achieve this objective.

What does the fulcrum actually represent in a supply chain? The fulcrum is the point at which we commit to source/produce/ship the product in its final form and where decisions on volume and mix are made. The idea here is that if that point of commitment can be delayed as long as possible then the closer we are to make-to-order i.e. mass customisation, with all the consequential benefits this brings. In practice the problem for many companies is that the fulcrum in their supply chains is more like that shown in Figure 2(c). Here the fulcrum is a long way from demand i.e. the forecasting horizon is long, necessitating more inventory and capacity to balance against demand. So it is clear that responding to the volatility of present-day customer demand requires the availability fulcrum to be located closer to demand.

Figure 2. The Availability Fulcrum about here

How in reality do we achieve this goal? The answer is to improve *visibility* of demand along with enhancing the *velocity* of the supply chain. In other words if we can have a clearer view of real demand in the final marketplace, rather than the distorted picture which more typically is the case, and if we can respond more rapidly then a more effective matching of supply and demand can be achieved. Thus it can be argued that visibility and velocity are the foundations for a customised supply chain. A related idea is that of the 'information de-coupling point' (Mason Jones & Towill (1999)). Effectively this notion suggests that the further upstream information on real demand can flow then the more responsive the supply chain as a whole becomes.

The Role of Postponement

The concept of 'postponement' is well established in logistics and supply chain management. Postponement can be physical, spatial or temporal (Christopher, 1998).

In other words, we can delay the final configuration, assembly or packaging of the product (physical postponement); the geographical dispersal of the product (spatial postponement) or the time at which we commit to a decision (temporal postponement).

Figure 3 depicts the postponement matrix proposed by Pagh and Cooper (1998). This differentiates between the postponement of manufacturing and the postponement of logistics activities as different options in the movement of the availability fulcrum of Figure 2 towards the point of demand. Such a movement reduces the capacity/inventory required to overcome volatility in the marketplace and also enables product customisation by not configuring until firm orders are known. We have populated Figure 3 with a number of real-world industrial examples. Our selection is based on a desire to show that each cell of the postponement matrix is a viable candidate pipeline to be selected as appropriate to the overall business strategy. The choice has also reflected the wide market sector applicability of the postponement matrix. Finally, we note that there is broad equivalence between "speculation" and "lean processes" and between "postponement" and "agile processes".

Figure 3. Populated Postponement Matrix about here

Market Characteristics
From the perspective of the design of supply chain strategies, it could be argued that there are five key market characteristics that should influence decision making. These attributes are **d**uration of life cycle; time **w**indow for delivery; **v**olume, **v**ariety; and **v**ariability (DWV^3) (Christopher & Towill (2000). They may be described in detail as follows:-

- **Duration of life cycle**
  The likely length of the product life cycle is an important consideration in the adoption of specific supply chain strategies. Short life cycles require both rapid time-to-market as well as a short end-to-end 'pipeline' to enable demand to be continuously replenished during the life cycle. For many products there is a recognisable pattern of sale from launch through to termination. The individual phases of the life cycle curve are introduction, growth, maturity, saturation and decline. It should be noted that today's turbulent marketplace has resulted in extreme volatility and hence uncertainty has become a characteristics of many product life cycles.

  In situations like this the time available to develop new products, to launch them and to meet market-place demand is clearly greatly reduced. Hence the ability to 'fast track' product development, manufacturing and logistics becomes a key element of competitive strategy. It is not just time-to-market resulting in lost sales that is a major contributor to the shortfall in revenue. Once a product is on the market the ability to respond quickly to demand is equally important. Here the lead-time to re-supply a market determines the organisation's ability to exploit demand during the life cycle. Also, too long a lead-time responding to the decline phase means that we also lose revenue from obsolescence resulting in price markdowns.

- **Time window for delivery**

  It is more likely to be the case that agile strategies are appropriate for products that are either expected to be short-lived in the marketplace, or require to be delivered to the customer very soon after the order is placed. In the first category, we need rapid response to replenish those products (say fashion goods and mobile phone) selling well at that particular point in time. In the second case we have products such as customised carpets and customised bicycles. The former has a time window of one week between purchase and subsequent fitting in the customer's residence (Johansson et al, 1993) whereas the latter has a two week window between customer being measured up/selecting cycle features and local delivery (Lowson at al, 1999).

  Interestingly, these two supply chains utilise both lean and agile paradigms, but in different ways. In bicycle manufacture, there is an 'agile' summer season, followed by 'lean' winter seasons where standard models are made for stock. But in the carpet supply chain there are two parallel value streams operating continuously and concurrently. The first produces customised 'agile' products whereas the second manufactures the standard 'lean' carpet ranges, which are made for stock.

- **Volume**

  Where products are aimed at mass markets with a prospect of high level of demand, conditions will often allow lean-type production and make-to-forecast strategies to be designed and implemented. Thus the focus can be an objective of maximising the economies of scale. Conversely, where volumes are likely to be smaller the benefits of flexibility, both in production and the wider supply chain, will be evident. However, it is important to recognise the impact of the Pareto distribution (the ‘80/20’ rule). In other words at a particular point in time the top 20% of the range may sell in substantial volume but the remaining 80% will be much slower moving. Hence it will sometimes be appropriate to adopt lean strategies for the top 20% and agile strategies for the remaining 80% where we do not want to over-stock or over-produce. But the Pareto Curve is itself dynamic as the volumes vary through out the product life cycle. Hence today’s ‘runner’ may be tomorrow’s ‘repeater’ and next week’s ‘strangers’ (Parnaby, 1994). We therefore need a supply strategy to cope with such changes in emphasis during the product lifecycle.

- **Variety**

  Typically, the higher the level of variety demanded by the marketplace, the lower will be the average volume per variant because total demand is spread across a greater number of stock keeping units (SKUs). This will often mean that demand will be more variable at the SKU level. It also implies a much higher level of flexibility in manufacturing with a need for more change-overs and set-ups. With increased variety generally comes greater complexity. The challenge is to seek to achieve a higher level of commonality at the Bill of Material level but to enable late configuration or customised finishing to meet the customer demand for variety.

- **Variability**

  The concept of variability relates to the ‘spikiness’ of demand. It also equates to unpredictability. Where demand cannot be forecast with any degree of accuracy, it is suggested that agility is critical. A measure of variability is the Coefficient of Variation (standard deviation divided by the mean). Where the coefficient of variation is high, then reliance on forecast-based management is to be avoided. Instead the focus must be upon lead-time reduction and the substitution of information for inventory. In other words, capturing information on demand as close to the marketplace as possible. This means that the ‘information enriched’ operation is a key enabler in agile supply (mason-Jones and Towill, 1997). Quick response is then activated by true demands, rather than rogue demands

The LightCo

To illustrate the opportunities that exist for managing multiple pipelines to enable tailored logistics solutions, the case of LightCo is presented. LightCo is a company producing a range of lighting products for diverse markets. Their product range varies from standard products made in volume (e.g. white fluorescent tubes) to architect-specified systems for large one-off projects (e.g. airport terminals).

Before 1996 the LightCo's organisation and management of its internal and external demand chains was based on a traditional functional approach. All seven forms of Ohno's (1988) wastes (or muda) were very apparent in the internal demand chain and material conversion operations. Management of the external supply chain was at an arm's-length contractual basis (Sako, 1992). No obligation for repeat transactions was anticipated if the supplier did not maintain the lowest price. To overcome these problems the company embarked on a two phase, four year re-engineering programme (Aitken, 2000). The first phase resulted in the introduction of lean production, whilst the second phase was aimed at making the plant responsive. But the clear aim of the re-engineering programme was to match customer requirements and product delivery processes. Using the DWV^3 supply chain classification described earlier enabled the segmentation of the product catalogue into a smaller number of focussed clusters. The next step was to design and engineer the four pipelines, which are summarised in Figure 4. This was deemed the optimum number of pipelines in the trade-off between economies of scale, economies of scope and diseconomies of averaging.

Cluster 1 consists of the low volume products. This cluster is akin to the concept of "strangers" in Lucas terminology (Parnaby, 1994) i.e. products for which demand is sporadic. It was decided that the existing MRP control mechanisms were the most appropriate for these types of products. The major order winner for this cluster of products is service level in terms of availability of small volume products within acceptable lead times. Cluster 2, the high volume, low variant products are increasingly becoming commodity-like in nature and are exposed to competition from low labour cost countries. Since the UK lighting company cannot win on the basis of cost alone, very short lead times are the only remaining competitive avenue. This is facilitated via a Lean supply channel (Womack and Jones, 1996) and a make-to-stock policy, so that deliveries to specific customer orders can be made in very short lead times (1 day if required). The Kanban controls and 2-bin system operated with the supply base maximises efficiency for these products with relatively predictable demand patterns.

To further combat overseas competition the lighting company and its associated supply chain increased customer service by offering multiple variants of relatively standard products. The products utilising this strategy make up Cluster 3 for which the order winner is cost followed by availability of multiple variants. To achieve this objective the concept of postponement was exploited. This was partially due to the nature of lighting products in that they are assembled from three major sub-assemblies. Therefore as shown in Figure 4 the de-coupling point has been placed at the sub-assembly level. Before the de-coupling point Lean principles are applied to maintain desired stock levels, as in the case of the Cluster 2 products. After the de-coupling point in the final packing centre specific customer orders are assembled and dispatched, therefore offering multiple variants cost effectively in very short order cycle times. Thus a Leagile strategy (Naylor et al, 1997) was adopted so as to obtain the best from both worlds.

Figure 4. Internal supply Chains Required to Support the Four Lighting Company Pipelines about here

Lastly the final group of products, Cluster 4, was seen as offering potential new opportunities in the marketplace in line with the increased demand for customised products. These products either have short life cycles or are in their introductory stages, with the duration of the life cycle being uncertain. Figure 4 also illustrates the internal demand chain for this cluster of products. It has been specifically designed to offer customised products in short development lead times as effectively and efficiently as possible, therefore maximising the order winning objective. These re-engineering programmes to provide customised pipelines also enabled activity based costing to be used to match price to effort (Aitken, 2000).

Dynamic Matching of Pipelines and Products

At this point we emphasise that the LightCo product routing is not static so there must be a continuous monitoring and appraisal of all SKUs. In fact the marketplace OWs and MQs are dynamic for any specific product as it proceeds through its product life cycle. This is noted by numerous authors including Hill (1993), Kotler (1994) and Porter (1980). Furthermore, as Hayes and Wheelwright (1984) have stated, the production and manufacturing processes must also dynamically adapt to best service these changing marketplace conditions. Figure 5 therefore summarises a particular lighting industry generic product range giving its OWs and MQs for each life cycle stage, and the resultant most applicable supply chain strategy selected from the four available pipelines.

Figure 5. How OW and MQ Characteristics Change as a Function of Life Cycle about here

During the introduction stage of the product life cycle, the *capability of design* is the key OW followed closely by the design lead time. Therefore the design and build strategy is most applicable. Once the product has entered the marketplace and if the demand increases, then the product enters its growth stage. During this time the service level in terms of *availability of a product* with unpredictable demand is the key OW. As a result the product is transferred to the MRP push based demand chain. When the product has reached its mature stage it is switched to the Kanban demand chain, so as to best compete on the key OW of *cost*. During the saturation stage low labour cost countries enter and compete in the marketplace, so LightCo competes by offering *multiple variants*. In order to do so the packing centre strategy is utilised. Finally, as the demand for the product tails off and enters the decline stage of the product life cycle, it is transferred back to the MRP pipeline so as to maximise the *service level* for the low volume highly unpredictable product.

This case is an excellent example of how a real-world manufacturer in an unglamorous market sector responds to the challenge outlined by Shewchuck (1998) to move away from the "one size fits all" mentality. Nor is LightCo operating in an industry where designing, implementing, and matching the optimum pipeline to product would be regarded as an obvious way to proceed. This is in contrast to the fashion and personal computer market sectors which tend to advertise their innovations in logistics and delivery policies quite widely. Furthermore as reported elsewhere (Aitken et al, 2002) these moves into planned pipeline multiplicity have proven to be essential in order to sustain competitive advantage. The consequence is an impressive contribution to bottom-line performance (Aitken, 2000).

Discussion

The LightCo case study offers a great deal of insight into the feasibility of developing a multiple pipeline strategy. The resultant four focussed pipelines depicted in Figure 4 have greatly enhanced the competitiveness of the company and its supply chain partners. Table 2 illustrates the historical development of the four strategies, together with some of the observed benefits from using the focussed approach. Costs have been greatly reduced for three of the four channels. In the case of the Design and Build pipeline the apparent price increase is because re-engineering has facilitated identification of the true activity based costs. Thus the cross-subsidy from commodity-like products at the expense of other items, which is one of Fuller et al's (1993) important averaging effects, is avoided. The order cycle times have been massively reduced for all four pipelines but especially for the Kanban and Packing Centre channels which often win orders on the basis of their responsiveness. Similarly the competitiveness of the customised Design and Build products has been greatly enhanced via the compression of the product development lead times.

Table 2. Overview and Results of BPR Programme to Engineering Multiple Leagile Pipelines about here

Although the target of this paper is to make a contribution to customisation theory, there are also implications for how companies remain competitive in changing market conditions. Clearly the "one-size-does-not-fit-all" philosophy is now an essential part of pipeline design and companies must build this into BPR Programme requirements. In the case of LightCo the BPR "product champion", in this instance the CEO, initially moved the company from traditional to lean operations. This step was helpful but inadequate to retain competitive advantage at either end of the spectrum (Aitken, 2000). The current solution required the company to create four distinct pipelines. Consequently the LightCo became more competitive in the high volume business by responding to overseas competition by offering a wider range of product variants. The Packaging Centre facility has enabled customisation and rapid response of particular products by moving the availability fulcrum of Figure 2 nearer to the marketplace via postponed manufacture. Finally, the re-positioning of the Design and Build facility has considerably improved responsiveness to the need to develop new products, which are now properly costed and not cross-subsidised by the fast movers.

Generic Delivery Strategies

We are now in a position to embed the outputs from the LightCo Case Study into a generic framework. This is undertaken in Table 3 in which the four LightCo delivery pipelines are placed in the context of three other established approaches. These are the "continuum of strategies" (Lampel and Mintzberg, 1996), the "one size does not fit all" strategy (Shewchuck, 1998), and "postponement and speculation strategies" (Pagh and Cooper, 1998).

Table 3. A Continuum of Delivery Strategies about here

An examination reveals that the broadest picture is painted by Lampel and Mintzberg (1996). They suggest that five delivery strategies are possible, described as pure standardisation; segmented standardisation; customised standardisation; tailored customisation; and pure customisation. The postponement and speculation strategies of Pagh and Cooper (1998) can now be seen as intensive exploitation of the middle three categories. "Full speculation" therefore equates to "segmented standardisation", whilst "full postponement" equates to "tailored customisation", interestingly "customised standardisation" is subdivided into "manufacturing postponement" and "logistics postponement" by Pagh and Cooper (1998). There are direct equivalences between Shewchuck's (1998) "mass customisation via processing" with "tailored customisation" and "mass customisation via assembly" with "customised standardisation". However both "compressed life cycle" and "compressed time to market" can be viewed as alternative adaptations of "segmented standardisation".

The four LightCo pipelines fit well into this continuum of strategies. The "MRP pipeline" qualifies under "pure standardisation", "Kanban" equates to "segmented standardisation" the "packing centre" with "customised standardisation" and "design and build" with "pure customisation". What does this mean? Firstly that there is agreement and consistency between the approaches by Pagh and Cooper (1998) and Shewchuck (1998) and the continuum of strategies defined by Lampel and Mintzberg (1996). But more importantly, it all relates to real-world practice as evidenced by the LightCo case. Furthermore LightCo have demonstrated the necessity for companies to establish parallel pipelines which may require quite different core skills to match the need for defined delivery categories. "Design and Build", for example, does not sit happily within an "MRP" environment.

The cross-referencing of these three insightful publications with the LightCo Case Study outputs has resulted in the development of seven generic delivery pipelines as highlighted by the right hand column of Table 3. By establishing such equivalence of meanings the sample of companies available for critical comment is thereby widened. For example, there is now a prima-facie case that there are major similarities between certain aspects of Mercedes Benz, HP DeskJet, and ABB Motors pipelines. Thus we have shown that such "carry over" may be reasonably expected, leading to opportunities to identify and transfer "best practice".

Conclusions

Today's diverse marketplace presents a challenge to supply chain management in that different solutions are required for a range of customer requirements. When seen in such a context it is apparent that there is a portfolio of production technologies, product modularisation techniques, logistics, postponement and marketing ploys which may be utilised to gain competitive advantage. Working from such a "pick and mix" scenario it then becomes much easier to select and implement multiple pipelines to serve all customers as the marketplace requires. As the "One Size Does Not Fit All" maxim (Shewchuck, 1998) implies, this does not mean offering each customer the same: it means tailoring delivery to suit clusters of products and their marketplace needs. Thus the National Bicycle Company (Lowson et al, 2000) has two clusters of products essentially manufactured by the same group of employees. But one cluster is a group of standard SKUs made to stock utilising lean production. The second cluster offers personalised items necessitating agile responses for information elicitation, assembly, and rapid delivery to the customer. Steps must be taken to ensure that there is no “interference” between these channels, an objective achieved here via temporal separation (Christopher and Towill, 2002).

Such a “mix-and-match” approach is not a substitute for learning-by-doing. We totally agree with the views of Victor and Boynton (1998) that process mapping is an essential core skill underpinning any proposed move from the traditional to the customised supply chain. The selection of the optimal set of pipelines appropriate to any particular business strategy is preceded by careful in-depth analysis of products, production processes, and market opportunities. As our LightCo case study demonstrates, this is not an exercise to be undertaken lightly. In that instance the outcome was the setting up of four parallel pipelines customised to the needs of moving particular clusters of products in such a way as to met the specific OWs/MQs appropriate to that group. In each pipeline the availability fulcrum was moved to the appropriate position to balance demand with capacity/inventory requirements. In the case of one particular pipeline, final assembly was postponed but with rapid pull-off to enable quick response to customer orders. The outcome of this particular multiple pipeline strategy was a substantial positive impact on bottom-line metrics.

An analysis of the literature on delivery strategies, and postponement/speculation strategies has produced a generic outcome. When compared and contrasted with the LightCo real-world pipelines, and the “One Size Does Not Fit All” perspective of Shewchuck (1998) it is found that a family of seven discrete pipeline types emerges. This appears to cover most (if not all) eventualities, and is regarded as particularly powerful when allied to an appropriate classification scheme (such as DWV^3, Christopher and Towill, 2000[a]) and to the OW/MQ concept of Terry Hill (1993). We therefore conclude that the pipeline engineering methodology outlined in the paper is capable of transfer within and between market sectors.

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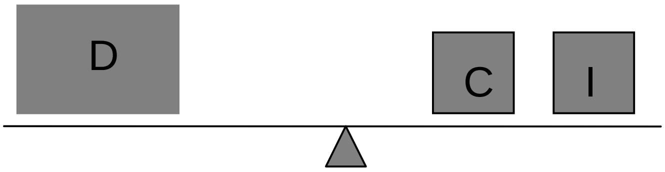
Supply Chain Focus	Market Qualifiers	Order Winners
Agile Supply	• Quality • Cost • Lead Time	• Service Level
Lean Supply	• Quality • Lead time • Service Level	• Cost

Market Requirements

Figure 1
Order Winners and Market Qualifiers as Determinants of Supply Chain Focus
(Source: Mason-Jones, Naylor, Towill, 2000)



(a) The typical supply chain inventory/capacity needed to balance demand

(b) Fulcrum moved nearer to demand, hence smaller inventory/capacity is required

(c) Fulcrum moved too far from demand, hence larger inventory/capacity is requried

Figure 2
The Supply Chain Availability Fulcrum

Supply Chain Evolution Stage	I	II	III	IV
• Supply Chain Time Marker • Supply Chain Philosophy • SC Type	Early 1980s Product Driven Lean Functional Silos	Late 1980s Volume Driven Lean Supply chain	Early 1990s Market Driven Leagile Supply Chain	Late 1990s Customer Driven Customised Leagile Supply Chain
• Order Winner • Market Qualifiers • Performance Metrics	Quality (a) Cost (b) Availability (c) Lead Time (a) Stock Turns (b) Production Cost	Cost (a) Availability (b) Lead Time (c) Quality (a) Throughput Time (b) Physical Cost	Availability (a) Lead Time (b) Quality (c) Cost (a) Market Share (b) Total Cost	Lead Time (a) Quality (b) Cost (c)Availability (a) Customer Satisfaction (b) Value Added

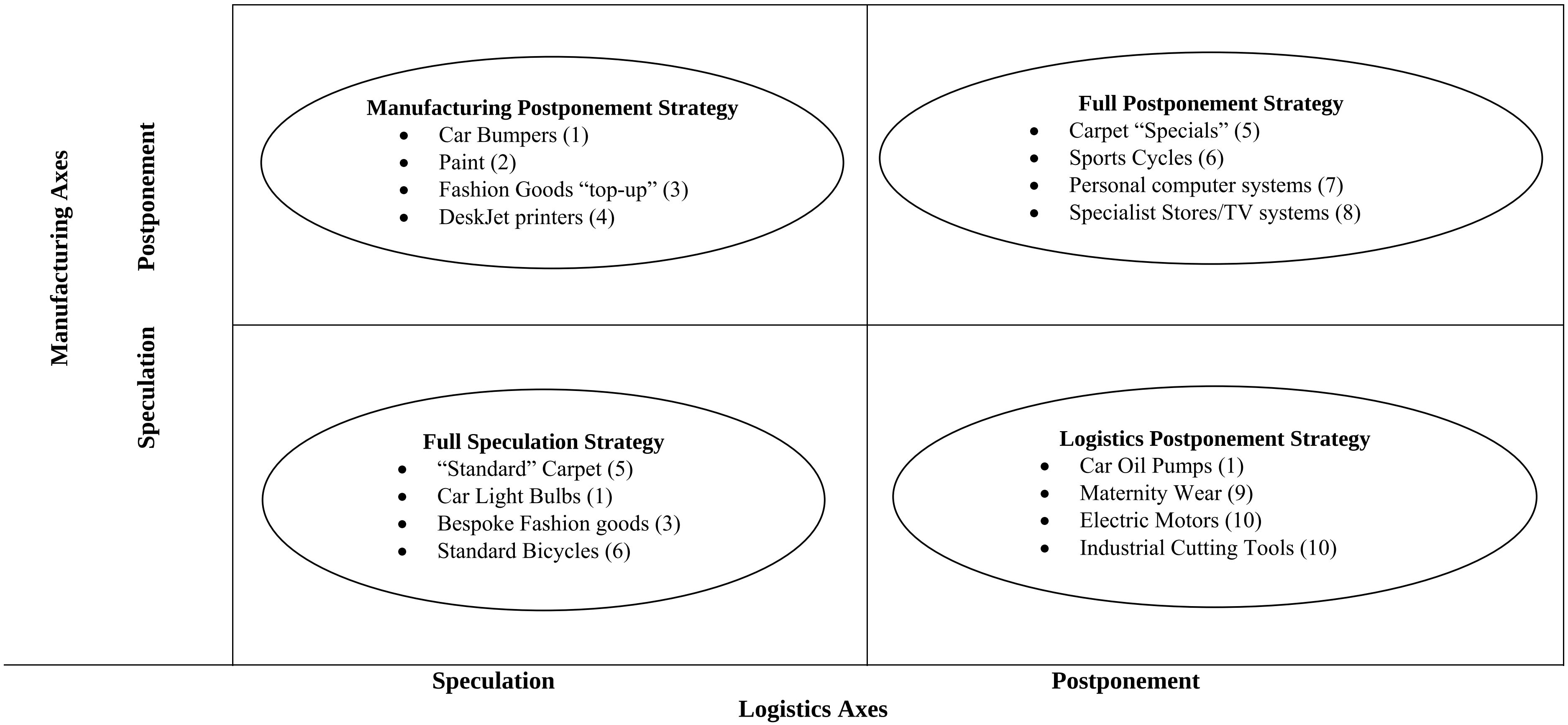
Table 1
Migratory Model Summarising the Transition from Lean Functional Silos to Customised Leagile Supply Chain
(Source: Christopher and Towill, 2000[b])

Process Innovation and Year of Implementation	Original MRP 1995	New MRP 1998	Kanban 1998	Packing Centre 2000	Design and Build 2000
CHARACTERISTICS					
Product Codes	8000+	3500	400	450	N/A
Material Flow	Push	Push	Pull	Pull	Pull
Material Control	MRP	MRP	Kanban	Kanban	Discrete Orders
Demand Predictability	Mix of High & Low	Low	High	Medium	High
Minimum Order Quantity	Pallet	Single Unit	Pallet	Single Unit	Single Unit
Service Offered	Made to Order	Made to Order	Ex Stock	Assemble to Order	Design to Order
PERFORMANCE METRICS					
Product Development	24 Months	6 Months	6 Months	6 Months	6 Months
Order Cycle Time	8-12 Weeks	2-4 Weeks	0-2 Days	< 5 Days	1-4 Weeks
Costs (1995 index = 100)	100	80	73	80	150
RESULTING	TRADITIONAL SC				
PIPELINE		LEANER PRODUCTION			
STRATEGY		MULTIPLE LEAGILE PIPELINES			

Table 2
Overview and Results of BPR Programmes to Engineer Multiple Leagile Pipelines
(Authors adapted from Aitken, 2000)

A Continuum of Strategies (Lampel and Mintzberg, 1996)		Postponement & Speculation Strategies (Pagh and Cooper, 1998)		One Size Does Not Fit All (Shewchuck, 1998)		LightCo (Childerhouse, et al 2002)	Emerging Generic Delivery Pipelines (Authors)
Pure Standardization	Product is pushed onto the market, no variants are offered, e.g. Model T Ford					MRP: No customization, products are made-to-order from a catalogue, e.g. Replacement lights.	Pure Standardization
Segmented Standardization	A basic design is modified to target clusters of customers, e.g. Cereal brands.	Full Speculation	Product is pushed onto the market, some variants may be offered, e.g. Xerox commodity products.	Compressed Life Cycle	Short PLC, high demand during mature stage, e.g. Home computers	Kanban: JIT manufacture to replenish desired finished goods levels, e.g. high volume, lights in mature PLC stage.	Compressed Life Cycle
				Compressed Time-to-Market	Short PLC, very short growth stage and high demand during mature stage, e.g. Mobile phones		Compressed Time-to-Market
Customized Standardization	Modularization, assembly is customized but fabrication is not, e.g. Mercedes Benz.	Manufacturing Postponement	Final assembly is postponed, e.g. HP DeskJet.	Mass Customization via Assembly	Single unit product demand and relatively short lead times, e.g. Personal computers.	Packing Centre: JIT manufacture to replenish sub-assembly levels and final assembly to order, e.g. partial customized lights.	Mass Customization via Assembly
		Logistics Postponement	Direct distribution to specific orders, e.g. ABB Motors.				Logistics Postponement
Tailored Customization	Portfolio of designs that are configured for specific customers, e.g. tailor-made-suits.	Full Postponement	Final assembly and distribution are postponed, e.g. B&O	Mass Customization via Processing	Single unit product demand and very short lead times, e.g. Spectacle lens.		Mass Customization via Processing
Pure Customization	Total customer driven from original design to manufacture, e.g. large scale construction.					Design and Build: Full customer orientated from design to delivery, e.g. large scale construction lighting refit.	Pure Customization

Table 3 A Continuum of Delivery Pipelines ~ Many Routes to Accomplishment



(1) McHugh et al (1995)
(2) Bowersox and Closs (1996)
(3) Stratton and Warburton (2001)
(4) Fetzinger and Lee (1997)
(5) Johansson et al (1993)
(6) Fisher (1997)
(7) Dell and Fredman (1999)
(8) Schary and Skjøtt-Larsen (1996)
(9) Siekman (2000)
(10) Abrahamsson (1993)

Figure 3
Populating the Pagh and Cooper Postponement/Speculation Strategy Matrix with Real-World Examples

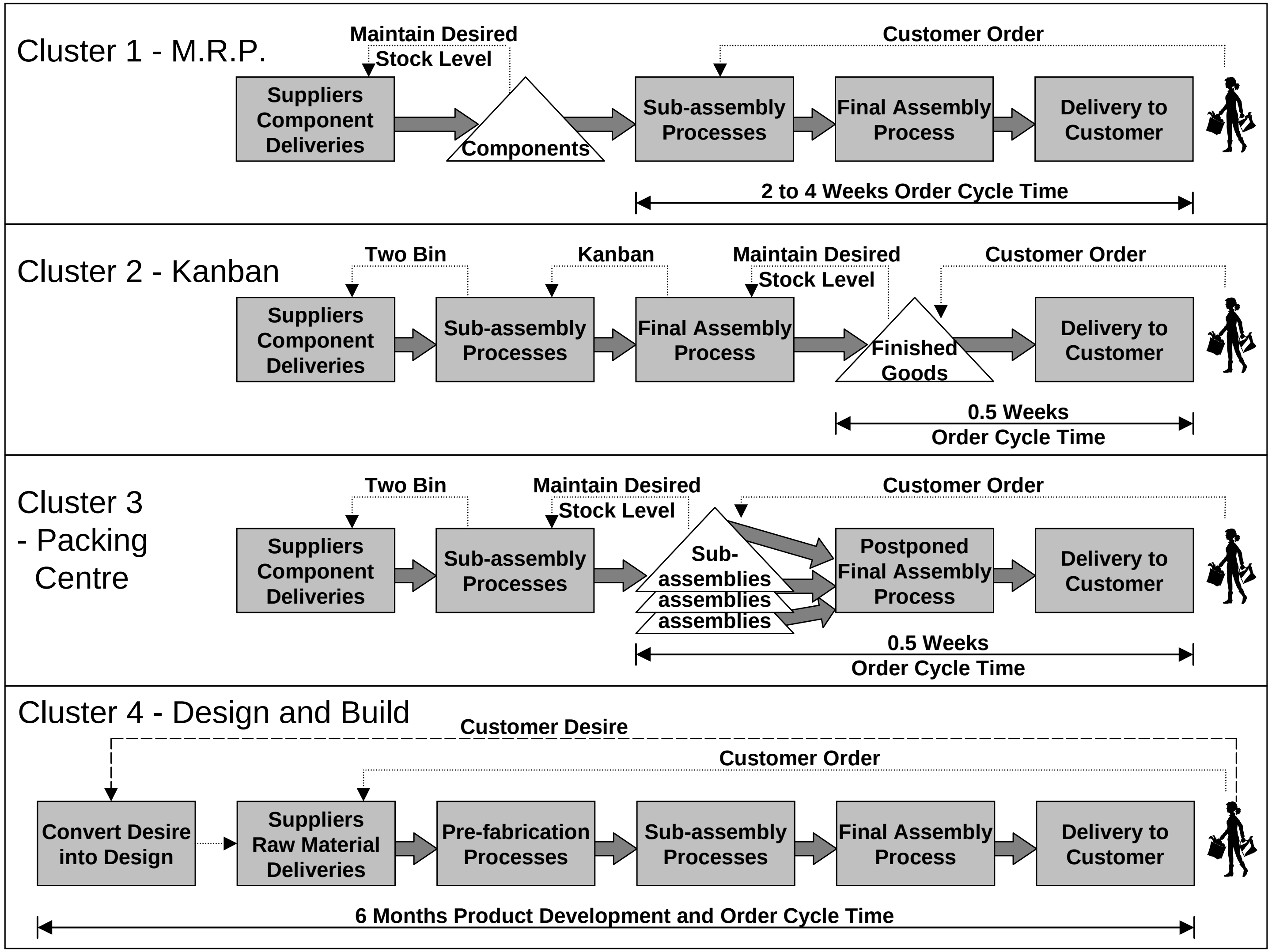


Figure 4. Internal Supply Chains Required to Support the Four Lighting Company Pipelines
(Source: Childerhouse et al, 2002)

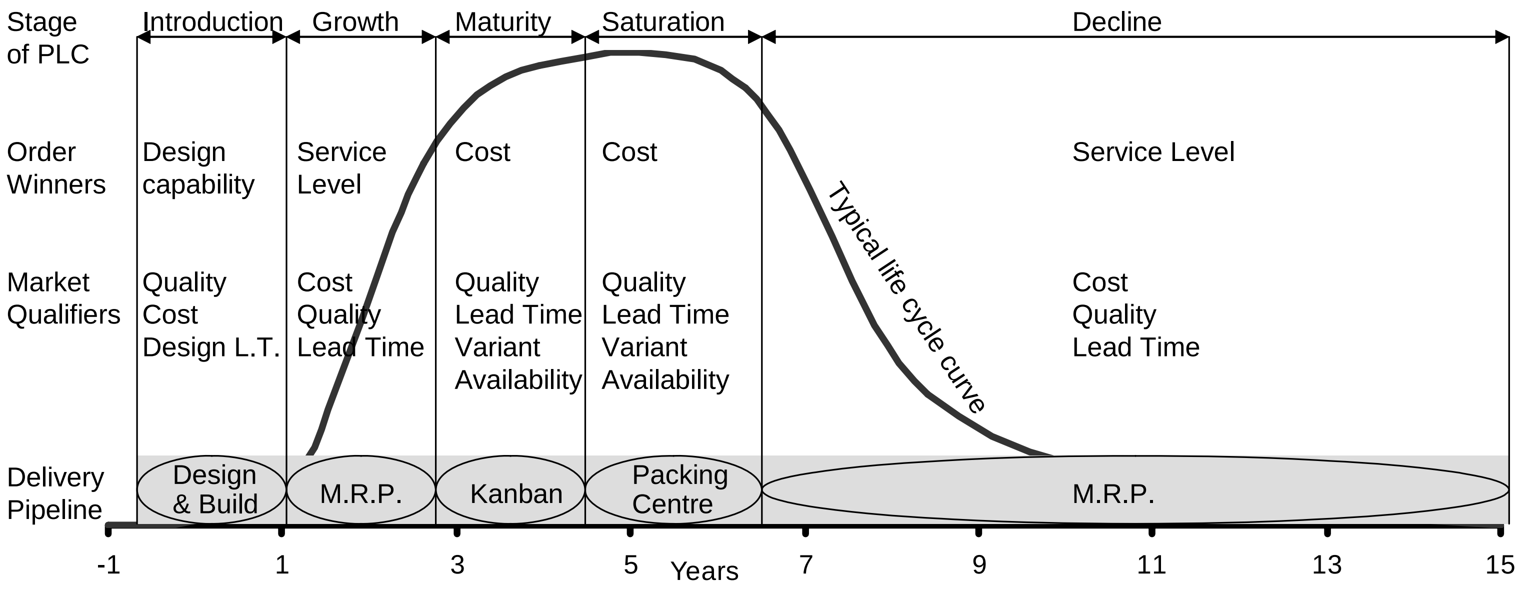


Figure 5. How OW and MQ Characteristics Change as a Function of Life Cycle (Source: Childerhouse et al, 2002)