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The Agile Supply Chain : Competing in Volatile Markets

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Turbulent and volatile markets are becoming the norm as life-cycles shorten and global economic and competitive forces create additional uncertainty. The risk attached to lengthy and slow-moving logistics 'pipelines' has become unsustainable, forcing organisations to look again at how their supply chains are structured and managed. This paper suggests that the key to survival in these changed conditions is through 'agility', in particular by the creation of responsive supply chains. A distinction is drawn between the philosophies of 'leanness' and 'agility' and the appropriate application of these ideas is discussed.

The importance of time as a competitive weapon has been recognised for some time (1). The ability to be able to meet the demands of customers for ever-shorter delivery times and to ensure that supply can be synchronised to meet the peaks and troughs of demand is clearly of critical importance in this era of 'time-based competition (2).

To become more responsive to the needs of the market requires more than speed, it also requires a high level of manoeuvrability that today has come to be termed *agility*.

What is Agility?

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 lies in flexible manufacturing systems (FMS). Initially it was thought that the route to manufacturing flexibility was through automation to enable rapid change (i.e. reduced set-up times) and thus a greater responsiveness to changes in product mix or volume. Later this idea of manufacturing flexibility was extended into the wider business context (3) and the concept of agility as an organisational orientation was born.

Agility should not be confused with 'leanness'. Lean is about doing more with less. The term is often used in connection with lean manufacturing (4) to imply a 'zero inventory', just-in-time approach. Paradoxically, many companies that have adopted lean manufacturing as a business practice are anything but agile in their supply chain. The car industry in many ways illustrates this conundrum. The origins of lean manufacturing can be traced to the Toyota Production System (TPS) (5), with its focus on the reduction and elimination of waste.

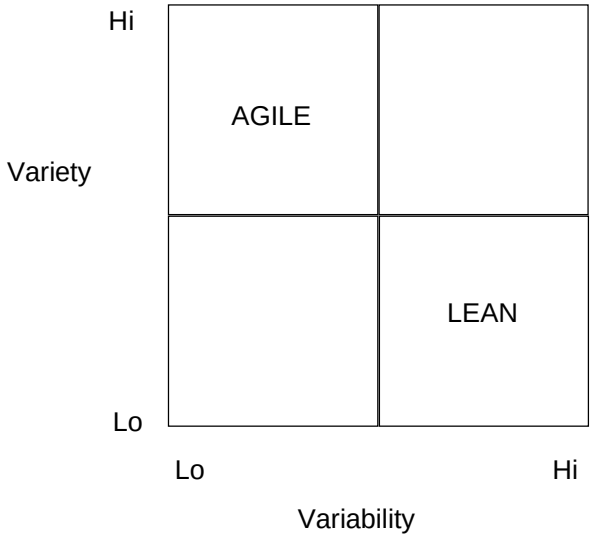
Whilst the lessons learned from the TPS principles have had a profound impact o manufacturing practices in a wide range of industries around the world, it seems that the tendency has been for the benefits of lean thinking to be restricted to the factory. Thus we encounter the paradoxical situation where vehicle manufacture is extremely efficient with throughput time in the factory typically down to twelve hours or less, yet inventory of finished vehicles can be as high as two months of sales – and still the customer has to wait for weeks or even months to get the car of their choice!

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'.

There are certain conditions where a lean approach makes sense. In particular where demand is predictable and the requirement for variety is low and volume is high. In fact the very conditions in which Toyota developed the lean philosophy. The problems arise when we attempt to implant that philosophy into situations where demand is less predictable, the requirement for variety is high and consequently volume at the individual stock keeping unit (SKU) level is low – a set of characteristics which is more typical of the Western automobile industry. In other words it could be argued that many firms have been misguided in their attempts to adopt a lean model in conditions to which is not suited.

Figure 1 suggests that the three critical dimensions of Variety. Variability (or predictability) and Volume determine which approach – agile or lean – make greatest sense.

Figure 1 : Agile or Lean?



"Agility" is needed in less predictable environments where demand is volatile and the requirement for variety is high.

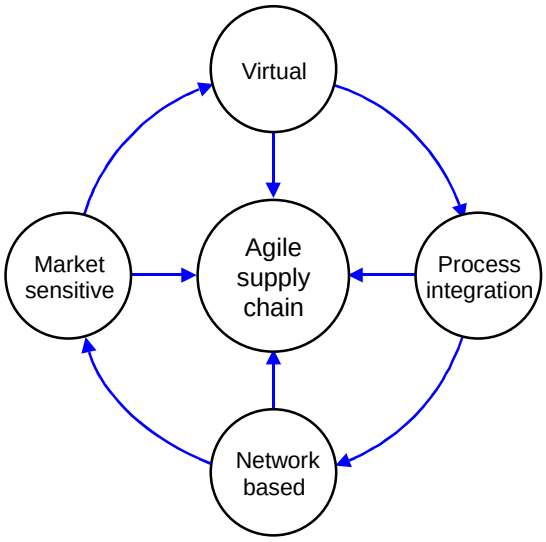
"Lean" works best in high volume, low variety and predictable environments.

Agility might therefore be defined as the ability of an organisation to respond rapidly to changes in demand both in terms of volume and variety. The market conditions in which many companies find themselves are characterised by volatile and unpredictable demand. Hence the increased urgency of the search for agility.

The routes to agility

To be truly agile a supply chain must possess a number of distinguishing characteristics as Figure 2 suggests. Firstly, the agile supply chain is *market sensitive*. By market sensitive is meant that the supply chain is capable of reading and responding to real demand. Most organisations are forecast-driven rather than demand-driven. In other words because they have little direct feed-forward from the marketplace by way of data on actual customer requirements they are forced to make forecasts based upon past sales or shipments and convert these forecasts into inventory. The breakthroughs of the last decade in the form of Efficient Consumer Response (ECR) and the use of information technology to capture data on demand direct from the point-of-sale or point-of-use are now transforming the organisation's ability to hear the voice of the market and to respond directly to it.

Figure 2 : The Agile Supply Chain



The use of information technology to share data between buyers and suppliers is, in effect, creating a *virtual* supply chain. Virtual supply chains are information based rather than inventory based.

Conventional logistics systems are based upon a paradigm that seeks to identify the optimal quantities of inventory ands its spatial location. Complex formulae and algorithms exist to support this inventory-based business model. Paradoxically, what we are now learning is that once we have visibility of demand through shared information, the premise upon which these formulae are based no longer holds. Electronic Data

Interchange (EDI) and now the Internet have enabled partners in the supply chain to act upon the same data i.e. real demand, rather than be dependent upon the distorted and noisy picture that emerges when orders are transmitted from one step to another in an extended chain.

Shared information between supply chain partners can only be fully leveraged through *process integration.* By process integration is meant collaborative working between buyers and suppliers, joint product development, common systems and shared information. This form of co-operation in the supply chain is becoming ever more prevalent as companies focus on managing their core competencies and outsource all other activities. In this new world a greater reliance on suppliers and alliance partners becomes inevitable and, hence, a new style of relationship is essential. In the 'extended enterprise' as it is often called, there can be no boundaries and an ethos of trust and commitment must prevail. Along with process integration comes joint strategy determination, buyer-supplier teams, transparency of information and even open-book accounting.

This idea of the supply chain as a confederation of partners linked together as a *network* provides the fourth ingredient of agility. There is a growing recognition that individual businesses no longer compete as stand-alone entities but rather as supply chains. We are now entering the era of 'network competition' where the prizes will go to those organisations who can better structure, co-ordinate and manage the relationships with their partners in a network committed to better, closer and more agile relationships with their final customers. It can be argued that in today's challenging global markets, the route to sustainable advantage lies in being able to leverage the respective strengths and competencies of network partners to achieve greater responsiveness to market needs.

Hybrid strategies are often appropriate

There will be occasions when either a 'pure' agile or lean strategy might be appropriate for a supply chain. However there will often be situations where a combination of the two may be appropriate i.e. a hybrid strategy.

Hybrid supply chain strategies recognise that within a mixed portfolio of products and markets there will be some products where demand is stable and predictable and some where the converse is true. As Fisher has pointed out (6) it is important that the characteristics of demand are recognised in the design of supply chains. However, it is not necessarily the case that a supply chain should be either lean or agile. Instead a supply chain may need to be lean for part of the time and agile for the rest.

Zara the Spanish fashion company provides a good example of this hybrid supply chain strategy (7).

Zara is one of Spain's most successful and dynamic apparel companies, producing fashionable clothing to appeal to an international target market of 18 to 35 year-olds.

Zara's international market positioning places it in direct competition with some of the most skilled operations in the business, including Italian fashion giant Benetton and US-based The Gap and The Limited. Its rapid growth and on-going success in such a fiercely competitive environment is in fact a testament to its ability to establish an agile supply chain which still incorporates many 'lean' characteristics. The pursuit of this hybrid strategy has enabled Zara to develop one of the most effective quick-response systems in its industry.

The whole process of supplying goods to the stores begins with cross-functional teams - comprising fashion, commercial and retail specialists - working within Zara's Design Department at the company's headquarters in La Coruña. The designs reflect the latest in international fashion trends, with inspiration gleaned through visits to fashion shows, competitors' stores, university campuses, pubs, cafes and clubs, plus any other venues or events deemed to be relevant to the lifestyles of the target customers. The team's understanding of fashion trends is further guided by regular inflows of EPOS data and other information from all of the company's stores and sites around the world.

Raw materials are procured through the company's buying offices in the UK, China and The Netherlands, with most of the materials themselves coming in from Mauritius, New Zealand, Australia, Morocco, China, India, Turkey, Korea, Italy and Germany. Approximately 40% of garments - those with the broadest and least transient appeal - are imported as finished goods from low-cost manufacturing centres in the Far East. The rest are produced by quick-response in Spain, using Zara's own highly automated factories and a network of smaller contractors. Material or fabric is also held in 'greige' i.e.undyed and unprinted and if demand for a particular garment turns out to be higher than expected then local manufacturers can quickly manufacture additional product.

Zara's manufacturing systems are similar in many ways to those developed and employed so successfully by Benetton in Northern Italy, but refined using ideas developed in conjunction with Toyota. Only those operations which enhance cost-efficiency through economies of scale are conducted in-house (such as dying, cutting, labelling and packaging). All other manufacturing activities, including the labour-intensive finishing stages are completed by networks of more than 300 small subcontractors, each specialising in one particular part of the production process or garment type. These subcontractors work exclusively for Zara's parent, Inditex SA. In return they receive the necessary technological, financial and logistical support required to achieve stringent time and quality targets. The system is flexible enough to cope with sudden changes in demand, though production is always kept at a level slightly below expected sales, to keep stock moving. Zara has opted for undersupply, viewing it as a lesser evil than holding slow-moving or obsolete stock.

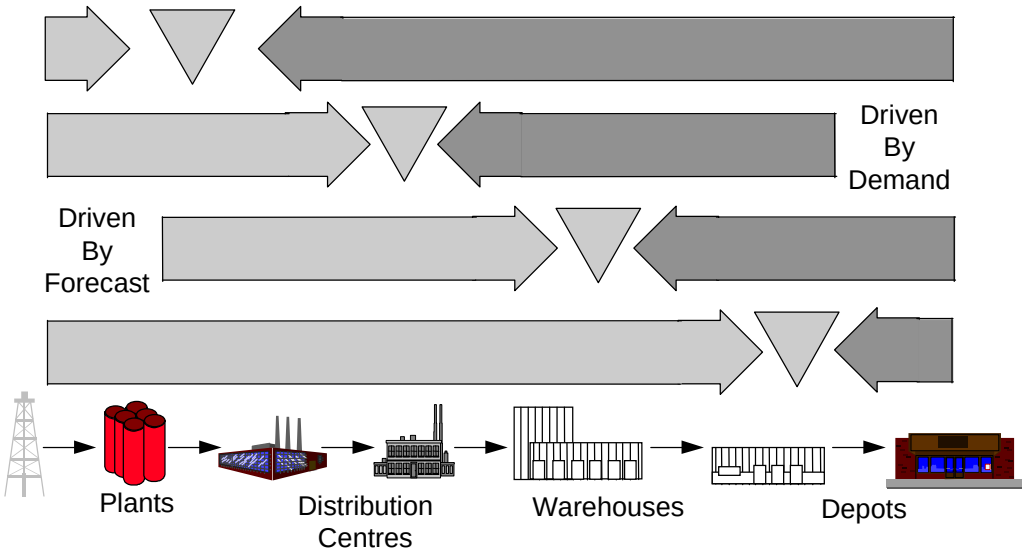
The role of the 'decoupling point'

A major problem in most supply chains is their limited visibility of real demand. Because supply chains tend to be extended with multiple levels of inventory between the point of production and the final marketplace, they tend to be forecast driven rather than demand driven.

The point at which real demand penetrates upstream in a supply chain may be termed the decoupling point. Previously, this idea has been termed the 'order penetration' point (8). However, the issue is not how far the order penetrates, but how far real demand is made visible. Orders are aggregations of demand, often delayed and distorted due to the actions and decisions of intermediaries (9). On the other hand, demand reflects the ongoing requirement in the final marketplace in as close to real-time as possible.

The decoupling point should also dictate the form in which inventory is held. Thus, in the uppermost example in Figure 3, demand penetrates right to the point of manufacture and inventory is probably held in the form of components or materials. In the lower example, demand is only visible at the end of the chain. Hence inventory will be in the form of finished product. The aim of the agile supply chain should be to carry inventory in a generic form – that is, standard semi-finished products awaiting final assembly or localisation. This is the concept of 'postponement', a vital element in any agile strategy.

Figure 3 : Decoupling points a strategic inventory



Postponement, or delayed configuration, is based on the principle of seeking to design products using common platforms, components or modules but where the final assembly or customisation does not take place until the final market destination and/or customer requirement is known.

The advantages of the strategy of postponement are several (10). Firstly, inventory can be held at a generic level so that there will be fewer stock-keeping variants and hence less inventory in total. Secondly, because the inventory is generic, its flexibility is greater,

meaning that the same components, modules or platforms can be embodied in a variety of end products.

Thirdly, forecasting is easier at the generic level than at the level of the finished item. This last point is particularly relevant in global markets where local forecasts will be less accurate than a forecast for worldwide volume. Furthermore, the ability to customise products locally means that a higher level of variety may be offered at lower total cost enabling strategies of 'mass-customisation' to be pursued.

The challenge to supply chain management is to seek to develop 'lean' strategies up to the decoupling point but 'agile' strategies beyond that point. In other words by using generic or modular inventory to postpone the final commitment it should be possible to achieve volume-oriented economies of scale through product standardisation. The flow of product up to the decoupling point may well be forecast driven; after the decoupling point it should be demand driven.

An important point to recognise is that there are actually two decoupling points. The first is the one already referred to i.e. the 'material' decoupling point where strategic inventory is held in as generic a form as possible. This point ideally should lie as far downstream in the supply chain and as close to the final market place as possible. The second decoupling point is the 'information' decoupling point. The idea here is that this should lie as far as possible upstream in the supply chain – it is in effect the furthest point to which information on real final demand penetrates.

Mason-Jones et.al (11) have demonstrated through simulation the beneficial impact that information feedback can have on reducing upstream amplification and distortion of demand.

By managing these two decoupling points a powerful opportunity for agile response can be created. At the same time the notorious 'bullwhip' or Forrester effect (12) (13) can be reduced. Billington and Amaral (14) have suggested that whilst the combined effect of shared information in a supply chain and delayed configuration through postponement can significantly improve responsiveness, the effect of delayed configuration is actually greater than the impact created by shared information (15).

Leveraging supplier relations

One of the keys to achieving agile response to fast-changing markets lies upstream of the organisation in the quality of supplier relationships. Often it is the lead-time of in-bound suppliers that limits the ability of a manufacturer to respond rapidly to customer requirements. Equally new product introduction time can be dramatically reduced through the involvement of suppliers in the innovation process.

Still today many companies have not recognised that competitive advantage that can be derived from closer relationships with key suppliers (16). Instead there is often an arms-length, even adversarial approach to managing the supplier base. To really leverage the

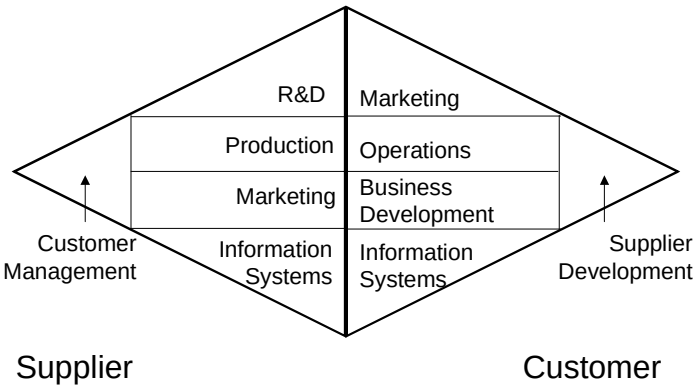
opportunity for greater agility through closer supplier relationships requires a number of pre-requisites to be in place.

Firstly, it is inevitable that the supplier base be rationalised. It is not possible to create close relationships through process integration with multiple suppliers. Agile companies have sought to identify a limited number of 'strategic' suppliers with whom they can work as partners through linked systems and processes. Whilst the dangers of single-sourcing need to be recognised, the advantages of having a network of key suppliers able to synchronise their production and deliveries with the requirements of the company are considerable. Opportunities for establishing information-based, paperless systems utilising concepts of vendor managed inventory (VMI), for example, are clearly greater when both buyer and supplier see each other as vital links in a more competitive supply chain.

A further pre-requisite for the creation of a more agile supplier base is a high level of shared information. In particular there has to be clear visibility of downstream demand; data on real demand needs to be captured as far down the chain as possible and shared with upstream suppliers. As wells as the IT and the IS necessary to make this possible there needs to be a willingness amongst the partners to put aside any previous mistrust and instead to create an environment in which information can freely flow in both directions in the chain.

Perhaps the most important pre-requisite is the need for a high level of 'connectivity' between the firm and its strategic suppliers. What this implies is not just the exchange of information on demand and inventory levels, but also multiple collaborative working relationships across the organisations at all levels. It is increasingly common today for companies to create supplier development teams which are cross functional and as such are intended to interface with the equivalent customers management team within the supplying organisation (17). Figure 4 illustrates the concept.

Figure 4 : Building stronger partnerships through multiple links



Reducing complexity to enhance agility

One of the biggest barriers to agility is the way that complexity tends to increase as companies grow and extend their marketing reach. Often this complexity comes through product and brand proliferation but also it can come through the organisational structures and management processes that have grown up over time (18).

The reduction of product complexity should be a major priority for marketing and logistics people working together. Product complexity includes not only design issues (e.g. the number of non-standard components in a product) but also excessive variety that does not contribute to greater customer or consumer value. Procter & Gamble for example have in recent years focussed on product range rationalisation, pack standardisation and reduced promotional activity in order to attack complexity.

Complexity is caused also by the way in which organisation structures and management processes are designed. One of the benefits of the Business Process Re-engineering (BPR) movement has been that is has highlighted the need to reduce or eliminate the many non-value activities that are inherent in traditional functionally-based business. Breaking down functional silos and re-grouping around value-creating processes will help reduce organisational complexity. A further aid to complexity reduction, and hence, enhanced agility, will be the development of a human resource strategy that leads to multi-skilling and encourages cross-functional working. Team-based management has been demonstrated (19) to be a highly effective facilitator of organisational agility.

Conclusions

Marketing management has not traditionally recognised the importance of logistics and supply chain management as a key element in gaining advantage in the marketplace. However, in today's more challenging business environment, where volatility and unpredictable demand becomes the norm, it is essential that the importance of agility be recognised.

Leading companies are already implementing marketing strategies which are underpinned by a supply chain strategy designed with agility in mind. These are the organisations that will be best equipped for survival in the uncertain markets of the 21st century.

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CHAPTER 7

Lean thinking and agile supply chains

Objectives

The intended objectives of this chapter are to:

- explain how lean thinking can be used to avoid the build-up of waste within and between supply chain processes;
- introduce the concept of the agile supply chain as a broad-based approach to developing responsiveness advantages;
- explore the challenges of coping with volatile demand situations;
- explain how capabilities can be developed and specifically targeted at thriving in conditions of market turbulence;
- describe how lean and agile approaches can be combined to meet market needs.

By the end of this chapter you should be able to:

- understand how lean thinking can be used to improve performance of the supply chain in meeting end-customer demand by cutting out waste;
- identify the type of market conditions under which agile strategies are appropriate, and how they can be operationalised;
- understand the distinctions between lean and agile strategies, and how the two can work together.

In Chapter 9 we consider another key aspect of the agile supply chain – the virtual organisation.

Introduction

In Chapter 6 we considered the way in which organisations approach their planning and control of supply chains. One important way of increasing the control of processes and improving reliability of plans is through the reduction of non-value-added activities – waste. The elimination of waste has been promoted under the banner of 'lean thinking' (Womack and Jones, 2003), who advise:

> To hell with your competitors; compete against *perfection* by identifying all activities that are *muda* and eliminating them. This is an absolute rather than a relative standard which can provide the essential North Star for any organisation.

Lean thinking and the just-in-time (JIT) pull approach to coordinating material flow across the supply chain share the same roots and originate from competitive strategies developed by the Japanese. Toyota Motor Company is held up as the role model and, although the Toyota brand has been damaged in recent years by widespread quality problems (Section 1.3.1), this focal firm's operational excellence has had a major influence on logistics thinking today.

A common view is that lean thinking works best where demand is relatively stable – and hence predictable – and where variety is low. But in situations where demand is volatile and customer requirement for variety is high, the elimination of waste in itself becomes a lower priority than the need to respond rapidly to a turbulent marketplace. So the second part of this chapter reviews developments under the banner of the 'agile supply chain'.

Marketplaces of the twenty-first century are often characterised by a proliferation of products and services, shorter product life cycles and increased rates of product innovation. Simply responding quickly and at the right time is not enough to meet the needs of such marketplaces. The mission of modern logistics is to ensure that it is the right product – to meet exact end-customer needs – that gets delivered in the right place at the right time. Such a mission means that the *end-customer comes first*. Section 7.2 proposes the agile supply chain as an approach that elevates speed capabilities in a given supply chain to much higher levels than would be possible using the tools and techniques discussed in Section 7.1.

We review the important capabilities required for an agile supply chain – market sensitive, process integration, network based and virtual integration – and how these are necessary to meet both predictable and unpredictable demand variability. Practices to enable agility are many, so we present those that are key, spanning: planning, product design, manufacturing and supply partnerships. Agility can increase costs in terms of the necessary capacities required to respond to volatile demand, so it is necessary to consider the preconditions to applying agility.

Finally, we consider the different ways in which lean and agile approaches can be combined to meet the changing market needs, building on the ideas of segmented supply chain strategy presented in Chapter 2. Lean and agile strategies must be combined and led in order to meet changing customer needs in the most efficient manner.

Key issues

This chapter addresses three key issues:

1. **Lean thinking:** the principles of lean thinking to improve material flow and minimise waste whilst ensuring customer value is delivered. Cutting out waste in all business processes. Simple, paperless systems versus central control.
2. **The concept of agility:** the dimensions of the agile supply chain, and the environments that favour agility. Agile practices: addressing the challenges of market turbulence, rapid response logistics and managing low-volume products.
3. **Combining lean and agile:** careful consideration of the how to minimise waste while delivering the flexibility and responsiveness demanded by the market is a conundrum facing for many organisations. The options available to balance the apparently competing demands need to take into account the skills and leadership challenges that may arise.

We acknowledge and are grateful for Corrado Cerruti's assistance with expanding and improving the section on agility, in particular his research on agile partnerships.

7.1 Lean thinking

***Key issues:* What are the implications of lean thinking principles for logistics? How can lean thinking be applied to other business processes and what are the practices associated with it?**

Lean thinking (Krafcik and MacDuffie, 1989) was the term used in the West to refer to the just-in-time production methods used by Japanese automotive manufacturers, such as the Toyota Production System, as discussed in Section 6.2. Suffering shortages and lack of resources in the 1950s and 1960s, Japanese car manufacturers responded by developing production processes that operated with minimum waste. The term 'lean' was used in the West because production required less space, resource and inventory due to the emphasis on minimising waste. However, waste comes in many forms, as we shall see in the next section.

7.1.1 Types of waste

In Chapter 5 we saw how any activity that does not add value but consumes resource, is a form of waste. By mapping processes through the supply chain, it is possible to sort value-adding and non-value-adding activities (transport, store, inspect and delay). Lean thinking goes further by adding three more types of 'waste' to make seven in all. They are as follows:

- *The waste of overproduction*: making or delivering too much, too early or 'just in case'. Instead, the aim should be to make 'just-in-time' – neither too early nor too late. Overproduction creates unevenness or lumpiness of material flow, which is bad for quality and productivity. It is often the biggest source of waste.
- *The waste of waiting*: takes place whenever time is not being used effectively. It shows up as waiting by operators, by parts or by customers.
- *The waste of transporting*: moving parts around from one process to the next adds no value. Double handling, conveyors and movements by fork-lift truck are all examples of this waste. Placing processes as close as possible to each other not only minimises the waste of transport but also improves communications between them.
- *The waste of inappropriate processing*: using a large, central process that is shared between several lines (e.g. a heat treatment plant) is an example of this type of waste. Another example is a process that is incapable of meeting quality standards demanded by the customer – so it cannot help making defects.
- *The waste of unnecessary inventory*: inventory is a sign that flow has been disrupted, and that there are inherent problems in the process. Inventory not only hides problems, it also increases lead times and increases space requirements.
- *The waste of unnecessary motions*: if operators have to bend, stretch or extend themselves unduly, then these are unnecessary motions. Other examples are walking between processes, taking a stores requisition for signature, and decanting parts from one container into another.

- *The waste of defects*: producing defects costs time and money. The longer a defect remains undetected (e.g. if it gets into the hands of the end-customer), the more cost is added. Defects are counteracted by the concepts of 'quality at source' and 'prevention, not detection'.

Lean thinking invites us to analyse business processes systematically to establish the baseline of value-adding processes and identify the incidence of these seven wastes. The aim is to get parts and data to flow through business processes evenly and synchronously. The more detailed approach, prompted by the concept of seven wastes, encourages a greater analysis and understanding of processes and their relationships than is made by supply chain mapping.

Gradually, the principle of minimising waste spreads from the shop floor to all manufacturing areas, and from manufacturing to new product development and supply chain management. Thus the term *lean thinking* refers to the elimination of waste in all aspects of a business and its supply chain.

7.1.2 The principles of lean thinking

Lean thinking is a cyclical route to seeking perfection by eliminating waste (the Japanese word is *muda*) and thereby enriching value from the customer perspective. The end-customer should not pay for the cost, time and quality penalties of wasteful processes in the supply network. Four principles are involved in achieving the fifth, seeking perfection (see Figure 7.1):

- specifying value;
- identifying the value stream;
- making value flow;
- pull scheduling.

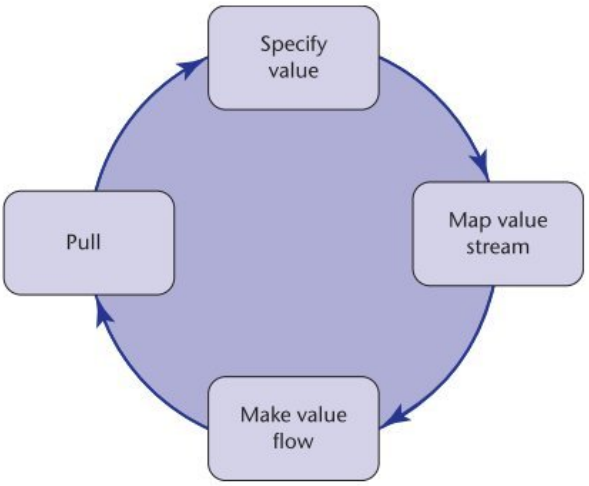


Figure 7.1 **Lean virtuous improvement cycle: striving for perfection**

Principle 1: Specify value

Value is specified from the customer perspective. In Chapter 2 we discussed value from the customer perspective. Value is added along the supply network as raw materials from primary manufacture are converted progressively into finished product bought by the end-customer, such as the aluminium ore being converted into one of the constituents of a can of cola (see Chapter 1, Section 1.1). From a marketing and sales perspective, the can of cola should be 'always within reach of your thirst'. That is an attempt to define value from the end-customer perspective. Another is Porter's concept of the *value chain* (Porter, 1985), which sees two types of activity that are of value to the customer. The first is the primary value activities of transforming raw materials into finished products, then distributing, marketing and servicing them. The second is support activities, such as designing the products, and the manufacturing and distribution processes needed to underpin primary activities.

Principle 2: Identify the value stream

Following on from the concept of value, the next principle is to identify the value stream – the whole sequence of processes along the supply network. The principles of time-based mapping are discussed in Section 5.2 and can be used to map the current state and the future state of the value stream.

Principle 3: Make value flow

In essence, this means eliminating the seven wastes, as identified earlier in Section 7.1. Minimising delays, inventories, defects and downtime supports the flow of value in the supply network. Simplicity and visibility are the foundations to achieving these key factors.

Principle 4: Pull scheduling

Make only in response to a signal that more is needed from the customer (the next process downstream). This implies that demand information is made available across the supply chain. Where possible, supply from manufacturing, not from stock. Where possible, use customer orders not forecasts.

Principle 5: Seek perfection

The fifth principle is achieved by getting better gradually at everything we do, squeezing waste out at every step.

Many supply chains attempt to apply the principles of lean thinking, and Case study 7.1 provides a good example of a food supply chain applying these principles in order to reduce waste and improve flow.

We continue this section by considering the way in which lean thinking can be applied to enriching value in business processes other than manufacturing, where it originated.

CASE STUDY 7.1

Improving value flow in Bernard Matthews' poultry supply chain

Almost a fifth of the UK's wheat crop goes into poultry feed and, although feed supply chains are often short and integrated, there are opportunities to improve the performance, even in these commodity chains. This was found to be the case during a project examining value flow in the feed supply chain for Bernard Matthew's' poultry farms, shown in Figure 7.2.

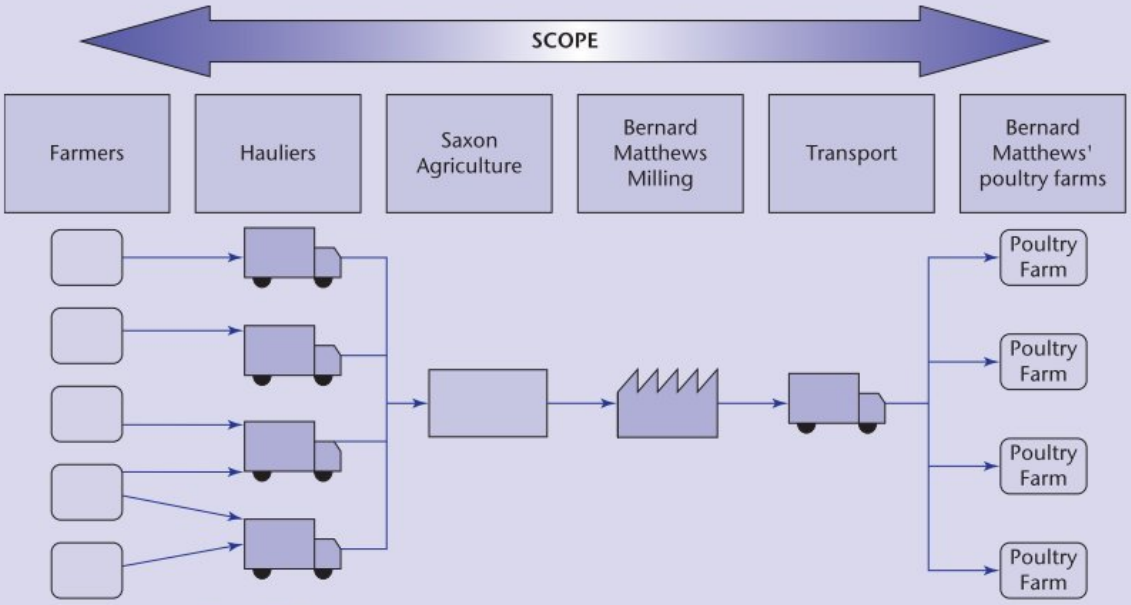


Figure 7.2 Project scope from grain trading to point of delivery into poultry farms

Principle 1: Specify value

In a supply chain it is complex to understand value, since all participants in the chain will have their own needs and expectations about what their internal or external suppliers should deliver. However, by understanding value it is possible to identify activity that does not add value and seek to reduce or eliminate it. A team of four people from Bernard Matthews and Saxon constructed a map of value in the supply chain (as shown in Figure 7.3) by analysing the value at each stage of the process.

The value map was used to understand the impact of various activities on customer value and to define non-value-adding activities. It is interesting to note that the value proposition changes substantially as we go through the chain. Earlier stages focus mainly on price and, to some degree, on quality and delivery, indicating the product's commodity status. However, at the retailer and consumer end, the value proposition appears to be considerably more complex, with the emergence of issues such as choice, brand, packaging, innovation and promotions.

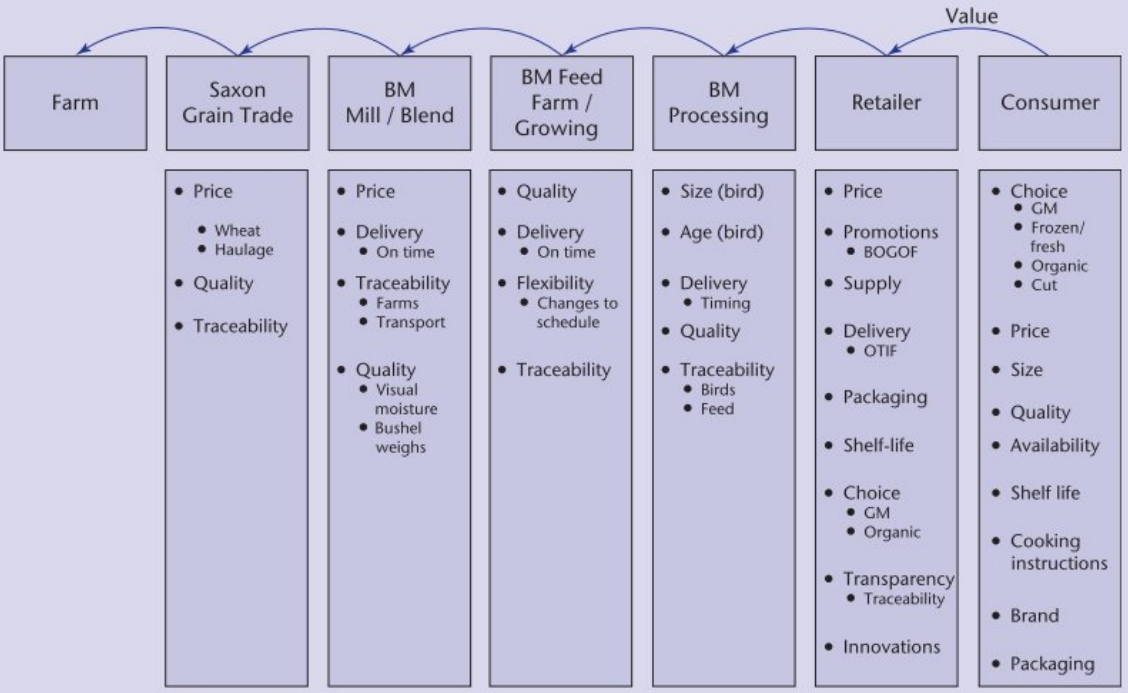


Figure 7.3 Value across the supply chain

Principle 2: Identify the value stream

Both the information and product flows along the supply chain were analysed and the time-based process map, shown in Figure 7.4, was produced.

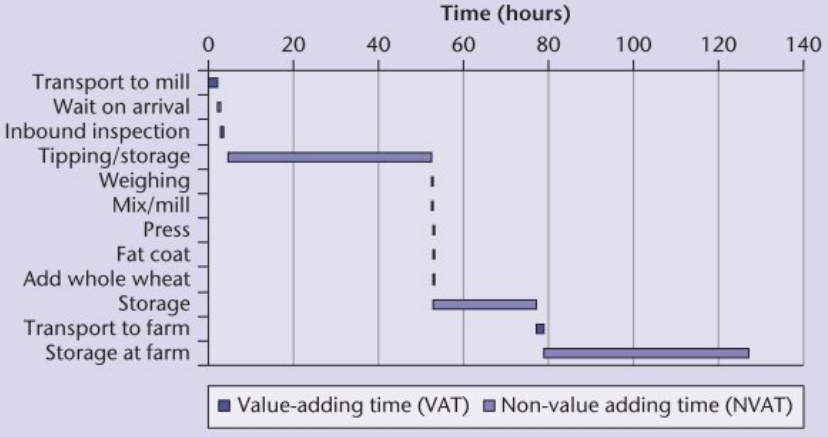


Figure 7.4 Time-based process map from Saxon agricultural transport to Bernard Matthews' poultry farm

This diagram shows that there is a large proportion of non-value-adding time (NVAT) (97 per cent); however, most of this is storage time at various stages. The milling activities are, in fact, very efficient, with an overall cycle time of around 15 minutes with practically no interruptions.

Despite the large proportion of storage time, it is recognised that in this industry, wheat has to be stored at some point in the process and that attempts to reduce stock simply would result in moving it from one stage in the supply chain to another. The question is not about how much inventory is held, but where is the optimal holding point.

Principle 3: Make value flow

Three main actions were identified to improve the value flow:

- *Improve communications.* Details of inventory levels at the poultry farms were not always visible and this created disruptions in orders and required schedule changes at the mill, leading to unnecessary changeovers and wasted time.
- *Reduce delays and inefficiencies in transport.* Transport of raw materials to the mill was identified as an issue in terms of both cost and reliability. An analysis of empty miles in the chain was proposed, particularly with a view to more extensive use of backhauling. Standardisation of processes for loading and tipping would help to improve waiting times.
- *Reduce the frequency of grain sampling.* Grain was being sampled by a number of participants and on several occasions. The use of an independent sampling service would help reduce the wasted time and effort associated with multiple sampling.

(Source: Dr Carlos Mena, Cranfield School of Management)

Questions

1 How might each of the improvement actions identified allow the reduction of inventory at each of the three storage points identified (see Figure 7.4)?

2 Which stocking point may be optimal and why?

7.1.3 Application of lean thinking to business processes

Working back from the end-customer, a focal firm should consider the following processes:

- order to replenishment;
- order to production;
- product development.

In each of these processes, the application of lean thinking involves examining the process, quantifying waste within it, identifying root causes of the waste, and developing and implementing solutions. Examining the process involves mapping

it using a variety of techniques, such as flow charting, depending on the nature of the process. Performance is quantified by taking measures of the different kinds of waste. For a first attempt, using the time-based measures of lead time and value-adding time often reveal the main incidences of waste. Having identified waste, lean thinking applies the problem-solving tools associated with total quality control (TQC) to identify root causes and develop solutions.

The application of lean thinking is the means by which many companies bring their processes under control. Following a systematic approach to tackling waste, they seek to minimise defects, to minimise inventory and to maximise simplicity and visibility.

Order to replenishment

The order replenishment cycle concerns the time taken to replenish what has been sold and assumes that a 'make to stock' approach is being used. Lean thinking seeks to manage the order replenishment cycle by replacing only what has been sold within rapid replenishment lead times. Typically, a *kanban* approach to material flow is used where a *kanban* quantity is defined – this is a fixed replenishment quantity where the replenishment is initiated by the 'customer' of the process sending back a *kanban* ticket.

Order to production

The order to production cycle assumes a 'make to order' approach and is the series of steps that are followed to respond to an order, organise and undertake production, and deliver the product to the customer. This 'make to order' process may be contained within a company or can extend up the supply chain.

Product development

Product development delivers new products or services that can be sold. This process is essential if an organisation is to have future success. Lean thinking can be applied to this process to make it more effective by supporting the development of products with desirable attributes and features, whilst minimising time to market. It can also make the process more efficient and ensure that products are developed to cost. Beyond lean thinking, product development for agility, covered in Section 7.2.2, can reduce further time to market, product development costs and, ultimately, the costs inherent in the supply chain that delivers the product.

7.1.4 Lean manufacturing practices

Lean thinking is associated with a number of operational practices that help to deliver the aim of waste minimisation. Two of the most significant are:

- small-batch production;
- rapid changeover.

These two practices are associated closely with each other, but are considered separately here to aid clarity.

The target in small-batch production is a batch size of 1. The traditional logic behind large batches is to take advantage of reduced costs through economies of scale. The established approach to determining the appropriate batch size in manufacturing is the economic batch quantity (EBQ) (see Section 6.1.3), which is the optimum batch size that mitigates the trade-off between changeover costs and inventory holding costs, given an average demand rate. This is a fair approach, as it considers both production costs and inventory costs. However, since changeovers are typically lengthy and therefore costly, this pushes the EBQ up, leading to large batch sizes, which result in a lack of flexibility. The rationale behind small batches is that they can reduce total cost across a supply chain, such as removing the waste of overproduction and excessive inventory. They help to deliver products that the end-customer wants within the expected lead time (D-time – Section 5.3).

The discussion above links changeover time to batch size – shorter changeovers are lower cost and enable reduced batch sizes (i.e. EBQs). The contribution of rapid changeover was shown graphically by the changeover of press tools used to make car body panels. These cumbersome pieces of equipment can weigh up to 10 tonnes, and historically took up to 8 hours to change within the large presses. The consequence of these long changeover times was that component production runs (batch sizes) were long, often going on for days before the press tools were changed so that another component could be made. Extensive work, again pioneered by Toyota, was undertaken on press design, tooling design and component design over a number of years to help reduce changeover times. The effect has been to reduce changeover times for tools for large pressed parts to around five minutes. Consequently, practices that reduce changeover times are often known as *single minute exchange of dies* (SMED; Shingo, 1988). The ability to undertake rapid changeovers allows a batch of each different body panel to be produced each day in line with current demand, instead of having to produce to forecast.

The lesson from the automotive industry is that even very large pieces of equipment can be developed to allow rapid changeovers. This effort may take a number of years, and is reliant upon developments in machinery and product design. The effect is to provide the flexibility to make possible small-batch production that responds to customer needs.

7.2 The concept of agility

The 'agile supply chain' is essentially a practical approach to organising logistics capabilities around changing end-customer demands. It is about moving from supply chains that are structured around a focal company and its operations (for example, Ford Production System) towards supply chains that are focused on end-customers. Enabling the agile supply chain requires many significant changes: as an example, consider the position of Li & Fung, the largest exporter of textiles into the USA. The organisation coordinates manufacturers mainly across Asia to supply major customers, such as Levi's, mostly in the USA (as described in Case study 7.4). One of the key features of the Li & Fung approach is to establish an organisation that is customer centric, rather than being split into geographic

divisions that end up competing against each other for global customers. The customer-focused divisions were separate profit-making units often dedicated to serving one customer and lead by an entrepreneurial manager.

Mason-Jones et al. (1999) developed a helpful comparison between agile and lean supply, shown in Table 7.1. We have extended this table into our comparison of further characteristics of lean and agile supply, shown in Table 7.2.

There is no reason why there should be an 'either-or' approach to logistics strategy. Thus, many supply chains can adopt a 'lean' capability up to a given downstream process, and then adopt an 'agile' capability thereafter. This enables high productivity, low cost processes to start with, followed by responsive processes to allow high levels of customisation thereafter. Such a strategic choice has been referred to as 'leagility' because it combines the benefits of both supply capabilities. The concept of leagility is close to that of postponement, which we discuss later in this chapter.

The comparisons in Tables 7.1 and 7.2 help us to place 'agile' in relation to 'lean', and thus to complement our earlier concept of logistics performance objectives. In Table 1.1 (in Chapter 1), we considered the issue of competing through logistics. The relative importance of the three logistics objectives (quality, time and cost) can be assessed with the help of order winners and order qualifiers (see Section 1.3.4). To actually win orders demands that performance of the focal firm must be superior to that of its competitors, so that products win orders in the marketplace. The order winner provided by a lean supply chain is *price* as the focus is on waste, and therefore cost minimisation, whereas the order winner enabled by an agile supply chain is *availability* of the product, despite it being subject to volatile demand. In fact, agility is typically appropriate either in the early stages of the product life cycle – during the introduction and growth phase – or for products that simply are

Table 7.1 Comparison of lean supply with agile supply: the distinguishing attributes

Distinguishing attributes	Lean supply	Agile supply
Typical products	Commodities	Fashion goods
Marketplace demand	Predictable and stable	Volatile
Product variety	Low	High
Product life cycle	Long	Short
Order winner	Price	Availability
Profit margin	Low	High
Dominant costs	Physical costs	Marketability costs
Stockout penalties	Long-term contractual	Immediate and volatile
Purchasing policy	Buy materials	Assign capacity
Information enrichment	Highly desirable	Obligatory
Forecasting mechanism	Algorithmic	Consultative

(Source: Adapted from Mason-Jones et al., 1999)

Table 7.2 Further characteristics of lean and agile supply

Characteristic	Lean	Agile
Logistics focus	Eliminate waste	Responsiveness to customers and markets
Partnerships	Long term, stable	Fluid clusters, frequently reconfigure
Performance measures	'World class' output measures, like productivity and cost	Measure capabilities, like responsiveness and flexibility, and focus on customer satisfaction
Employee process focus	Work standardisation, conformance to quality and productivity standards	Focus on operator self-management to maximise autonomy

not allowed to mature, for example fashion products or consumer electronic goods (e.g. mobile phones) where the product life cycles are short.

So far we have focused on the differences between lean and agile. However, there are similarities. Both lean and agile supply chains aspire to establishing product flow synchronised with demand, but of course for lean supply chains this is far simpler as demand is stable and predictable. As discussed under lean practices, in Section 7.1.4, large batches lead to lack of flexibility in responding to changes in demand volume or demand mix (the range of different product variants). It therefore follows that small batch sizes are desirable for both lean and agile supply chains to ensure product flow is synchronised with demand. However, the main drivers for small batches are different – lean requires reduced waste (inventory, changeover time, etc.), whilst agility requires flexibility to changes in demand.

Case study 7.2 compares and contrasts two supply chains for the same cured fish product (bacalao) but that supply two different markets and employ different strategies akin to lean and agile.

CASE STUDY 7.2

Bacalao – two supply chains for two markets

Bacalao is fish that has been salted and dried, traditionally in the open air on rocks; today it is done in a drier. It has been produced in Norway since about 1640, can be kept refrigerated for several years, and is said to improve over time. It has developed a strong position in the food cultures of many Latin countries – such as Brazil, the Dominican Republic and Portugal – where consumers often follow the Catholic tradition of eating more fish on Fridays and in the run-up to Easter. Marketing over many years has created the association with Norway as 'the land of bacalao', or *'bacalhau da Noruega'*, as it is called. It is a matter of great pride amongst consumers to master a variety of recipes for serving bacalao.

The overall supply chain is illustrated in Figure 7.5. It takes at least four weeks to make the end-product. The best fish is wild and taken by line, but trawled fish is also good, whilst nets give the lowest quality because the fish can be dead for a while before being

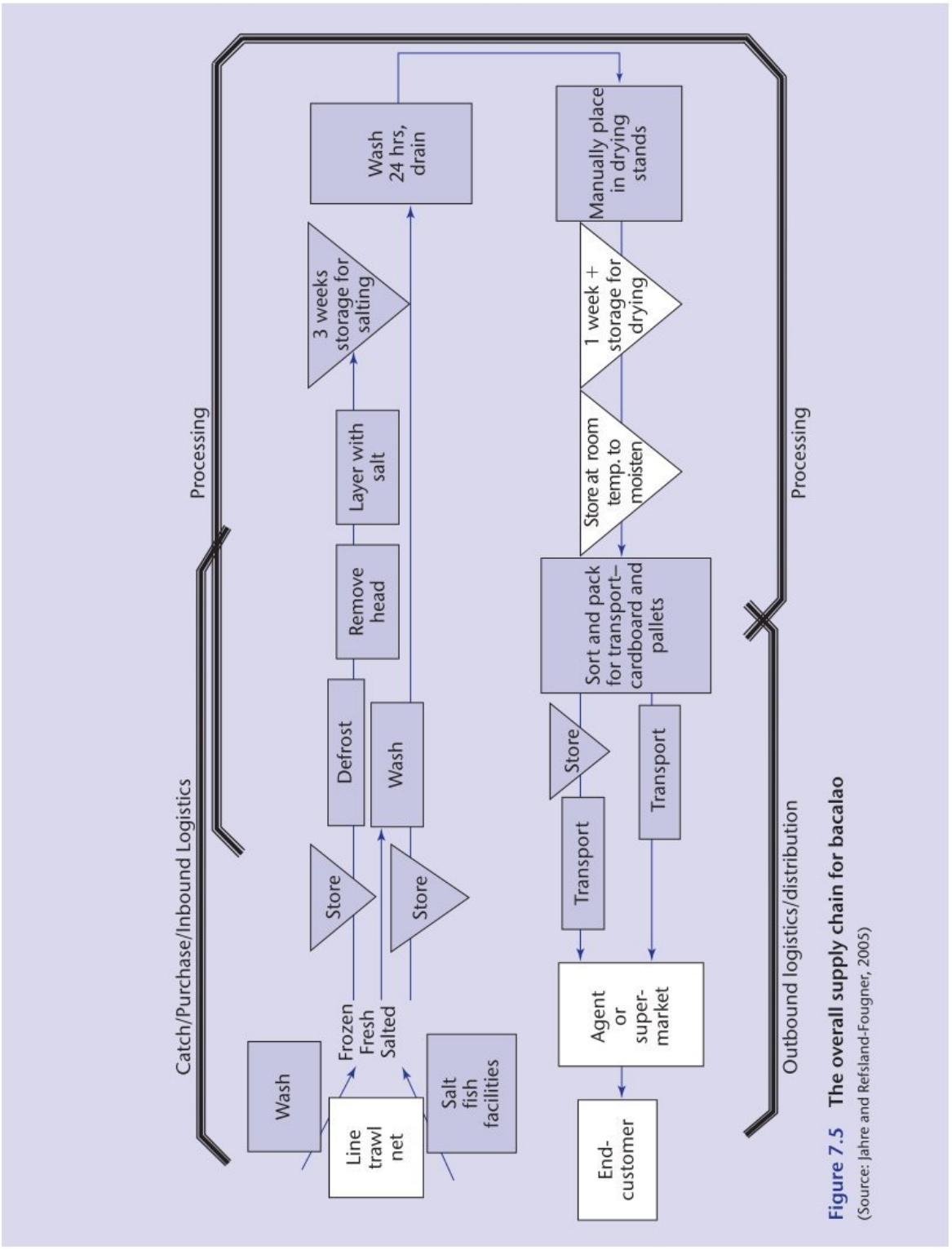


Figure 7.5 The overall supply chain for bacalao
(Source: Jahre and Refsland-Fougner, 2005)

hauled up. Today, the fish is increasingly farmed as well. The raw material is the major cost item: prices are set by the Råfiskelaget (the Norwegian raw fish association). Prices can vary a lot – for example from NOK26/kg to NOK15/kg within a year. Electricity and insurance are the other two major cost items. The fish is slaughtered (and bled on the boat for the best quality), then matured in salt for two to three weeks. After salting, it is dried, sorted, packed and distributed. There are no reliable ways of measuring salt and water content, so manual methods of touching and feeling the fish during each stage are used to ensure consistent quality and weight.

Bacalao is produced mainly from cod, which is preferred by Portuguese customers. But consumers in the Dominican Republic prefer pollock, which is a darker-fleshed fish that is more abundant in the North Atlantic. Cod is up to three times more expensive than pollock. The Norwegian fish industry is highly fragmented, with many small-scale fish farmers, fishermen and producers. Marketing activities are coordinated by the Norwegian Seafood Export Council.

Consumers are very quality conscious when buying bacalao. Quality is determined by colour, texture and firmness, as well as water content and size. Portuguese consumers prefer smaller cod, around 2.5 kilos, whilst consumers in the Dominican Republic are less concerned with size. Note that quality here refers to *grade* of fish rather than to conformance quality: both grades are fit for purpose in the markets they serve.

Bacalhau da Noruega

Company Noruega (CN) has 150 employees, and built its bacalao production facility in 1997 in the Port of Ålesund – which has one of the largest harbours in Norway and one of the most modern fishing fleets in Europe. The company focuses on volume in order to benefit from the economies of scale. Production is stabilised through the year by ensuring a stable supply of fish through sourcing a combination of frozen and fresh fish, creating a buffer of some three to four months' supply. The company trades only in full truckloads, which are distributed via Hamburg or Rotterdam. Product is sold under the generic brand name of *Bacalao da Noruega* in standard transport packaging. Whilst CN serves most Latin markets, 80 per cent of its sales go to the Dominican Republic as pollock bacalao. This market is relatively stable throughout the year, which matches CN's stable production policy. CN is experimenting with pollock farming further to improve supply reliability.

Bacalao Superior

Company Superior (CS) is also based in the Ålesund area, and accounts for 15–20 per cent of Norwegian bacalao exports to Portugal. Only cod bacalao is exported to this market, which commands a 10–15 per cent price premium over other Norwegian bacalao. The product is popular with consumers, which creates a strong relationship with the single supermarket chain that sells it. Fish are sold whole, with a CS tag showing guarantee of origin from fresh Norwegian cod, which was an idea that came from the supermarket customer. This ensures that CS bacalao stands out from other offerings. Joint marketing campaigns are funded by both CS and its supermarket customer, and include TV promotions. Only fresh cod is used in *bacalao superior,* caught by the coastal fleet in small boats. During the winter, supply is heavily dependent on

quotas that are permitted in the famous Lofoten fishing field in the far north. CS buys from three fresh cod suppliers, and from 15–20 suppliers of salt fish. Processing follows traditional routes, but some technology has been introduced into cutting and drying. Finished product is transported to Portugal in 22-tonne truckloads three times per week. Storage of finished product is in Lisbon at the customer's warehouse.

Comparing da Noruega and Superior

Table 7.3 summarises some of the major differences between these two products.

Table 7.3 Comparing da Noruega and Superior

Characteristic	da Noruega (Dominican Rep.)	Superior (Portugal)
Raw material	• Fresh/frozen pollock • Different sizes • Line/trawl/net/farm • Continuous supply • 3–4 months' inbound stocks	• Fresh cod, some salted • Size specific (around 2.5 kg) • Mostly line • Seasonal supply • Small inbound stock
Production process	• High volume • All types of fish processed in a single factory • Undifferentiated packaging	• Low volume • Cod only in single, focused factory • Whole fish individually tagged
Marketing	• Continuous consumption • Generic marketing through Seafood Export Council • Low price • Generic packaging • Little differentiation	• Special occasions • Joint promotion with supermarket customer • Premium price • Tagged to show origin • Differentiated by market

CN accepts more variation in its raw material source to enable continuous supply. This applies to type of fish as well as where and how it is caught. Farming and a healthy stock of frozen fish help to reduce further supply variations. On the other hand, CS seeks the best quality with minimum variation. The only inbound stock that is permitted is small quantities of salted cod.

Whilst the raw materials and end-product have many similarities, there are substantial differences in inbound and outbound logistics as well as processing and distribution strategies. These differences are fundamental to the need to support the brand (raising consumer expectations) by means of logistics strategy (meeting consumer expectations). We can conclude as follows:

- *Two fundamentally different inbound strategies*: CN focuses on secure, continuous supply and accepts greater variation in terms of type of fish, where and how caught – so farming is encouraged. They buffer and store extensively. CS goes for consistently high quality by not accepting much by way of variation: size, line catching and location are all important requirements. They do not store fresh fish or use frozen.
- *Internally consistent marketing and logistics*: CN matches the low price, continuous availability marketing mix by means of efficient sourcing and continuous

availability, and of 'lean' production and distribution methods. This enables high and consistent production volumes supported by a flexible product mix. There is less to go wrong in terms of supply, but the generic nature of the product works against better margins or customer loyalty. CS matches the high price, seasonal availability marketing mix by means of highly selective sourcing and by focused factory production that is seasonal and relatively inefficient. Production is possible only when high-quality, line-caught fresh fish are available. Limited and sporadic availability mean that the product has to reassert itself following supply interruptions, so the marketing pull must be consistent and strong. Traceability through tagging reinforces the superior quality image in consumers' minds, supported by joint marketing with the major retail customer.

The way that the two supply chains have evolved illustrates the trade-offs at stake: more of one thing means less of another. The CS supply chain has become focused on top quality (grade) product, but at relatively high cost and sporadic availability. The CN supply chain has become focused on the opposite: low cost and continuous availability, but at average quality (grade).

(Sources: Jahre and Refsland Fougner, 2005; Alan Harrison, 2010)

Question

1 Discuss and evaluate to what extent Company Noruega (CN) has a lean supply chain and Company Superior (CS) has an agile supply chain.

There is no reason why there should be an 'either-or' approach to logistics strategy. Lean and agile can be combined in different ways (as described in Section 7.3). Further, as discussed in Section 2.3.2, agility costs more. Wherever possible, the supply chain should be lean and waste minimised. However, to respond to volatile demand, capacity and inventory buffers are required.

Agility is defined in many ways but it is understood that it centres on being able to compete and prosper within a state of dynamic change, which involves two aspects: responding to changes (anticipated or unanticipated) in proper ways and due time; exploiting changes and taking advantage of changes as opportunities.

(Source: Zhang and Sharifi, 2007)

Zhang and Sharifi (2007) go on to define a taxonomy based on three types of agility:

1 capability to satisfy and be close to customers;
2 capability to thrive in changes that may be anticipated, e.g. seasonality, promotions;
3 capability to cope with unanticipated changes, e.g. disruption in supply, competitor product introductions.

Whether changes are anticipated or not depends on the organisation's predictive capabilities in terms of sales forecasting (as covered in 'Demand Profiling', Section 2.2), risk management (see Section 4.5) and market research.

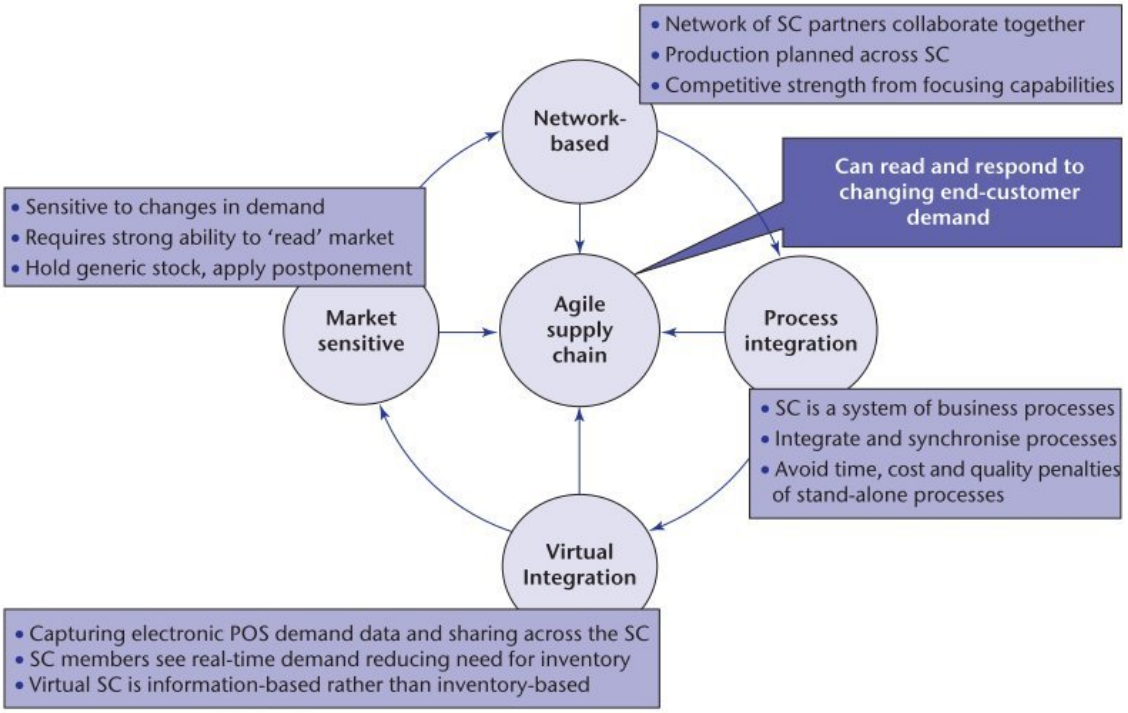


Figure 7.6 Model of agile capabilities
(Source: After van Hoek, et. al., 2001)

Compatible with this view is an earlier understanding of agile capabilities (van Hoek et al., 2001), which defines agility as the capability to read and respond to changing end-customer demand and identifies four distinct capabilities that are required, as shown in Figure 7.6:

- *Market sensitive.* Organisation requires a strong ability to 'read' the market, both in terms of demand for existing products and services and new, hitherto undefined, products and services. This requires strength in terms of market research and being close to the customer.
- *Process integration.* The supply chain can be viewed as a system of business processes, which, if integrated and synchronised (as described in Section 8.1), can avoid the time, cost and quality penalties associated with 'stand-alone' processes. For example, where the component delivery process is not synchronised with the manufacturing process, the penalty will be a high inbound component inventory.
- *Network based.* A network of supply chain partners collaborate to meet the end-customer needs and demand by collaboratively planning across the supply chain. In the case of Li & Fung they configured and orchestrated the whole supply network, as described in Case study 7.4. The competitive strength is gained through focusing the distinct capabilities provided by each company on the end-customer needs.

- *Virtual integration.* This depends on capturing electronic point of sale (EPOS) demand data and sharing it across the supply chain, such that member companies see the 'real time' demand, rather than the distorted picture of demand provided by sales forecasts. This reduces the level of inventory required to buffer against the inaccurate sales forecasts, thus replacing inventory with demand data. However, the proviso here is that even the EPOS data is past demand from the moment it is generated, as opposed to future demand (such as customer future orders) so, when we refer to sharing 'real time' demand data, it is more like the 'latest available' demand data, which can improve forecast accuracy.

Now we have an understanding of the capabilities required for agility, it is time to further consider the practices that will enable these capabilities. However, there are a wide range of practices and:

> **Different organisations experience different sets of changes, and different levels of pressure resulting from the changes, and therefore would require different combinations of practices and tolls to cope with the changes.**
>
> (Source: Zhang and Sharifi, 2000)

Through the rest of Section 7.2 we will consider a selection of agile practices concerned with:

- product design;
- manufacturing;
- logistics; and
- supply partnerships.

This will culminate in a consideration of three preconditions for agility.

7.2.1 Product design for agility

Agile supply chains are a response to shortening product life cycles, typical of fashion products, and proliferating product variants. Equally, agile supply chains must respond to unanticipated changes in demand due to technological or environmental changes, as illustrated by a leading global oil company supplying marine oil for large freight ships. The engines powering these enormous vessels burn considerable oil on every long trip and therefore top-ups are required in each port. Following the financial crisis of 2008, and subsequent global recession, freight ships reduced their speeds to improve fuel consumption. However, an unexpected consequence of this behaviour was an increase in oil consumption. Effectively, the oil was not designed for the new slow speeds. A new marine oil was developed quickly that was appropriate for the slower speeds and, ironically, drew on an old technology from days when ships were slower.

Crucial to achieving market sensitivity necessary for agility is the capability to develop products quickly and efficiently – time to market must be short or the product will have been superseded before it is available or the competition will have cornered the market! But, just as important as the time to market, is production cost and speed. Both these goals can be achieved through product development being coordinated with supply chain design (manufacturing, sourcing and logistics).

Unfortunately, far from being a coordinated process of product and supply chain design, supply chain considerations, such as component sourcing and manufacturing location, are often afterthoughts. As Ellram et al. (2008) observed, there is a lack of inclusion of supply chain decisions in product design, despite the fact that 75 per cent of life cycle costs are determined by product specification (Balasubramanian, 2001). This can lead to higher purchasing costs, excessive transportation and unresponsive supply chains that fail to meet end-customer needs. Here we will discuss a number of approaches to product design for agility.

Design for manufacture and assembly

Recognition of the criticality of coordinating product design and manufacturing process design decisions has led to 'design for manufacture and assembly' (Boothroyd et al., 1994). This involves the careful consideration of component manufacture and assembly early in the product design cycle, reducing the number of components, materials and assembly steps where possible. It thereby reduces the time to market and the production costs through simplification of design.

Concurrent engineering (CE)

Concurrent engineering (CE) requires that the related functions, such as product design, manufacturing and logistics, work concurrently on the product design rather than the 'over the wall' approach. It is renowned for reducing time to market.

Design for supply chain (or design for logistics)

The aim is to keep the product in a 'vanilla' (or generic) form for as long as possible in the manufacturing process by delaying product differentiation. Indeed it is sometimes referred to as *delayed product differentiation* and, as we shall see in Section 7.2.2, it is important to enable the application of form postponement.

Lee (1993 and 1995) develops ideas in this area and identifies three main approaches to design for supply chain or logistics:

- *Product and process modularisation* (Ulrich, 1994; Pine, 1993). Ulrich (1994) claims that 'a completely modular design embodies a one-to-one correspondence between each functional element and physical component, in which every interaction between components is critical to the function of the system'. The idea is that many product variants can be assembled from a relatively narrow range of modules. Pine (1993) identifies six different types of modularity (as shown in Figure 7.7). 'Component swapping' is the complement of 'component sharing' and is where different components are paired with the same basic product, creating as many products as there are components to swap. In many cases the distinction between component sharing and component swapping is a matter of degree. Consider Swatch watches: are the basic watch elements a component shared across all the range of watches (component sharing) or are the watch parts the basic product and the incredible variety of face styles the components (component swapping)? Component swapping is associated

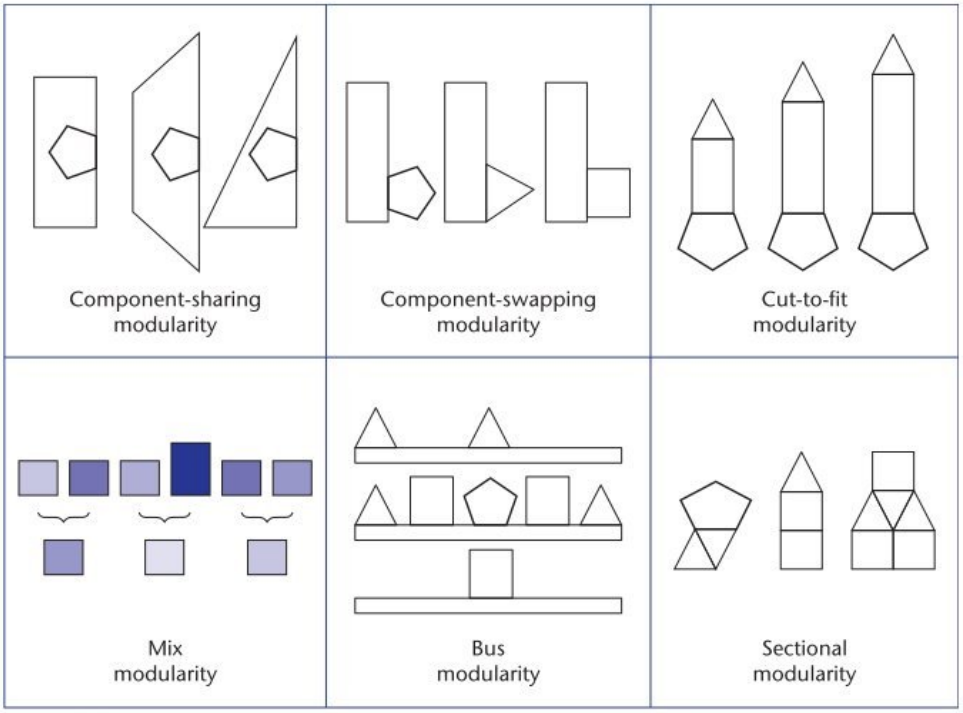


Figure 7.7 Illustration of the six types of modularity
(Source: Abernathy and Utterback, 1978)

often with the creation of product variety as perceived by the customer, as we will see later in the Smart Car Case study 7.3.

- *Product and process standardisation* (Erixon, 1996). This involves standardising and rationalising components across the product range. Ultimately this leads to a standardised product.
- *Process re-sequencing* (Lee and Tang, 1998), such that the differentiating products are postponed. Benetton provides the classic example when the dyeing and knitting processes were swapped, such that the jumpers were knitted out of natural yarn and then dyed when more accurate sales forecasts were available. Dyeing is the main differentiating process – think of the colours of Benetton – so, by delaying it until after the lengthy knitting process, it radically reduced forecast horizon for jumpers by colour.

Three-dimensional concurrent engineering (3DCE)

Fine (1998) effectively brings together concurrent engineering (CE) and design for supply chain by proposing the extension of CE to supply chain design in an approach termed *three-dimensional concurrent engineering* (3DCE). Fine's framework for 3DCE proposes that only those activities that fall into the overlaps between product, manufacturing process and supply chain design need to be undertaken

concurrently by the integrated product team. Many authors cite coordinated product and supply chain design as an area requiring further research. Rungtusanatham and Forza (2005) claim that:

> **Despite the undeniable appeal and importance of coordinating decisions across product, manufacturing process and supply chain design to both science and practice, we know very little about how to do so to maximise operational, supply chain and firm performance.**

They find that coordinating product and supply chain design decisions improves performance in terms of reducing supply chain costs and improving customer service.

7.2.2 Manufacturing for agility

Agility – responding to changes and exploiting changes – requires responsive and flexible manufacturing, which can be adapted quickly to new products and accommodate changes in mix (range of variants) and volume of production with minimum cost or time penalties. Allocation of finished goods to given customer orders is a familiar way of responding quickly to demand – for example, selling cars from a dealer forecourt. But this approach to supply means that inventories of finished goods must be built up first – made-to-stock (MTS). The problem is that they must be built up in anticipation of *unknown* demand, which depends on accurate forecasts. If stocks pushed by a manufacturer onto its dealer network are too high, they will have to be discounted. If they are too low, sales are lost to competitors. Reducing the risks of speculative manufacture by delaying the exact specification of the car until the customer order is known, and then delivering it within an acceptable D-time, is called *form postponement*. The concept of 'postponement' now is increasingly widely employed by organisations in a range of industries (van Hoek, 2001). Form postponement is widely used to improve responsiveness, and is defined (Skipworth and Harrison, 2004) as:

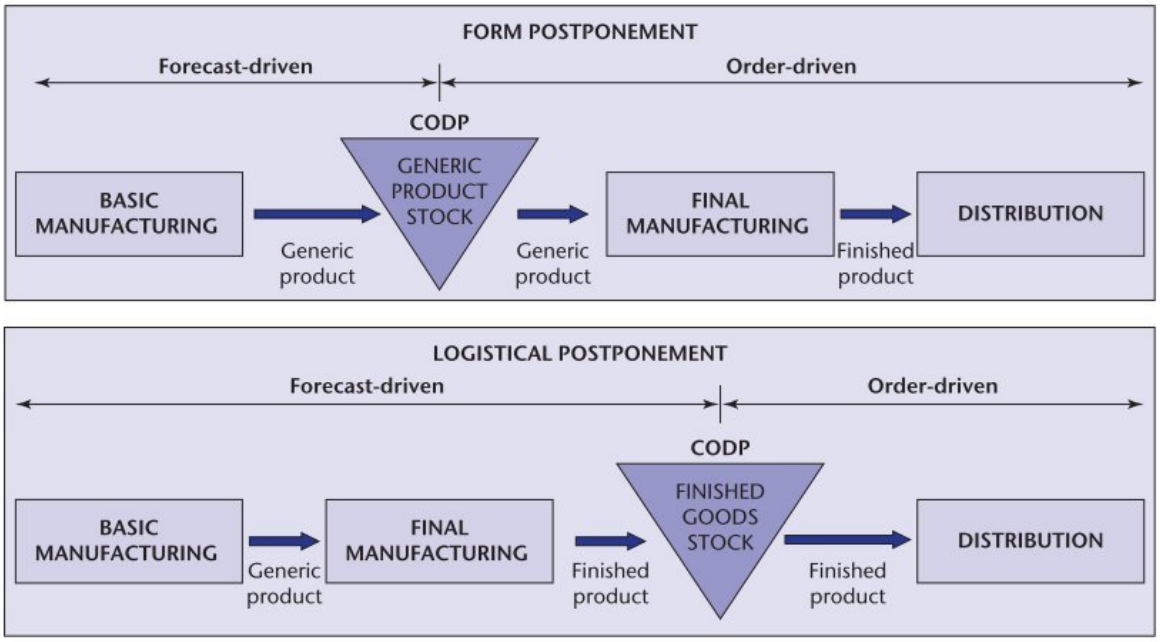
> **The delay, until customer orders are received, of the final part of the transformation processes, through which the number of SKUs proliferates, and for which only a short time period is available. The postponed transformation processes may be manufacturing processes, assembly processes, configuration processes, packaging or labelling processes.**

For example, the aim of the 'three-day car' project is to complete paint, trim, final assembly and delivery of a car to dealer within three days (Holweg and Miemczyck, 2003). However, many less ambitious form postponement applications delay packaging, labelling, adding documentation or product peripherals, all of which are frequently conducted in distribution centres. Further, the postponed process may take place even further downstream, such as paint mixing in DIY retailers, where the customer can choose almost any shade of any colour and the 'vanilla' paint is mixed with a customised combination of pigments to give the precise colour required.

The customer order decoupling point and form postponement

There are two main types of postponement, as illustrated in Figure 7.8, which are distinguished by the location of the customer order decoupling point (CODP),

the point in the value-adding process where a product is linked to a specific customer order. Therefore, downstream from this point production is order-driven and upstream it is forecast-driven (Hoekstra and Romme, 1992). As we discussed in Section 5.3 on P:D ratios, for MTO the production process is entirely order-driven and the CODP is positioned before the beginning of the first transformation process. In contrast, for MTS the entire production process is forecast-driven, because the CODP is located after the end of the last transformation process. In the case of form postponement (FPp), the CODP is at the semi-finished product stage, where the product, or component modules, are in a generic form, as shown in Figure 7.8, thus mitigating the weaknesses of MTO and MTS by enabling a high variety or customised product to be provided on a short lead time with minimum (and generic) inventory. The other type of postponement – logistical postponement – is in essence MTS, where only the distribution is postponed until the receipt of an order. Thus it is akin to centralisation of inventory in, say, a Central European distribution centre.



CODP is the Customer Order Decoupling Point

Figure 7.8 A schematic showing form and logistical postponement
(Source: Skipworth and Harrison, 2004)

Conceptual model for form postponement

Form postponement relies on the product being designed for the supply chain (as explained in Section 7.2.1) such that the appearance of wider customer choice can be created whilst the basic design of the product is the same. The Smart Car Case study 7.3 is an excellent example of this. The conceptual model of form postponement, shown in Figure 7.9, illustrates how it can be applied by bringing together the product/process design and the CODP.

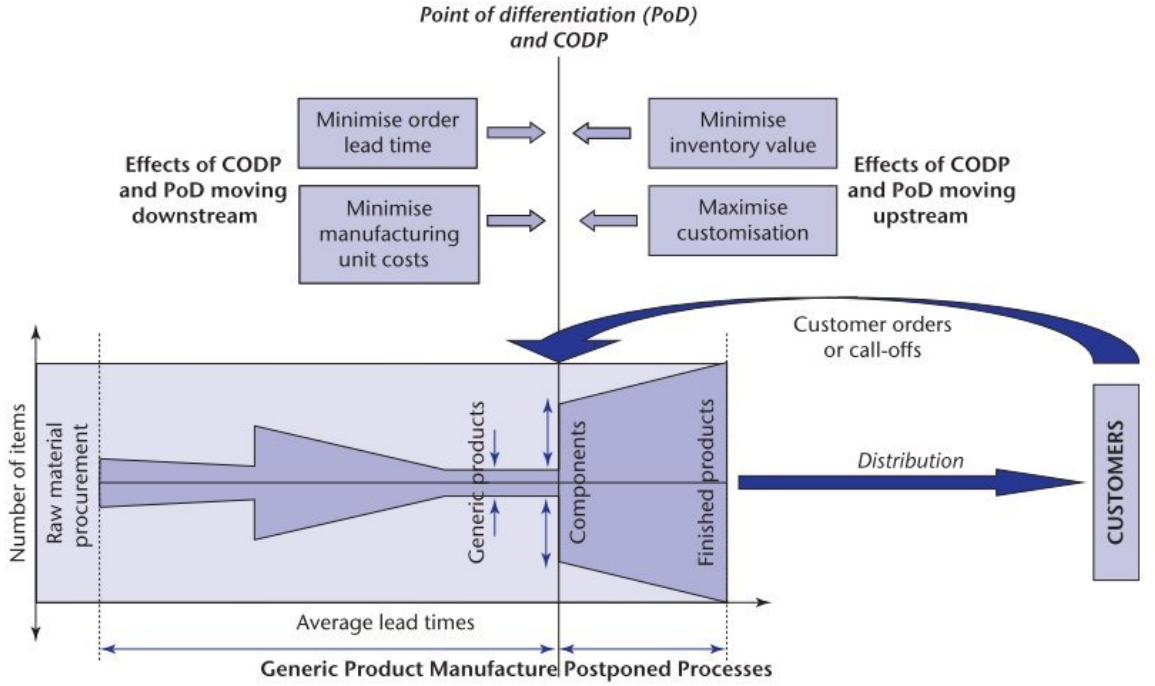


Figure 7.9 **A conceptual model for form postponement**

(Source: Skipworth and Harrison, 2004)

The model is based upon a production variety funnel (PVF; New, 1993), which represents graphically the number of distinct parts that occur at each manufacturing stage. The vertical axis represents the number of items, the horizontal axis throughput time. The PVF is hypothetical, yet typical of FPp applications, and shows how a relatively limited range of components can be assembled into a wide range of finished products. The CODP should be located at a point of differentiation where there are relatively few generic components to be stored, reducing the risk and cost associated with inventory.

The benefits of form postponement are rooted in the fact that it mitigates the trade-offs between MTS and MTO, enabling a customised or high variety product to be manufactured with both a short order lead time (D-time) compared to MTO and a low inventory value compared to MTS. This allows a better match between supply and demand. However, our research (Harrison and Skipworth, 2008) shows that there are many obstacles to successful application of form postponement:

- *Product design*: the extent to which it is possible to standardise the product to give only a small number of generic base products or modules. This is dependent on the demand for the different product varieties as well as the product characteristics themselves.
- *Manufacturing planning and control*: mindsets associated with MTO and MTS are inhibitors to FPp, an aspect of the lack of structural and cultural fit referred to by Yang et al. (2004). MTO and MTS tend not to require either manufacturing planning or manufacturing processes to be responsive in the way that FPp does.

- *Postponed process capacity*: if this is insufficient it may not be possible to maintain the required responsiveness in terms of short, reliable order lead times (D-time).

One final point on the application of form postponement: it is not always customer orders that are used to drive the postponed differentiation processes. In some supply chains, particularly retail chains, it is a sales forecast based on the latest electronic point of sale (EPOS) data. But the form postponement principle is the same – differentiation of the product is delayed until the latest possible moment when more accurate demand data is available.

Now we will consider the Smart Car (Case study 7.3), which illustrates the use of product 'design for logistics', manufacturing approaches for agility and the challenges of entering new geographic markets.

CASE STUDY 7.3

Smart Cars – customisation using the same basic design

Micro Compact Car AG (MCC), a wholly owned subsidiary of Daimler-Benz (formerly a joint venture of Daimler-Benz and Swatch), is the company behind the Smart Car. The Smart City Coupé is a two-seater car measuring 2.5 metres in length, which promotes individual mobility in cities, whilst minimising environmental impact – it requires only half a normal parking space, it is fully recyclable after use and is powered by a relatively small fuel-efficient engine.

Smart Car concept

The Smart Car is a modular design based on a rigid integral body frame or safety cell (called 'TRIDION'), to which external body panels – doors, the front and rear panels – are attached. The customer can customise the product by combining two colours of the frame (black and silver) with the various colours of the external body panels plus internal trim panels and comfort features, not to mention the size and type of engine. This way the customer is given the impression of a high level of choice, although the car is the same basic design, and variation in the manufacturing process is kept to a minimum.

All the customisable parts, with the exception of the engine and the body frame, can be changed through the life of the car at the Smart Centres (the small city dealerships where the cars are sold), allowing the customer easily to repair damage to the car and refresh 'the look' like a fashion item.

Smartville and the supply chain

The Smart Car is manufactured at a purpose-built manufacturing site called 'Smartville' in Hambach (France), with 20 production buildings covering 68 hectares. The seven main module suppliers (plus a number of second-tier suppliers) designed their own modules and invested in dedicated manufacturing facilities, fully integrated with MCC's cross-shaped assembly flow line (as shown in Figure 7.10). The single-stage delivery concept allows Smart Centres to procure their cars – via the sales logistics department – directly from the manufacturing plant in Hambach instead of through a dealer or

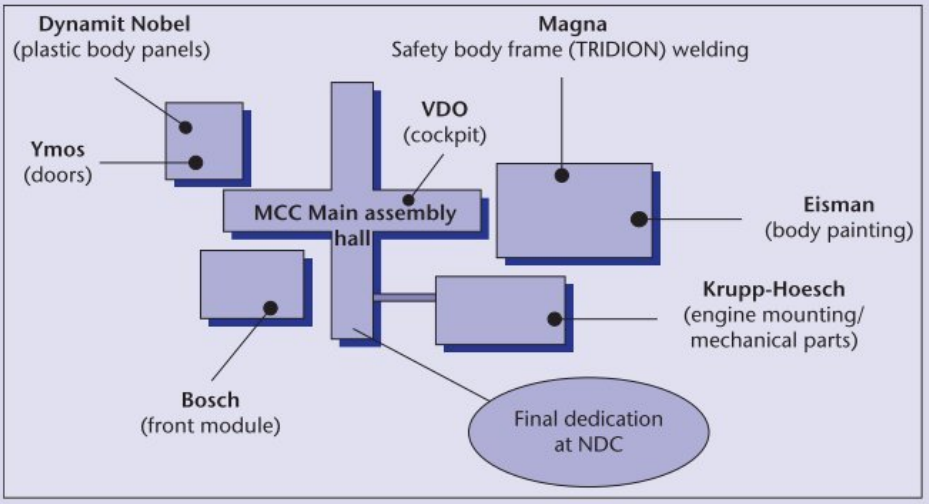


Figure 7.10 Smartville integrated manufacturing plant

import organisation. This distribution system is very different to the tiered sales structure in the traditional automotive industry, in which national sales organisations and importers add another layer between dealers and the manufacturer. This resulted in just a two- or three-week lead time for a made to 'specific customer order' Smart Car, whilst, at the time of the Smart launch, VW had a lead time of up to six months on some models – customers could have what was in stock now, or wait!

As can be seen from Figure 7.11, the manufacturing lead time is seven days with a further week or two allowed for distribution. The order from the Smart Centre is translated into orders for the first- and second-tier suppliers, triggering manufacturing to order up the supply chain. When material has arrived, the modules are supplied in sequence for final assembly by a small number of first-tier suppliers on a one- to three-hour lead time. Final assembly takes just five hours.

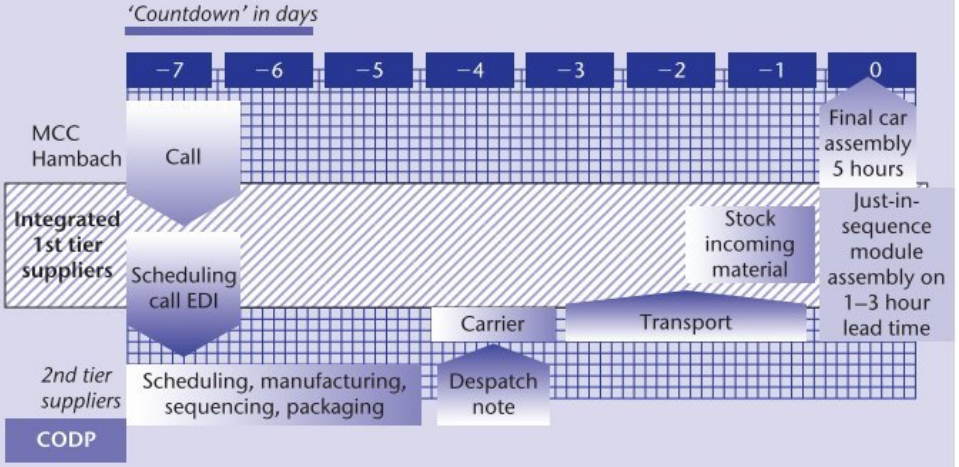


Figure 7.11 Smart Car manufacturing lead time

Initial launch in 1998

In 1998, when production was launched, employment across the site started with 1,500 (only 650 on the MCC payroll), but was expected to rise to 2,200 as the Smart concept took off: the targeted capacity for the year 2000 was 200,000 vehicles a year (or 750 a day). Following a host of teething problems and poor sales (sales in 1999 were half the targeted 120,000), a cost reduction project was pursued in 1999, securing 15 per cent reduction in component costs – 60 per cent of that came from suppliers.

Annual production at Smartville has never come close to the envisaged capacity of 200,000 vehicles (as shown by Table 7.4), in spite of the recession and the soaring price of fuel, which should have favoured the brand. A number of variants on the original ForTwo model were produced – ForFour, ForTwo Cabrio and the Roadster – however they were all discontinued, leaving Smart a single-model brand.

Table 7.4 Smart Car sales

	2006	2007	2008	2009	2010
Total	81,995	102,588	140,072	115,469	97,373

Launch into America

When launched into North America in 2008, sales peaked at about 29,000, but have since fallen from approximately 18,000 (2009) to just 9,000 in 2010. At the start of the Smart Car production it was envisaged that global capacity would be expanded by replicating the Smartville site anywhere in the world, however sales did not justify such investment. Therefore, Smart Cars were made in Smartville (France) and shipped to America.

In March 2007 a $99 reservation programme was launched, but Smart Cars were not planned to be produced for the American market until 2008. This necessitated a long wait for customers and many did not follow through with a purchase.

Questions

1 What could be the rationale behind the decision to conduct the final assembly at the plant in Hambach when the modular product concept would allow product customisation in the dealer channel at the Smart Centres?

2 Why might the lead time (D-time) be long for US Smart Car customers, considering that sales are still a long way below the capacity of 200,000 vehicles per year?

3 How could Smart improve the lead time (D-time) for cars delivered into the USA (without establishing a completely new assembly plant) and what are the associated supply chain issues?

4 Supply partnerships are important to agility but, given the turbulent nature of agile supply chains, what type of partnerships can be established?

3-D printing

3-D printing, also known as additive manufacturing, represents a group of technologies that create objects from the bottom-up by adding material one cross-sectional layer at a time, whereas conventional manufacturing reduces an object

(e.g. steel plates) through cutting, milling and turning to deliver the end product. Printers typically utilise a moving inkjet-print head to deposit material across a build area to create a range of products and customer services. The materials which can be used include polymers, metals, sand, ceramics and composites, as well as organic substances.

The development of 3-D printing has started to challenge the design, manufacturing and flow of parts as the potential of decentralising production becomes a financially viable option. This disruptive technology provides customers with the opportunity of becoming involved with the design and manufacture of the product at the point of consumption. For example, bio-printing is allowing hospitals to provide patients with bone engineering services in-house, simplifying the medical supply chain and improving the success of surgical interventions. On the high street restaurants are also utilising 3-D printing technology, using the ChefJet printer to create customised product designs for diners.

The range of possible printers and materials has led to a multitude of shapes, sizes (from microscopic to the size of large aircraft wings) and applications. The agility of the technology has resulted in several applications for 3-D printing each with its own implications for agile manufacturing;

- *Prototyping*: the rapid production of new product and innovative designs. Firms are actively involving the customer in the design process through quickly printing new concepts which the customer can examine and provide feedback on. This allows firms to incorporate customers' comments and fine-tune ideas before committing cash to tooling (for high volume items) and capacity.
- *Spare parts (equipment and components)*: after-sales service is a key part of any organisation's value stream. Providing spare parts can be costly due to the high-variety and relative low-volume demand of items to be stored. Ensuring a good match between available inventory and demand for such items is problematic due to the unpredictable nature of the demand for spare parts. In addition, each model of product requires spare part provision for its life in use, which can be decades, for example in the case of passenger aircraft. 3-D printing enables parts to be printed to order, reducing the complexity and cost of managing spare parts inventories. The ability to take a previously digitally created object (through a system such as Computer Aided Design (CAD)) and print the item without having to create hard tools reduces the need to hold inventory. Decentralised printers' provide the opportunity to deliver a localised and quick service without the need for centralised spare parts warehousing.
- *Low-volume products*: the ability to print products on demand has the potential to simplify supply chains through minimising lead times and inventories. For low-volume, high-value items 3-D printing can be used to manufacture smaller batch sizes without the need to invest in expensive hard tools such as die-casts. This not only reduces the overall cost of the supply chain but also improves the time to manufacture. 3-D printing provides an agile alternative to traditional MTS process management due to the opportunity to manufacture locally reducing P-time (see Section 5.3). Therefore, decentralising production at a cost which is not prohibitive is becoming a reality for many businesses
- *Customised products*: 3-D printing provides the opportunity for engineering-to-order as the CODP is moved upstream allowing for high levels of customisation

and perceived value by customers (Rylands et al., 2016). Each design can be unique to an individual customer and the batch size can be one, offering a truly personalised product. Further, the flexibility and agility of the technology enables businesses to decouple design and engineering activities from where actual manufacturing occurs.

- Though the technology is still relatively new for many businesses it has begun to cause disruptions in how supply chains deliver value. 3-D printing is appearing in a myriad of sectors including aerospace, automotive, food, healthcare and military. Through its ability to produce small quantities, flexibly, quickly and a relatively lower cost, businesses are actively deploying the technology to gain a competitive advantage. 3-D printing is supporting the movement of the CODP upstream to provide customised solutions. This is leading to a reduction in P-time in a manner similar to the impact of automation (see Section 5.4). However, this is not the only significant change as the technology also supports the production of more complex products with fewer components than would historically be required, leading to the lowering of inventory costs and number of suppliers. Bringing the manufacturing of previously outsourced components inhouse is displacing historical suppliers while introducing new vendors of printers and the specialist printing material (Figure 7.12).

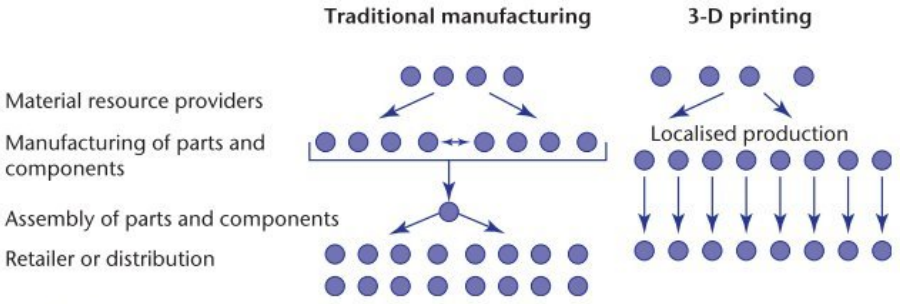


Figure 7.12 Traditional supply chain compared to the supply chain for 3-D printing with localised production

(Source: Thomas and Gilbert, 2014)

3-D printing provides an alternative approach to design and manufacture of products across a wide range of sectors. Most experts agree, however, that it is a complement, rather than a direct competitor, to high volume products due to the low unit costs and high output per hour of mass manufacturing.

7.2.3 Logistics for agility

Through focusing on improving customer experience and end-customer demand, logistics organisations have developed responsive and adaptable distribution networks capable of delivering small volumes quickly and reliably. Digital technologies such as barcode readers, electronic signature capture, tracking software and hardware, i.e. radio frequency identification devices (RFID) tags, and improved reporting functions, support the rapid movement and delivery of products across networks. However, digitalisation of the processes used to deliver customer value is only one

aspect of the changes which are increasing the agility of logistics operators. Automation and robotics (Section 5.4.3) have also reduced the transit time through the warehouse/distribution centre, as well as the cost of labour to pick products. Likewise, improved transport routing, transport mode selection and machine learning has reduced waste in miles travelled, while improving the responsiveness of the distribution system.

Focusing upon customers and what they value has led to the establishment of a network of parcel pick-up and drop-off locations. Recognising the value of time to customers, parcel distributors have developed alternative delivery mechanisms to provide greater flexibility in terms of location and time. This has reduced the frustration experienced by customers when they are not at home to receive parcels as well as the costs associated with failed deliveries and fixed delivery time windows across individual customer delivery locations. The solutions which have been developed satisfy customers' demand for flexibility, while optimising the cost of delivery through consolidation of shipments. Distribution companies have developed new innovative approaches to storing and delivering products. Some have expanded pick-up points by forming a network of small, independent high street retailers where customers can drop off and receive parcels. In the UK, Hermes and collect plus have over 5,000 and 7,000 collection points respectively. Others have installed specialised automated parcel storage lockers at petrol stations and large supermarkets. This removes the need for sales engineers to travel to a central location to pick up equipment as these can now be sent to local 24-hour accessible lockers (Figure 7.13). Morganti et al. (2014) report that in Germany, DHL/Deutsche Post have over 2,500 lockers while in France over 90 per cent of the population is less than a 10-minute drive (or a 10-minute walk in cities) from a locker.

Figure 7.13 **24-hour accessible InPost parcel lockers**
(Source: InPost lockers)

These significant service and infrastructure changes, which place the customer at the centre of the supply chain, have greatly increased the responsiveness and flexibility of logistics operations. Digital and infrastructure innovation has improved the agility of logistics operators; however, organisations are also investing in different types of equipment used to deliver products. Road congestion continues to be a major source of delays and costs, especially in the last mile logistics. To overcome these barriers some businesses are looking towards the sky and investigating the use of drones.

Drones

Drones have become synonymous with military applications and as consumer toys; however, their future as practical logistics tools is beginning to show promise. For example, within the field of humanitarian logistics these remote-controlled flying machines are actively being used in the mapping of disaster sites and delivery of medicines to areas cut off by natural catastrophes. They provide unparalleled and quick access to difficult terrains, particularly in the agile responsive phase of a humanitarian crisis (see Chapter 10 for more on the stages of humanitarian logistics).

Drones have begun to be deployed within day-to-day commerce, creating the opportunity to make a positive change to society, particularly to those in rural and remote areas. Across the globe countries and businesses are developing prototype services to exploit the agility of drones. These initiatives include the following:

- In Rwanda, Zipline operates a commercial service delivering blood supplies packaged inside containers attached to biodegradable parachutes.
- Swiss Post is working with the Ticino EOC hospital group and drone manufacturer Matternet to deliver laboratory samples autonomously between two EOC hospitals in Lugano.
- Google is piloting drone food deliveries in Australia.
- DHL, with its Parcelcopter 3.0, is conducting trials in Alpine areas for transporting goods to remote or geographically challenging locations.
- Amazon has been trialling deliveries within the UK using autonomous drones to deliver packages weighing up to 2.25 kg within 30 minutes.
- Similarly, Google is planning to offer a drone delivery service, as are several retailers including Walmart to improve customer experience.

However, there still exists a significant gap between the publicity the technology is attracting and actual usage. Currently, several organisations are running pilots to experiment with drones. Logisticians are currently faced with many major challenges to the effective use of the technology. Regulators of airspace have yet to establish rules and legislation around the commercial use of drones. Concerns exist regarding the use of airspace and potential conflicts with aircraft. Other legislative issues which need to be addressed relate to citizens' privacy and possible surveillance use. Regardless of these issues. however, several major logistics businesses are investing heavily in drone technology (and supporting big data infrastructure) which will offer greater agility in the future to address the challenges of increasing internet sales and road congestion.

The disruptive nature of drone and 3D technologies is forcing businesses to reassess where and how they manufacture, as well as revaluating the relationships they have with customers and suppliers. The relationships and partnerships which can support changes in such a dynamic and agile environment are discussed in the next section.

7.2.4 Supply chain partnerships for agility

Relationships could be described as the critical success factor of many agile supply chains, which are dependent on a network of supply chain partners that collaborate to meet the end-customer needs by making available their resources to each other. Earlier in this chapter we compared lean and agile, indicating that fluid clusters (such as the supply networks in Section 8.6) – that are frequently reconfigured – are required in agile supply chains, whereas lean supply chains depend on long-term stable partnerships. However, herein lies a paradox: on the one hand agile supply chain relationships can be described as highly involved strategic partnerships, but on the other hand they are frequently reconfigured, which suggests a short-term relationship. This is contrary to the conventional (*stable*) strategic partnerships (described in Sections 8.3 and 8.4), which are expected to have a long duration, in part due to the investment of resource (time and effort) required to establish them and, indeed, the cost of terminating such a relationship.

Agile versus stable supply partnerships

Literature describing agile supply partnerships (high involvement, short term, HI-ST) highlights four characteristics that contribute to overcoming the apparent paradox of partnerships in an agile supply chain. They:

1 are part of a portfolio of both short-term and long-term high-involvement relationships;
2 have project-based features with a clear shared and common goal to be completed within a given time frame, e.g. large construction projects (Gadde and Dubois, 2010);
3 are developed, starting from a group of pre-qualified suppliers with whom the company is collaborating intensively on a recurrent, if not necessarily continuous, basis (Christopher et al., 2004); and
4 are supported by organisational procedures and information technology (IT) tools aimed at creating a standard platform for supply relationship management, to reduce the loss of administrative and operational efficiencies related to a supplier change (Baramichai et al., 2007).

Studying the fashion industry, which requires agility due to its short life cycles, high volatility and low predictability, Cerruti (2013) investigated the types and characteristics of supply partnerships to achieve agility. He proposed a supply partnership portfolio model, shown in Figure 7.14, which defines four types of relationships on the basis on two dimensions: degree of involvement and duration of the supply relationship.

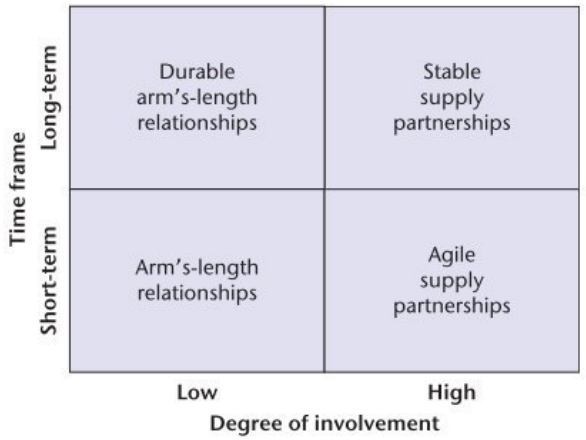


Figure 7.14 Supply relationships portfolio model
(Source: Cerruti, 2013)

Here, a high degree of involvement between a footwear manufacturer and its suppliers of leather and soles, is related to inter-firm knowledge-sharing routines, investment in relation-specific assets and a trust-based governance mechanism (as shown in Table 7.5). An example is the collaboration required to design a high and thin heel for women's shoes, providing an aggressive fashion look but also the required stability. The time frame of the relationship is evaluated in relation to the industry clock speed (Fine, 1998). So, for instance, in the fashion industry, the clock speed is related to the development and delivery of the seasonal fashion collections, normally two collections per year (Spring/Summer and Autumn/Winter). Therefore, Cerruti (2013) considered a supply relationship with an uninterrupted sequence of purchasing orders for more than four seasons to be 'long-term'.

Table 7.5 Indicators of high-involvement relationships

Indicators	Examples specific to the footwear manufacturers
Inter-firm knowledge-sharing routine	In the collection development, the contribution to product development and industrialisation In the production and delivery phase, collaboration in the rescheduling of production and delivery plans related to the frequent 'emergency fighting'
Investment in relation-specific asset	Investment in moulds or other tools dedicated to the manufacturing of customised items Investment in equipment required for customised processes IT hardware and software supporting data exchange
Trust-based governance mechanism	Reliance on verbal agreement (versus formal contracts) with respect to areas such as: delivery timing; schedule replanning; or unconformities settlement

(Source: Cerruti, 2013)

This matrix covers the familiar arm's-length relationships (low-involvement and short-term) and stable supply partnerships (high-involvement and long-term). In addition, it also defines two further options: durable arm's-length relationships (low-involvement and long-term) and agile supply partnerships (high-involvement and short-term). Durable arm's-length relationships are distant relationships maintained over a long period of time, which 'minimise procurement (transaction) costs; allow suppliers to maximise economies of scale, which is critical. . . ; and maintain vigorous competition' (Dyer et al., 1998). Agile supply partnerships, whilst potentially short-lived, are not created by chance, or in an extemporary way, but are the result of deliberate investments (as to IT infrastructure, organisational procedures and/or supplier pre-qualification) aimed at acquiring future degrees of freedom.

Supply partnerships required for agile supply chains

In agile supply chains, both stable and agile supply partnerships are required, but what are the criteria for determining the suitable approach? Cerruti (2013) found that the type of strategic supply partnership (stable long-term or agile short-term) is dependent on the characteristics of the component/service (the extent to which it is impacted by the fashion look) and on the degree of turbulence an agile strategy is designed to face.

Cerruti (2013) studied footwear companies, and their suppliers, in the Macerata-Fermo district, the largest footwear district in Italy. Footwear companies consider agile supply partnerships for categories of supply materials that are sensitive to the fashion trends, such as the leather upper on shoes. They can have 25–30 different leather upper suppliers every season, changing and adding them in order to get a fashion 'look' in line with the expected market trend or simply to provide more variety. These materials are difficult to be sourced in a stable way – season after season – from the same suppliers.

The use of agile supply partnerships is particularly strong in the case of footwear companies that:

- are subject to high-turbulence agility drivers: a high proportion of each seasonal collection was renewed; and
- had developed strong agile capabilities: a local, as opposed to remote, supply network and postponed purchase orders.

In an agile supply chain, strategic supply partnerships, whether agile or stable, aim to focus the distinct capabilities provided by each company on the end-customer. Nowhere do you see this done more successfully than at Li & Fung, who configure and coordinate agile supply chains.

CASE STUDY 7.4

Li & Fung – configuring the agile supply chain

Li & Fung is a Hong Kong based company that was established in the early 1900s as a mediator between Chinese speaking sellers and English speaking buyers. A century later it is one of the world's leading textile exporters (the largest into the USA) and generates a turnover of US$16 billion (2010), 70 per cent of which is from the US and

European markets (2011). Soft goods, such as apparel, account for about 70 per cent of sales, whilst hard goods (e.g. toys, footwear and beauty) make up the rest.

A global supply network

By 2012 Li & Fung had established a global network of 240 sourcing offices across 40 economies and now employs 27,000 people. This enables it to configure and coordinate a vast global supply network across Europe, USA, Asia and Southern Africa, including 15,000 regular suppliers. It configures the entire supply chain (as shown in Figure 7.15) for its clients, which include household brands like Disney, Levi's and Reebok. Depending upon the client requirement, it begins with product design, using an in-depth understanding of consumer needs, and it finishes with delivery into the retailer. Despite this, it is known as a 'smokeless factory' since it doesn't own manufacturing facilities.

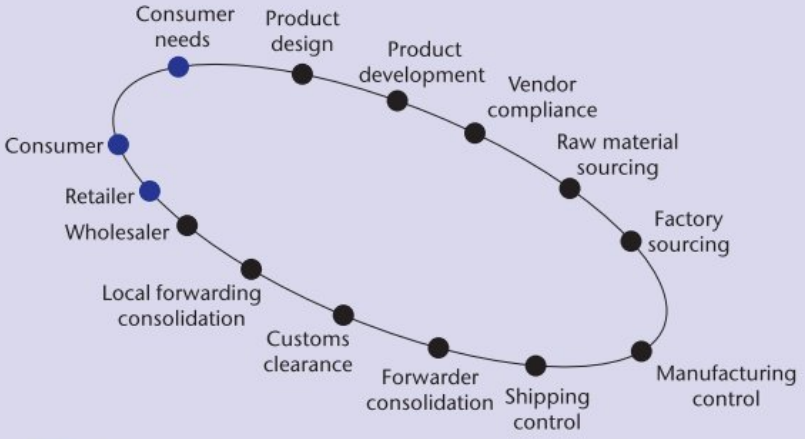


Figure 7.15 The supply chain processes that Li & Fung configure and coordinate

Li & Fung ensures there is plenty of capacity by employing suppliers in parallel for the same components (e.g. yarn providers, weavers, assemblers). This has two key advantages: it allows reduction of lead times and, should unforeseen manufacturing problems occur, production can be switched quickly to another supplier.

To drive down costs, Li & Fung shifts activities to countries with low labour costs, low taxes and favourable regulations, leading to a globally dispersed supply chain, as shown in Figure 7.16, for Levi's jeans. In the past this has meant sourcing from emerging

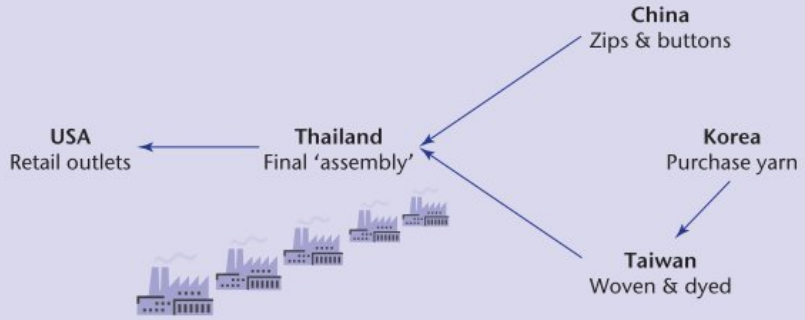


Figure 7.16 Globally dispersed manufacturing processes for Levi's jeans

economies to supply the developed world. However, the three-year plan (2011–2013) declared that, with the emergence of consumer markets in China, and Asia in general, Li & Fung had to reverse the direction of flow for the first time in its history. The company needed to source everywhere, including the developed world, and sell to the developing world.

Supplier management

Li & Fung typically utilises between 30 and 70 per cent of a supplier's capacity to ensure that, on the one hand, they are an important customer but, on the other, the supplier is not entirely dependent on their business. Suppliers enjoy detailed performance feedback based on benchmarking across the network, giving them the opportunity to not only satisfy Li & Fung's stringent requirements but also improve their competitiveness. In any case, there is a strong incentive for suppliers to improve their performance – Li & Fung can provide ample and steady business.

Quick response is a key priority to ensure manufacturing can respond to fluctuating demand without excessive mark-downs or stock-outs. This is achieved by reserving capacity with suppliers on the basis of blanket orders and providing a detailed order breakdown (by size, style and colour) near the time of manufacture – postponed purchasing. In addition, short production runs are expected so production can be altered in tandem with market trends.

(Source: Based on data and information from Gupta and Radika (2005) and McFarlan et al. (2012))

Questions

1 How does Li & Fung enable agile manufacturing?

2 To what extent does Li & Fung develop partnerships with its suppliers and are they 'agile supply partnerships'?

3 Why has the internet not made trading companies like Li & Fung redundant?

7.2.5 Preconditions for successful agile practice

In addition to the above supply capabilities within the supply chain, there is another set of factors that need to be in place for the agile principles and practices to pay off or work at all. These are related to cross-functional alignment and enterprise-level focus on the contribution of logistics management and strategy. If revenue-generating functions (e.g. sales and marketing) in particular do not adopt at least a base-level understanding of agile principles, all efforts within logistics may be wasted. And if there is not an enterprise-wide focus on the potential value of logistics, agile efforts are not going to be recognised for what they are worth – and might not provide a compelling enough business case for the possible investment in them to be made. We propose an *enterprise-level reality check* and a *cost of complexity sanity check* before investing in agile capabilities. We also argue that service measures must put the customer first.

Enterprise-level reality check

Starting with the enterprise-wide context, most senior managers know that turning to logistics and the supply chain is a 'good call' when times get tough. Logistics probably gets mentioned most in earnings reports when cost cutting is a response offered to poor performance. In spite of its potential to contribute to cost-saving programmes, the value of logistics should not be seen as a first port of call when the bottom line needs to be improved. Agility centres on the notion of winning in the marketplace based upon service and responsiveness. Whilst such a strategy can be aimed at doing more for less, it may actually – and more importantly – be doing less to earn more. Top line improvement can flow from outperforming competitors through responsiveness to customer needs. Delivery speed and reliability can be such important sources of productivity to customers that we can earn more of their business and/or charge a premium price for the service, driving increased revenues.

Conversely, if the delivery service does not meet customer expectations, sales can be lost. Marks & Spencer (M&S), a household retail brand in the UK, was faced with online shoppers expecting next-day or even same-day delivery of their orders, but its antiquated technology and delivery systems were not up to the job, Butler (2013) reports. This contributed to seven consecutive quarters of falling sales in general merchandise ranges (clothing and homewares). Whilst rival retailer H&M boasts it can get designs from the drawing board to the store in a fortnight, M&S takes longer than that just to get its merchandise from the ports to the shops. M&S's finance director outlined the scale of the challenge:

> **The business we have got has underinvested in infrastructure for upwards of 20 years. The way the company buys and distributes its clothing. . . [is] no longer appropriate.**

In addition, in a retail supply chain the improved availability, provided by effective agile logistics processes, has the potential to increases sales. In short, an enterprise-level recognition of the contribution of logistics to increases in revenue, as well as improvements in efficiencies, is a precondition for any business case on agile practices.

Cost of complexity sanity check

The value potential of logistics can be capitalised on only if other functions comply with another key precondition: lowering the cost of complexity where differentiation has no competitive value. As much as agility principles are based on the notion that differentiation is good and 'do-able', it does not mean that revenue groups (e.g. sales and marketing) should be given carte blanche to create proliferating service, product assortments and promotions. There are limits to how much value that variety creates, and the extent to which these demands can be met without the cost of complexity spiralling out of control, even for the most agile supply chain. The key point is not to exceed the capability of the supply chain to deliver the marketing promise.

Three examples illustrate the cost of complexity:

- Product, packaging and stock-keeping-unit proliferation, leading to extremes of 80 per cent or more of products not even generating 1 per cent of revenue.
- Delivery speed is too high, resulting in increased costs for the customer because products arrive too early. This increases handling, storage and related costs.
- Promotions and special events that cause upswings in demand based on sales efforts, not on true customer demand. This in turn leads to downswings shortly thereafter.

Whilst differentiation of logistics service can generate short-term gain, the question that revenue-enhancing proposals need to answer is 'will it do so profitably?' Adding a product feature, offering special delivery service and timetables, and engaging in a special promotion might help close a deal in the market in the short term. But such deals can also create added logistics and supply chain costs that are not compensated for by the added revenue. One executive from a manufacturing company put it well:

> **When we showed the financial impact of certain deals our sales teams had closed, it made them realise there were certain deals we should have walked away from.**

Even though it may be hard to assess economic gain or pain from product/service differentiation, reality can be checked by asking questions and pursuing actions that help to reduce non-value-added costs of complexity, such as:

- Has the organisation conducted an analysis of revenue contribution by SKU?
  - *Often a large proportion of SKUs contribute an incredibly small proportion of the revenue.* Remember, some product proliferation produces only short-term sales gains. Consider using a revenue threshold for maintaining a given SKU.
- Does the organisation have a process for reviewing the product portfolio at least annually?
  - *One-off SKU reductions do not address the ongoing tendency to proliferate SKUs over time.* There must be a limit to the number of product variations that the market can absorb? Do customers really value, or even recognise, the new flavour/colour/recipe?
- Are there hard revenue forecasts related to promotion requests that can be evaluated?
  - *Revenue upside potential is used most often to justify adding events and SKUs. Reviewing real sales impact after the event helps force discipline.*
- Is the profitability, as well as revenue contributions, reviewed at SKU level?
  - *Are added warehousing and distribution costs offset against added revenue potential?*
- Do customers *really* want fast delivery, or is reliable delivery more important, even when slower? Do customers *really* want delivery whenever they ask for it?
  - *Understanding what the customers really value about the delivery service is crucial.*
- Are those people ordering shipments aware of the cost of rush orders and are they asked to organise shipment around real and explicit customer requests?
  - *Ticking the 'ASAP' ('as soon as possible') box on a shipment form may become standard behaviour, irrespective of customer need.*

Heineken, the brewer, offers a powerful example of the fourth (profitability) point. During a recent Christmas season it introduced a special product for promotion in the market – the magnum bottle. This seasonal promotion and product won several marketing prizes, and created a lot of buzz (or fizz, even!) in the marketplace. It was also a product that suffered from substantial added shipment, packaging and production costs because different production line set-ups, bottles, labels and boxes were needed for a very limited demand window. Was it worth the effort and focus of the responsive capabilities that were needed for a short-term gain in revenue?

Another powerful illustration of the promotions issue is a tactic that one executive calls the 'warehouse dust test':

> **We take our sales people through our warehouse when they come to us asking for new products and promotions and show them the dust levels on other promotional products and product variations that we stock. We ask them, 'Which products can be discontinued when we introduce a new product?' *or*, 'Do we need the new product to begin with?'**

An important approach to driving improvements in customer service that the customer values is to measure it from the customer perspective.

Develop measures that put the end-customer first

All companies include customer service in some form in their performance measurement system. However, almost all operationalise this measurement internally, leading to responsiveness that is misguided and focused incorrectly, thereby limiting network integration across the supply chain. In particular, most companies measure delivery service in one or multiple ways based upon their internal definition of success. Typically, the measures focus on how reliably and quickly the company delivered against the timetable it put forward. This misses the point, as this timetable might not be aligned with end-customers' needs at all. So companies are not tracking responsiveness to these needs. It is much better to ask customers for their desired delivery window and measure execution against that customer-defined measure of success. General Electric realised this when it presented high delivery reliability scores from its own measurement to customers and received a negative reaction. Customers said performance was not as high at all by their measurement, against when they needed deliveries to take place.

GE changed its measurement set towards what it calls 'Span' measurement. Span stands for the range of delivery around customer-requested due dates. Essentially, the company now measures, across all deliveries globally, how close it was to the delivery date the customer requested when ordering. In its plastics business the company brought Span down from 30 days to just a few days within a matter of months. This means that every customer can depend upon GE delivering any product, anywhere in the globe, when they ask for it, with a maximum variation of just a few days.

The experience of GE suggests the value of several actions to improve measurement for agility:

- Share measurement dashboards with customers.
- Do not measure against your own measures of success; ask the customer what defines success for them.
- Hold all parts of the supply chain accountable against the customer-defined measure of success so that there is no escape from market sensitivity.

7.3 Combining lean and agile

As discussed earlier, there is no reason why there should be an 'either-or' approach to logistics strategy. In any case, lean approaches should be applied wherever possible, as agility always costs more. Lean and agile can be combined in three main ways, as described in Table 7.6.

Table 7.6 Three main approaches to combining lean and agile

Hybrid strategies	Appropriate market conditions
Pareto analysis across a product range – 80:20 Use lean methods for the volume lines and agile methods for the slow movers	High levels of variety Demand is heavily skewed towards a small proportion of the product range
Decoupling point The aim is to be lean up to the decoupling point and agile beyond it, as in form postponement	Product design allows for this so the product remains generic in the early stages of manufacture, e.g. design for supply chain
Separate volatile and base demand for a given SKU Meet the forecastable element of demand using lean principles and use agile principles for the less predictable demand	Where base level of demand can be confidently predicted from past experience

(Source: After Christopher and Towill, 2001)

Considering the three approaches, the Pareto analysis 80:20 strategy proposes using a lean approach for the SKUs accounting for, say, 80 per cent of sales and an agile approach for the remaining long tail of SKUs accounting for, say, only 20 per cent of sales. This effectively segments on the basis of demand volume only, but some SKUs, subject to high volume demand, may also be subject to high demand variability, as shown by the Kimberly-Clark Case study 2.5 in Chapter 2.

In the second approach, where a decoupling point is located when the product is still in a generic form, lean can be used up to the decoupling point and agile beyond it, as shown in Figure 7.17. Form postponement, explained in Section 7.2.2, results in this configuration. The third approach is where the predictable stable demand for an SKU is satisfied with a lean approach and the unpredictable variable demand for the same SKU is fulfilled with an agile approach.

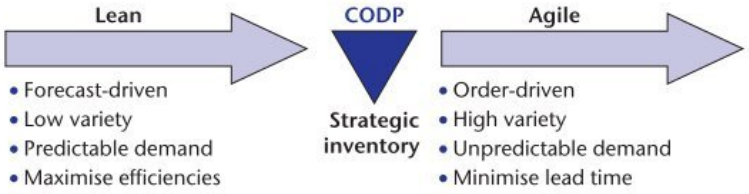


Figure 7.17 Combination of lean and agile using a customer order decoupling point (CODP)

All three of these approaches to combining lean and agile are relevant, but the application of lean and agile strategies should be driven by what the market needs. The approach to segmented supply chain strategy explained in Section 2.3 describes how supply chain strategy drivers (demand, competitive and product) can be used to determine the appropriate supply chain strategy, which may employ lean and agile approaches. Accordingly, the driver matrix in Figure 7.18 provides an example of how specific elements of the competitive profile (lead time and delivery frequency) and demand profile (demand variability) can be used to segment the SKUs and determine the appropriate segmented strategies.

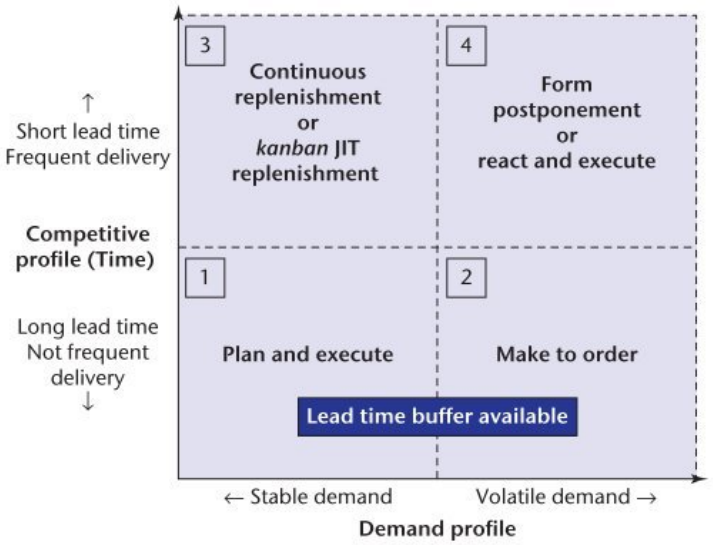


Figure 7.18 An example of a driver matrix showing four supply chain strategies
(Source: After Christopher, 2011, p. 101)

Supply chain strategies 1 and 3 in the diagram are lean approaches where demand is stable, whereas strategy 4 is agile where not only is demand volatile but also a short lead time is required. The four supply chain strategies are described in more detail below:

- *Plan and execute (quadrant 1)*: this is the least demanding situation where demand is stable and the lead time is long. This allows a plan and execute approach where economic batch quantities are used for production and waste is minimised through the most efficient methods of production and delivery by reducing waste in the system. This strategy can be prone to excessive inventories of finished product outbound. High volume, low variety auto products typically are produced by means of this strategy.
- *Make to order (quadrant 2)*: when demand variability is high (volatile), yet the order lead time is long and delivery frequency low, there is the opportunity to make to order. This reduces the risk associated with speculative manufacture based on forecasts, which are highly inaccurate when demand is volatile.

- *Continuous replenishment or kanban JIT replenishment (lean) (quadrant 3)*: if we take the situation where demand is stable but lead times are short and deliveries frequent, then some type of continuous replenishment system is appropriate where deliveries are made on a regular and frequent basis, say daily, or a *kanban* pull system is operated. Both these approaches are part of a lean approach and depend on stable demand. Fast-moving consumer products are examples where continuous replenishment strategies are most often used.
- *Form postponement or react and execute (agile) (quadrant 4)*: in the most challenging situation where demand is volatile and lead time is short, a react and execute approach is required, akin to an agile approach. This strategy prioritises investment in reducing lead time, and building up processes that can respond quickly to volatile demand. If, despite investment in lead-time reduction, the order lead time is still too short to allow full manufacture, the manufacture of the generic product can be conducted speculatively and the final manufacture or assembly can be postponed, as in form postponement.

Deciding upon which supply chain strategy to opt for is a significant step forward for any organisation; however, it still requires skilled personnel and visionary leadership to realise the opportunity and potential that the strategy offers. Case study 7.5 provides an example of a business that has successfully deployed and nurtured a lean and agile approach to deliver value to the customer and the company.

CASE STUDY 7.5

Lean and agile leadership

DW Windsor is a service-led manufacturer of exterior lighting that delivers road and street lighting products and design services to clients globally from their world-class production facility. The business was established in the late 1970's and has continued to flourish through innovation and investing in its people. Within the assembly department of DW Windsor there are two very different sections and processes, reflecting the characteristics of the products they are manufacturing. The low-volume, high-variety agile area assembles bespoke lighting items tailored to specific client needs. The higher-volume, lower-variety lean section manufactures products which are more standardised in terms of components, assembly processes and material flows. Operating within and providing leadership of these two distinct areas is an everyday challenge for DW Windsor assembly management.

Lean and agile assembly areas

The high-volume, low-variety lean area requires employees to conduct repetitive tasks for the duration of their shift while working at a constant tempo and maintaining consistent attention to detail. The ability to produce high quality at a constant rate is critical for the productivity and delivery performance of the area. Any deviation from the standard processes could result in re-work or a customer receiving a product that does not meet the required quality standard. Failure of the assembly line to work at the constant tempo will not only result in an unbalanced line, it could potentially cause

larger-scale problems with regard to logistics. Customer delivery failures and interruptions to material flows from suppliers delivering through JIT will occur if the assembly line does not adhere to its planned schedule.

The low-volume, high-variety agile assembly area operates with standard operating procedures (SOPs) similar to the lean area as both are required to manufacture high-quality and tested lighting products. However, the processes used to assemble MTO bespoke items are extremely varied requiring highly skilled individuals which can work independently while remaining aware of assembly times and customer deadlines. Operating in the agile area requires employees to have multiple skills, a methodical manner and the ability to adapt to sudden changes in what is required of them.

Lean and agile manufacturing approaches each require a significantly different skill and personality profile in employees. Chris Gucci, production manager, encapsulates the differences as follows:

> **The skill set is not so much about training and more about the personality of the individual. An individual who had previously worked in an agile manufacturing system would potentially struggle to adapt to the lean working conditions due to the repetitive nature of the tasks. In contrast, an individual who enjoys the lean approach to working may find the agile area challenging due to the apparent 'unstructured' way people have to self-organise their assembly tasks.**

The skill requirements of the team members operating in the two areas is shown in Table 7.7.

Table 7.7 Lean vs agile skills matrix

Skill	Lean environment	Agile environment
Trained in multiple operations		✓
Ability to work to standard procedures	✓	✓
Ability to deviate from standard procedures to allow for customisable options		✓
Ability to use skills and creativity to complete task to correct quality		✓
Ability to conduct repetitive tasks	✓	
Ability to work at constant tempo	✓	
Ability to problem solve		✓
Can respond quickly to changes		✓
Can work in a methodical manner	✓	✓
Highly responsible		✓
Ability to self-organise		✓

Lean and agile leaders

Each of the two assembly areas in DW Windsor has different team leaders to oversee and support the operators and processes in delivering quality products and service. The team leaders of lean and agile assembly areas have similarities as well as differences in their skills sets that reflect the characteristics of the product and process they manage. All leaders are required to be self-motivated and organised, and have the ability to assess and transfer knowledge and lead change. They are also expected to have a knowledge of lean principles to aid them in driving improvements through identifying what is value added and what is waste. Having the ability to identify problems and resolve them before they occur is another very important aspect of their roles. If a problem can be identified and resolved before reaching the respective lines this will eliminate or reduce any downtime that might have otherwise occurred.

Within the lean environment the team leader is expected to have a knowledge of every aspect of the assembly process and be able to communicate and demonstrate this to his or her team members in a way that allows the operator to then carry out the task to the desired quality level and within the allotted time. Agile team leaders must also have the ability to flexibly move resources within their area to meet changes in demand or process complexity while maintaining performance. In order to achieve this, they must have a knowledge of all aspects of the process and be able to match team members' skills to the tasks required or to source skills from outside their teams to enable them to deliver an on-time customisable solution.

Questions

1 Why might someone operating in the agile assembly area of DW Windsor struggle to work in the lean area and how could these issues be addressed by the team leaders?

2 Combining lean and agile operations within DW Windsor has been successful. What type of relationship would you expect the supply base that supports both areas to have with each of them?

3 What inventory management approaches would you suggest for the two areas?

The vision of creating an agile supply chain is a valuable starting point but until recently it was little more than a vision. The experiences and cases presented in this section show how the vision can be realised and how the implementation of agility can be approached practically.

Summary

What is lean thinking, and how does it apply to logistics?

- Lean thinking is a philosophy that has been derived from JIT principles. It seeks perfection by gradually reducing waste from each of four areas: specifying value from the end-customer perspective; identifying the value stream through time-based mapping; making the product flow through the supply network by applying JIT principles; and letting the customer pull through application of pull scheduling.

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How agile is your supply chain?

Raoul Dubeauclard, Kerstin Kubik, and Venu Nagali

Our research shows that ten operating practices are tied to higher service levels and lower inventory costs.

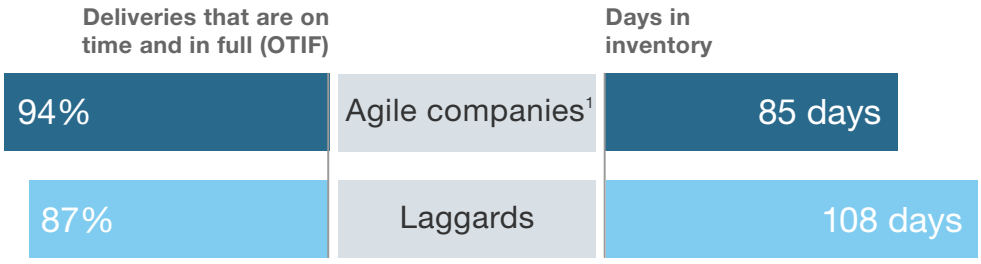
What would it take for manufacturing businesses to operate like the best online retailers? How can such companies turn orders around in a day, deliver them with greater customization, and replenish stocks seamlessly? These aren't idle questions for the top teams of manufacturers, because customers, across both B2C and B2B markets, are more fickle now; service demands are steadily notching upward; and economic volatility shows no sign of abating. Supply operations often struggle to keep pace, as many aren't sufficiently agile to capture fleeting upside opportunities or to mitigate fast-moving risks.

To shed light on the enablers and enemies of agility, we examined the supply-chain performance of companies in five industries, as well as a range of practices that influence it. We analyzed proprietary data from interviews with operations executives at more than 250 global companies. The interviews assessed ten supply-chain capabilities, including portfolio and complexity, order and demand, forecasting, and risk.[1] Responses were plotted on a scale of one to five and the overall agility scores organized into quartiles. We then compared those scores with two widely employed measures of supply-chain performance: service levels, as measured by the proportion of orders delivered on time and as promised,[2] and days of inventory held.[3] Companies with more agile supply-chain practices (as described by executive-survey respondents) had service levels that were seven percentage points higher and inventory levels that were 23 days lower than their less agile peers did (Exhibit 1).[4]

We also looked at specific agile practices and how consistently top-quartile companies adopted them (Exhibit 2). Most, we found, do well in areas such as demand forecasting, labor flexibility, and the optimal placement of inventory across distribution networks. Fewer had mastered capabilities such as modularization and postponement, which require standardized manufacturing and process inputs so that companies can respond more fluidly to fluctuations in demand and to lower stock levels. Most struggled to shape demand, a practice that relies on variable pricing—increasingly grounded

Exhibit 1

Agile companies offer higher service levels even though their inventories are lower.



[1]Defined as those in top quartile in aggregated agility score; all others are laggards.

McKinsey&Company

in advanced analytics—to regulate the flow of products through supply networks and to optimize margins. One example of a company that uses these techniques is Amazon, which adjusts prices and inventory levels in real time in response to competitors' moves, among other things.

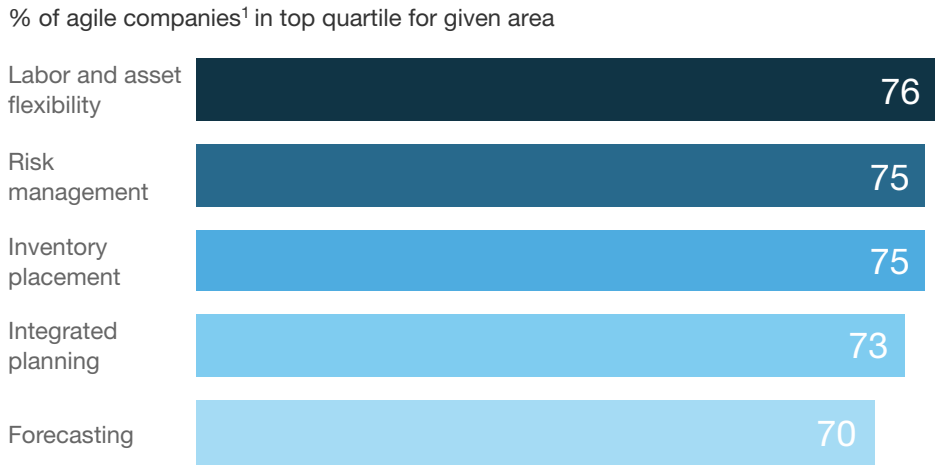
Experience in two industries demonstrates how supply-chain agility accounts for divergent levels of performance among companies.

Chemicals. One top-quartile company is an industry leader producing a full range of chemicals used in agriculture and food processing. After regularly missing shipments as a result of raw-material shortages, executives shook up their operations and now tightly integrate planning efforts with those of suppliers: the company shares data on forward orders with them and solicits their insights into the availability of materials and capacity constraints.

The company has also invested in redesigning processes (the modularization and postponement mentioned above) so that end products can be made more efficiently and quickly from standard inputs that are always in the production stream. Thus, when demand increases for an individual product, a plant manager can access the modular base and rapidly create the final formulation with only a few more steps than would be necessary with nonstandard inputs. That capability has not only sharply reduced the number of end products the company needs to stock but simplified SKU management as well. This company has also negotiated greater labor flexibility across its plant network, easing contractual

Exhibit 2

Agile companies perform well in a number of areas.



[1]Defined as those in top quartile in aggregated agility score.

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constraints on hours worked. In addition, it has trained employees in multiple areas of process knowledge, so teams can quickly shift from one site to another to meet demand peaks. Factories now run at nearly full capacity, with lower logistics costs and far fewer expensive express shipments.

An industrial-chemical company with a broad product portfolio ranks two quartiles lower. Its service levels have slipped, because chronic shortages of materials, resulting from inconsistent coordination with suppliers, often delay shipments. Meanwhile, the company carries high levels of inventory because of its difficulties adjusting work schedules when demand increases.

Consumer products. A large consumer-goods company had trouble meeting demand for its fast-moving food and beverage categories. On closer inspection, it found that a lack of transparency across its supply chain was the culprit. To remedy the problem, the company charged a senior supply-chain executive with managing sales and operations planning end to end—something consumer-products companies often strive to do but rarely get right. After a successful pilot, the company extended the program to most of its suppliers, retail stores, and distributors. Inventory data became more reliable, collaboration improved, and on-time order fulfillment rose significantly.

Operations executives also sought ways to lower the risks when gyrating geographic and seasonal demand patterns put pressure on the supply chain. After a review of the company's distribution network, these executives found they could mitigate customer stockouts by outsourcing a significant portion of their warehouse operations. When regional demand for a line of new products surged, the business could easily add low-cost warehouse capacity.

By contrast, service and inventory performance were less strong at one home-products manufacturer, which like the consumer-products company above boasted a diverse product line but had lower agility scores for operations planning and risk management. Its logistics costs are 25 percent higher than those of the consumer company, and it has been hit by persistent transport problems that require it to carry twice as much inventory.

• • •

Agile practices can help companies navigate an increasingly volatile and unforgiving global economic environment. Only a few companies, however, are adopting these approaches broadly enough to improve their supply-chain performance significantly.

[1] The survey solicited self-reported answers to more than 60 questions on the following topics: forecasting, the ability to shape demand, risk management, modularization and postponement, integrated planning, labor and asset flexibility, network agility, lean fulfillment, inventory placement, and disruption-response planning.

[2] Operations executives use the term "on time and in full," or OTIF.

[3] Inventory days average raw materials, work in progress, and finished goods across the supply chain. For this analysis, we examined more than 70 companies distributed across five industry groups. Industries such as chemicals and pharmaceuticals had higher average inventory levels than consumer products and automotive did.

[4] We found statistically significant correlations between reported OTIF service levels and agility scores across quartiles. Regression analysis also revealed a statistically significant relationship between reported inventory days and agility quartiles.

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SUPPLY CHAIN POSTPONEMENT AND SPECULATION STRATEGIES: HOW TO CHOOSE THE RIGHT STRATEGY

by

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and

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Effective management of a supply chain includes thinking creatively about how to integrate and perform logistics and manufacturing activities. Postponement and speculation strategies offer opportunities to achieve delivery of products in a timely and cost-effective manner by rearranging the conventional production and logistics structures, which are often designed and managed autonomously.[1] Supply chain advancements have frequently been achieved by reducing risk and uncertainty through the employment of sophisticated forecasting techniques, with a low degree of cooperation and integration between the manufacturing and logistics processes. By employing the concept of postponement and combining it with a holistic view of the supply chain, a small number of best practice companies, some of which serve as examples in later sections, have managed to increase the performance of their firms and the supply chain as a whole.[2]

Few substantial efforts have been made to operationalize the theory of postponement and speculation (P/S) in a way useful to managerial decision making.[3] This article identifies generic supply chain P/S-strategies, and provides manufacturing and logistics managers with a diagnostic and normative framework for selecting P/S-strategies. Focus is placed on the downstream part of the supply chain, from factory level to end customer.

THE CONCEPT OF POSTPONEMENT

The concept of postponement has a long history of practical applications, as well as academic literature. Practical application of the concept can be traced back to the 1920's.[4] The first detailed empirical descriptions appeared in the 1960's.[5] In the literature, the concept was originally proposed by Alderson[6] and later expanded by Bucklin.[7] The logic behind postponement is that risk and uncertainty costs

are tied to the differentiation (form, place and time) of goods[8] that occurs during manufacturing and logistics operations. To the extent that parts of the manufacturing and logistics operations can be postponed until final customer commitments have been obtained, the risk and uncertainty of those operations can be reduced or fully eliminated.

The notion of manufacturing postponement is to retain the product in a neutral and noncommitted status as long as possible in the manufacturing process.[9] This means to postpone differentiation of form and identity to the latest possible point.[10] The notion of logistics[11] postponement is to maintain a full-line of anticipatory inventory at one or a few strategic locations.[12] This means to postpone changes in inventory location downstream in the supply chain to the latest possible point.[13]

Two key and very well known contributions to the concept of postponement are the results by Cooper, and Zinn and Bowersox.[14] Cooper identifies four different supply chain postponement strategies for global brands. These are the bundled manufacturing strategy, the unicentric strategy, the deferred assembly strategy, and the deferred packing strategy. In the key work by Zinn and Bowersox, five different types of postponement strategies are identified. Four different strategies of form postponement (labeling, packaging, assembly and manufacturing) which, when combined with time postponement, constitute the five postponement strategies. In a later discussion section, the strategies outlined in this article will be examined in relation to Cooper's, and Zinn and Bowersox's postponement strategies.

The converse concept of postponement is speculation, which holds that changes in form, and the movement of goods to forward inventories, should be made at the earliest possible time to reduce the costs of the supply chain.[15] Speculation makes it possible to gain economies of scale in manufacturing and logistics operations, and limit the number of stock outs.

The remainder of the article is structured into four sections. In the first section, four generic supply chain P/S-strategies are identified and described. The second section will examine different decision determinants suited for selecting a P/S-strategy. A managerial tool, the Profile Analysis, that can be used to select the most appropriate P/S-strategy, is presented in the third section. The fourth section compares and contrasts the presented framework with two key works on postponement by Cooper, and Zinn and Bowersox.[16] Finally, this is followed by a brief conclusion.

IDENTIFICATION OF GENERIC SUPPLY CHAIN P/S-STRATEGIES

A 2x2 matrix presented in Figure 1 identifies four generic supply chain P/S-strategies, by combining manufacturing and logistics postponement and speculation. The matrix will be referred to as the *"P/S-Matrix"*. The four strategies are: *the full speculation strategy, the logistics postponement strategy, the manufacturing postponement strategy, and the full postponement strategy.*

FIGURE 1

THE P/S-MATRIX AND GENERIC SUPPLY CHAIN P/S-STRATEGIES

		Logistics	
		Speculation *Decentralized inventories*	**Postponement** *Centralized inventories and direct distribution*
Manufacturing	**Speculation** *Make to inventory*	**The full speculation strategy**	**The logistics postponement strategy**
	Postponement *Make to order*	**The manufacturing postponement strategy**	**The full postponement strategy**

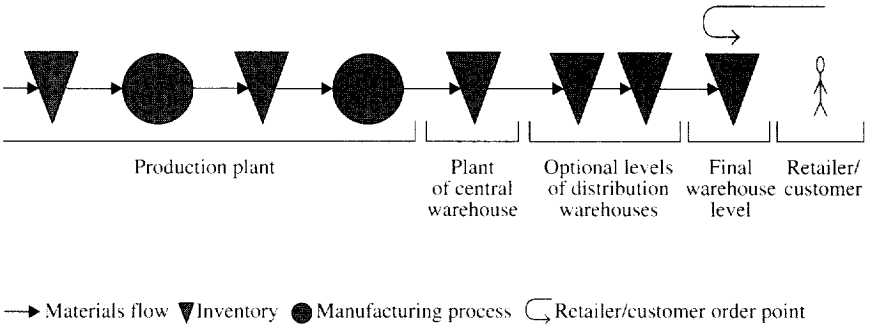
The rows of the matrix represent whether manufacturing postponement or speculation is employed, and the columns whether logistics postponement or speculation is employed. The various strategies have several inherent advantages and disadvantages. Some of these, together with a short description of each strategy are outlined below. The discussion of advantages and disadvantages is primarily based on costs and customer service[17] as evaluation parameters.

The full speculation strategy

This strategy is traditionally the most often used by companies.[18] Based on inventory forecasts, full speculation of all manufacturing and logistics operations is practiced. The retailer/customer order point is positioned at the lowest level downstream in the supply chain. All manufacturing operations are performed prior to the product being differentiated by location. The product is stocked close to customers, and distributed through a decentralized distribution system; see Figure 2.

FIGURE 2

ILLUSTRATION OF THE FULL SPECULATION STRATEGY



An illustrative example of employing this strategy is Xerox.[19] Since 1990, Xerox has been working on integrating the supply chain from supplier to end customer. A main result of the work was three envisioned integrated supply chain P/S-strategies, based on the identification of three different supply chain P/S needs. One of these needs was for Xerox's standard commodity products (plug-and-play products like small workstations, small copiers, telecopiers, etc.). These products are now both fully manufactured and distributed in anticipation of future demand. Commodity stocks are held close to customers, since short delivery time is a vital order-winning criterion. This strategy is similar to the full speculation strategy described above.

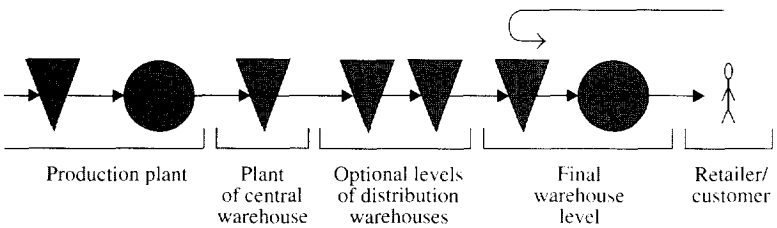
The consequences of employing the full speculation strategy are difficult to generalize. Some points are, however, rather obvious. Full manufacturing and logistics economies of scale can be achieved, since products can be both manufactured and distributed in large lot-sizes.[20] As a result of the decentralized inventories, the inventory investment will be high, the highest of all four of the P/S-strategies. Further, obsolete products and transshipments may occur.

The manufacturing postponement strategy

In this strategy, the final manufacturing operations, whether it is light manufacturing, final assembly, packaging and/or labeling,[21] are performed at some point downstream in the supply chain, after the product, to some degree, has been logistically differentiated. Furthermore, these final operations are deferred until a customer order has been received. This is illustrated in Figure 3, where the retailer/customer order point is positioned prior to the final manufacturing operations. The first stages of the manufacturing process are centralized and inventory initiated. This strategy could also be named the post-factory manufacturing strategy, as described by Schary and Skjøtt-Larsen.[22] Full anticipatory logistics are applied, since products and/or components are distributed and stocked throughout a decentralized distribution system, in anticipation of future customer orders.

FIGURE 3

ILLUSTRATION OF THE MANUFACTURING POSTPONEMENT STRATEGY



One of the first, and now classic, examples of this strategy was to postpone the color of paint to the retailer/customer level. Rather than holding a wide variety of premixed colors, retailers began to stock paint in a neutral color, and customize the final color upon specific customer orders. This of course, dramatically reduced the retailers' number of necessary stock keeping units (SKU's).[23] Another example is Hewlett-Packard's employment of decentralized final customization of their DeskJet printers for the European and Asian markets. Instead of fully customizing the DeskJet printers at the factory, HP decided to postpone the final manufacturing operations (power supplies, packaging, and manuals) until the local distribution centers.[24] It is now only necessary to manufacture, distribute and stock (at the local distribution centers) one kind of DeskJet printer. The final customization, at the local distribution centers, is now based on customer orders. As a result of the decentralization of the final manufacturing operations, manufacturing cost has increased slightly, but the number of SKU's and the safety stock have dropped. Furthermore, the total manufacturing, shipping and inventory costs were reduced by 25%.[25]

The manufacturing postponement strategy can be successfully applied when it is vital to have inventories close to customers, and to the extent that no specialized manufacturing capabilities (e.g. technological or knowledge based) or highly restrictive economies of scale, requires that the operations are performed centrally.[26] The impacts of employing this strategy are several. The variety of differentiated products moved and stocked in anticipation of sale can be reduced,[27] while providing a full assortment. Further, the effect is a reduced total value of inventory and a simplification of the inventory planning and management. On the other hand, the costs and complexity of customer order processing, most likely, will increase. For the manufacturing operations performed downstream in the supply chain, economies of scale will be reduced, as in the HP DeskJet case. Logistics economies of scale will, most likely, not change much.

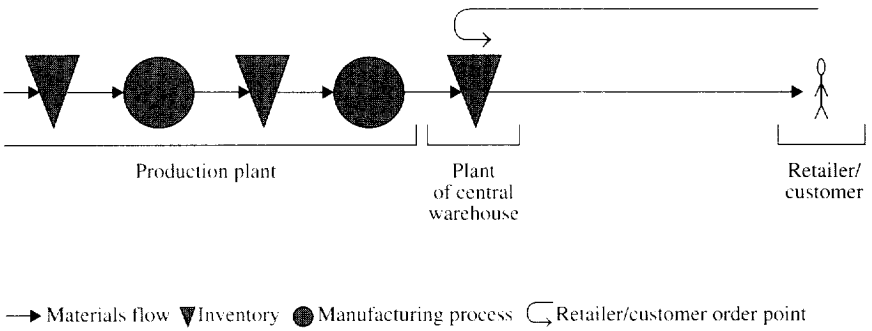
Application of this strategy has increased considerably.[28] Many third-party providers are now capable of performing operations such as labeling and packaging, and in some cases even light manufacturing and final assembly, and even at a very competitive price and quality. Therefore, many companies have decided to spin-off such operations,[29] and thus employ a manufacturing postponement strategy. But as Schary and Skjøtt-Larsen stated, separation of manufacturing stages emphasizes the importance of coordination between the separated stages.[30] The decision then becomes a trade off between cost savings from postponing final manufacturing stages and increased costs because of increased coordination and lack of economies of scale from separating stages.

The logistics postponement strategy

In this strategy, manufacturing is based on speculation, and logistics is based on postponement. This is carried out by direct distribution of fully finalized products from a centralized inventory to final retailers/customers. Figure 4 illustrates that the retailer/customer order point has been moved upstream to the plant or central warehouse level. All manufacturing operations are inventory initiated, and performed prior to the logistics operations. The logistics operations are purely customer order initiated.

FIGURE 4

ILLUSTRATION OF THE LOGISTICS POSTPONEMENT STRATEGY



Applications of this strategy have increased during the last few years.[31] For example, in a study by Abrahamsson, three Swedish international companies (Atlas Copco Tools, Sandvik Coromant and ABB Motors) have changed their supply chain P/S-strategy from a full speculation strategy (stocking fully finalized goods in each European country) to a logistics postponement strategy.[32] Among other things, the change of P/S-strategy has resulted in increased on-time deliveries of complete orders, shorter and more reliable lead-times, reduced inventory costs, constant transportation costs, and faster introduction of new products in the assortment.

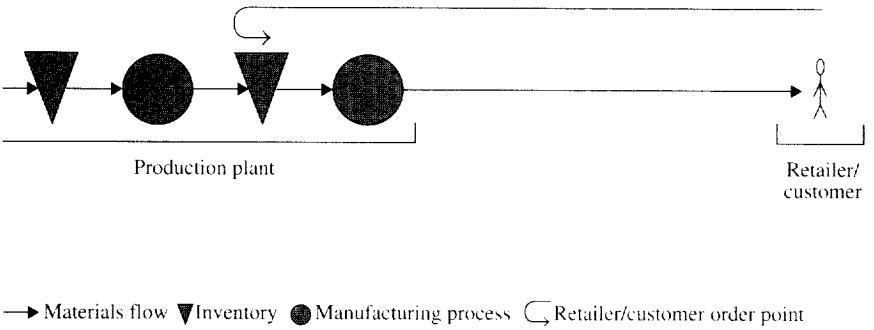
By employing this strategy, the anticipatory nature of logistics is reduced or completely eliminated, since products are distributed directly to retailers/customers. The centralization of inventories reduces the amount of stock required to offer high in-stock availability,[33] but shipment cost may increase due to smaller shipment sizes and faster modes. Finally, manufacturing economies of scale are preserved.

The full postponement strategy

This strategy represents the highest level of postponement application among the four P/S-strategies. Both manufacturing and logistics operations are customer order initiated. In order to shorten delivery time or utilize manufacturing economies of scale it may be beneficial, in some cases, to perform some of the early manufacturing operations in anticipation of customer orders. This situation is illustrated in Figure 5, where the retailer/customer order point initiates the last stage of the manufacturing process.

FIGURE 5

ILLUSTRATION OF THE FULL POSTPONEMENT STRATEGY



An example of employing this strategy is the Danish company Bang & Olufsen.[34] B&O manufactures, distributes, and sells high-end television and stereo systems to a global market with emphasis on design and quality. Based on orders from retail stores, specifically expressing the single customer's unique wishes (units, models, features, colors, sizes, etc.), final assembly and packaging are performed at the production plant, and products are shipped directly to the customer or retailer. Before changing to this strategy, B&O employed the full speculation strategy, resulting in high inventory levels and a slow-response delivering process. Another example is Xerox's fully customized and complex network products that are sold in low volumes. The supply chain P/S-strategy for these products is to fully postpone all operations and only manufacture and distribute the products upon received customer orders.[35]

The result from employing the full postponement strategy is low manufacturing inventory costs and reduction of inventories in the distribution system. Economies of scale will probably only exist in the anticipated stages of the manufacturing process. Logistics economies of scale will most likely be reduced, however recent studies indicate that logistics economies of scale can be maintained.[36]

In the above sections, four generic supply chain P/S-strategies and their general implications have been described. The implications are summarized in Figure 6.

FIGURE 6

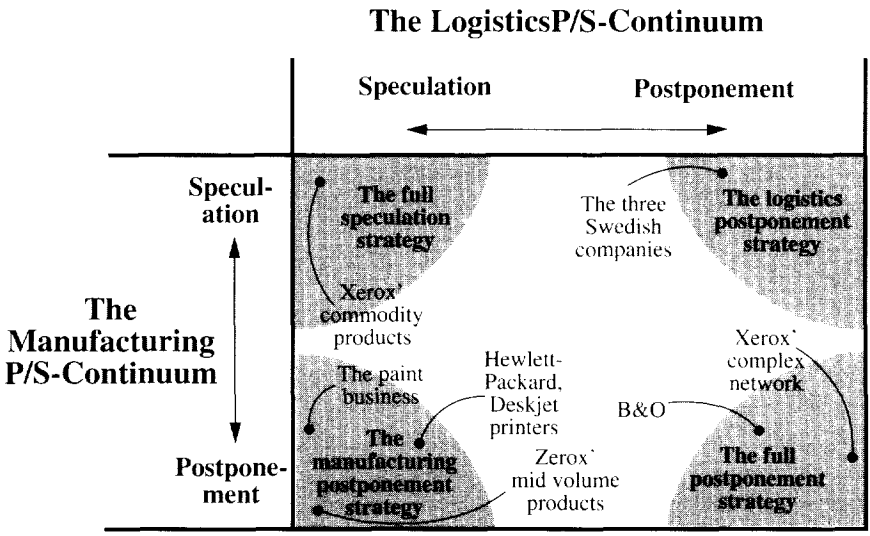
THE P/S-MATRIX, AND IMPLICATIONS RELATED TO EACH GENERIC SUPPLY CHAIN P/S-STRATEGY

		Logistics	
		Speculation	**Postponement**
Manufacturing	**Speculation**	• Low production costs • High inventory costs • Low distribution costs • High customer service	• Low production costs • Low/mid. inventory costs • High distribution costs • Low/mid. customer service
	Postponement	• Mid./high production costs • Mid./high inventory costs • Low distribution costs • Mid./high customer service	• Mid./high production costs • Low inventory costs • High distribution costs • Low customer service

The strategies are end points in a two-dimensional continuum, where each dimension ranges from a full postponement strategy to a full speculation strategy; see Figure 7. In between the four generic supply chain P/S-strategies, a wide range of hybrids exists, which results from mixing together aspects of two or more generic supply chain P/S-strategies. In order to match their specific P/S needs, companies can employ hybrid P/S-strategies.

FIGURE 7

GENERIC AND CONTINUUM OF HYBRID P/S-STRATEGIES, AND POSITIONING OF THE CASE-EXAMPLES



The interesting and inevitable question for managers is: which supply chain P/S-strategy should I use? This question can only rightfully be answered by identifying the supply chain P/S needs. In the following section, the discussion will move on to assess some of the decision determinants that should be considered when identifying the P/S needs and selecting a P/S-strategy.

IMPORTANT DECISION DETERMINANTS

Which decision determinants should be considered when identifying the P/S needs and selecting a matching P/S-strategy? For some companies, it is the structure or constraints within the manufacturing and logistics system, or it may be the product itself and the way it is designed. For others, it is the market and demands from intermediaries and final customers. However, for most companies, the P/S needs are determined by a combination of all three categories, and, accordingly, all three should be considered.[37] Each category comprises a number of decision determinants. In this article the following important determinants will be examined: product life cycle, monetary density, value profile, product design characteristics, delivery time, frequency of delivery, demand uncertainty, economies of scale, and special knowledge.

The product

The *life cycle* of the product, and each stage of the life cycle, are significant for selecting an appropriate P/S-strategy. In the manufacturing, marketing and logistics literature, consensus seems to exist on dividing the life cycle of a product into a series of four distinguishable stages: introduction, growth, maturation and decline.[38] The supply chain P/S needs change across stages of the product life cycle, and consequently different P/S-strategies should be employed.[39] The focus in the first two stages is primarily on customer service,[40] and some degree of anticipatory manufacturing and logistics will likely be appropriate. In the two final stages, a P/S-strategy that minimizes risk, uncertainty, and costs would likely be preferable.[41] As a result, P/S-strategies from the upper-left corner of the P/S-Matrix in Figure 1 will be more appropriate in the first two stages, and strategies from the lower-right corner more appropriate in the two final stages.

The *monetary density* and *value profile* of the product are, likewise, two important decision determinants. Monetary density expresses the ratio between the dollar-value of a product and its weight and/or volume. Since products with high monetary density are expensive to store, but relatively inexpensive to move, it will likely be beneficial to postpone the final logistics operations.[42] In general, the higher monetary density, the greater benefit of applying logistics postponement, and vice versa. The value profile refers to when and how much the product increases in value throughout the manufacturing and logistics process.[43] The value profile of a product should also influence the choice of P/S-strategy. If the major proportion of the product's total value is added in the final operations of the manufacturing or logistics processes, it presumably is beneficial to postpone these operations.

Product design characteristics should strongly influence the choice of P/S-strategy.[44] For a standard product, the risk of speculation is limited. For a highly customized product, some degree of postponement will presumably be beneficial. Cooper identifies three different product characteristics to be important:[45] 1) is the brand global, or is it country specific? 2) is the formulation (such as electrical standards, color, size and software) common to all markets? and 3) are peripherals, such as labels, packaging and instruction manuals, common to all markets?[46] Very different P/S needs result from combining these product design characteristics, and hence different P/S-strategies should be preferred.[47] Standardized and narrow product lines should employ a strategy from the upper-left corner of the P/S-Matrix. The opposite seems to be more appropriate for a specialized and broad product line.

The market and demand

Perhaps the most important determinants for selecting a matching supply chain P/S-strategy are the needs of the final customers and intermediaries. Logistics is a primary means through which customer value is created and delivered to the final customers.[48] Several logistics decision determinants that create customer service/value have been identified that would influence the choice of P/S-strategy. It is not, however, the purpose here to comment on all; yet it is meaningful to examine a few.

The *relative delivery time* and the *relative delivery frequency* are two closely related and important determinants. The relative delivery time refers to the average delivery time to customers, in

proportion to the average manufacturing and delivery lead-time. The relative delivery frequency refers to the average delivery frequency to customers, in proportion to the average manufacturing and delivery cycle time, for the same product. If customers demand a high relative delivering frequency and/or a short relative delivery time, it will likely be appropriate to employ some degree of manufacturing and/or logistics speculation. Therefore, a P/S-strategy from the upper-left corner in the P/S-Matrix presumably should be employed, and vice versa for low delivery frequencies and/or long delivery times.

Another important decision determinant is the degree of *demand uncertainty*. Based on the predictability of products' demand patterns, Fisher has found that products can be classified into one of two categories.[49] Products are either primarily functional, with a low demand uncertainty and long life cycle, or primarily innovative, with a high demand uncertainty and short life cycle. If the uncertainty is high, the risk of speculation will also be high. Therefore, for primarily innovative products, it will be appropriate to postpone the final manufacturing and logistics operations, and vice versa for primarily functional products.[50]

The manufacturing and logistics system

Lastly, it is crucial to acknowledge the constraints within the manufacturing and logistics processes. Two constraints seem to be especially important to most supply chains. To the extent that large *economies of scale* exist or *special knowledge* is needed in the manufacturing and/or logistics processes, some degree of speculation might be beneficial.[51] Consequently, a P/S-strategy from the upper-left half in the P/S-Matrix presumably will be more appropriate to employ, and vise versa.

In this section, several decision determinants have been described. These are not exhaustive. Nevertheless, they do provide insight into some of the aspects that manufacturing and logistics managers should consider when selecting a P/S-strategy. Based on the determinants described above, a managerial tool for selecting the most appropriate supply chain P/S-strategy is presented in the following section.

THE PROFILE ANALYSIS: A MANAGERIAL APPLICATION

Companies need to have a comprehensive understanding of the implications for supply chain performance as different P/S-strategies are chosen. However, when companies choose a P/S-strategy, they often fail to incorporate and evaluate the trade offs, and subsequent implications. Likewise, as the P/S needs change, companies may not recognize that the mix of trade offs embodied in the currently employed P/S-strategy are often relatively fixed, and will remain so unless the strategy is modified.

The main purpose of the Profile Analysis is to assist managers in the process of selecting the most appropriate P/S-strategy, and to identify how the alignment between determinants and P/Sstrategy can be improved. Thus, the Profile Analysis is both descriptive (AS-IS) and normative (TO-BE). The Profile Analysis is a two-step procedure as follows[52]:

1. Select supply chain decision determinants

Select the relevant decision determinants to use in the Profile Analysis; see Figure 8 and Appendix 1. When selecting determinants, it is essential that the selection is based on each determinant's relevancy for choosing the best P/S-strategy. Ballou asks the question: can a satisfactory scope of decision determinants be established that will capture the comprehensiveness of the decision without burdening the decision process with unnecessary details?[53] If the number of selected determinants is too extensive, it will blur the importance of the essential determinants. On the other side, an insufficient number of determinants will not reflect the complete P/S needs, and can result in an inappropriate mismatch between needs and strategy. Many companies may not fully appreciate the complexity of the supply chain, and thus only base their P/S-decision on a limited and often insufficient number of determinants.

FIGURE 8

THE CONCEPT OF THE PROFILE ANALYSIS

Some important P/S-decision determinants			Generic P/S-strategies			
			The full speculation strategy	The manufacturing postponement strategy	The logistics postponement strategy	The full postponement strategy
Product	Life cycle	Stage	Introduction	Growth	Maturation	Mat./Decline
		Volume	Low/Med.	Med./High	Med./High	Low/Med.
		Cost/service strategy	Service	←	→	Cost
	Product characteristics	Product type	Standard	←	→	Customized
		Product range	Narrow	←	→	Wide
	Value	Value profile	Initial stages	←	→	Final stages
		Monetary density	Low	Low	High	High
Market and demand		Relative delivery time	Short	←	→	Long
		Delivery frequency	High	←	→	Med./Low
		Uncertainty of demand	Low	←	→	High
Manufacturing & logistics		Economies of scale	Large	Small	Large	Small
		Special capabilities	Yes	No	Yes	No

2. Profiling and analysis

Profile the supply chain P/S needs in relation to each of the selected determinants, as illustrated in Figure 9. The profile visualizes the degree of alignment between the P/S needs and the generic P/S-strategies. The selection of a P/S-strategy is a trade-off among determinants. The straighter the profile, the better the alignment with one P/S-strategy. The hypothetical profile illustrated in Figure 9 has a relatively straight profile, and is consistent with the "logistics postponement strategy". By predicting how the supply chain will change in the future, it is possible to examine the robustness of the P/S-strategy. Will the P/S-strategy still be in alignment with the needs in the future, or is it sensitive to changes and likely that it must be modified?

FIGURE 9

USING THE PROFILE ANALYSIS;
A MAINSTREAM PRODUCT HAS BEEN PROFILED

Some important P/S-decision determinants			Generic P/S-strategies			
			The full speculation strategy	The manufacturing postponement strategy	The logistics postponement strategy	The full postponement strategy
Product	Life cycle	Stage	Introduction	Growth	Maturation	Mat./Decline
		Volume	Low/Med.	Med./High	Med./High	Low/Med.
		Cost/service strategy	Service	←	→	Cost
	Product characteristics	Product type	Standard	←	→	Customized
		Product range	Narrow	←	→	Wide
	Value	Value profile	Initial stages	←	→	Final stages
		Monetary density	Low	Low	High	High
Market and demand		Relative delivery time	Short	←	→	Long
		Delivery frequency	High	←	→	Med./Low
		Uncertainty of demand	Low	←	→	High
Manufacturing & logistics		Economies of scale	Large	Small	Large	Small
		Special capabilities	Yes	No	Yes	No

It is important to emphasize that most companies operate a portfolio of products and markets, and that the supply chain may be different from combination to combination. This will presumably require that each combination is analyzed separately. Cooper stated that it is important to recognize that some companies will have not just one supply chain P/S-strategy but multiple strategies. This

is most often the case when a company is a member of several supply chains and manages several product groups.[54]

An illustrative example of employing multiple supply chain P/S-strategies is Xerox.[55] As described earlier, one of the main results of Xerox's work on integrating the supply chain was the implementation of three different P/S-strategies, based on the identification of three different supply chain needs. The one end of Xerox's product/market spectrum is the fully customized and complex network products that are sold in low volumes. These products employ the full postponement strategy. The other end of the spectrum is the standard commodity products (plug-and-play small workstations, small copiers, telecopiers, etc.). These products use the full speculation strategy. In the middle of the spectrum are the mid-volume product types. These products employ a manufacturing postponement strategy. Thus, Xerox has identified several different P/S needs and consequently the need for several different P/S-strategies. Another illustrative case is Volvo GM.[56]

For the best performance of the supply chain, it is essential that the P/S-strategy fit the P/S needs. The barriers to accomplishing that are the realities of designing and managing supply chains. It is highly complex, involves long-term decisions, and possibly large and fixed investments. Hill stated that "in many instances though, companies will be unable or unwilling to take the necessary steps to provide the degree of fit desired because of the level of investment, executive energy, and time-scales involved. However, sound strategy is not a case of having every facet correctly in place. It concerns improving the level of consciousness a company brings to bear on its corporate decisions. Living with existing mismatches or allowing the level of fit to deteriorate can be strategically sound if a company is aware of its position and makes these choices knowingly."[57] The Profile Analysis can provide increased awareness, and allow a conscious choice among P/S-strategies.

Based on the above, the Profile Analysis provides managers with a tool to identify: the supply chain P/S needs; the supply chain P/S-strategy that provides the best mix of trade offs; the degree of alignment between P/S needs and P/S-strategies; and the robustness when anticipating changes in the supply chain needs.

DISCUSSION

In this section, the concepts of this article are compared and contrasted with the key works by Cooper, and Zinn and Bowersox, in terms of approach and P/S-strategies. Cooper[58] identifies four different supply chain postponement strategies for global brands based on "yes" and "no" answers to questions related to different product characteristics; see Figure 10. Zinn and Bowersox[59] identify five different postponement strategies; four different strategies of form postponement (labeling, packaging, assembly, and manufacturing) plus time postponement.

FIGURE 10

THE BASIC CONCEPT OF COOPER'S KEY WORK

		Formulation: Is formulation common to all markets?	
Product characteristics		No	Yes
Peripherals: Are peripherals common to all markets?	Yes	Bundled manufacturing strategy	Unicentric strategy
	No	Deferred assembly strategy	Deferred packing strategy

Source: James C. Cooper, "Logistics Strategies for Global Businesses," *International Journal of Physical Distribution and Logistics Management*, Vol. 23, No. 4 (1993): 12-23.

Cooper's four postponement strategies are strongly related to the five postponement strategies identified by Zinn and Bowersox, and the strategies identified in this article. However, some important differences exist. Zinn and Bowersox's labeling and packaging postponement strategies correspond to Cooper's deferred packaging strategy. Similarly, Zinn and Bowersox's assembly and manufacturing postponement strategies closely relate to Cooper's deferred assembly strategy, since they mainly differ in the degree of warehouse assembly that occurs. Clearly, all of these postponement strategies are strongly related to the manufacturing postponement strategy identified in this article. They primarily differ in the degree of form postponement employed. Therefore, these postponement strategies can fit within the manufacturing postponement strategy. The fifth postponement strategy identified by Zinn and Bowersox, time postponement, is closely related to the unicentric strategy identified by Cooper, and to the logistics postponement strategy identified in this article.

Further, the bundled manufacturing strategy identified by Cooper, which does not have an obvious equivalent to the strategies identified by Zinn and Bowersox, is strongly related to the full postponement strategy identified in this article. The aim in both strategies is to retain product commonality as far downstream in the manufacturing process as possible. This leaves the full speculation strategy that neither Cooper, or Zinn and Bowersox include as a strategy option.

An interesting point, when comparing and contrasting Cooper's, and Zinn and Bowersox's key works with the concepts outlined in this article, is the extensiveness of decision determinants incorporated in the models. Cooper solely bases his identification of supply chain postponement strategies on product characteristics, whereas Zinn and Bowersox incorporate a wider range of determinants, including demand, demand uncertainty, product value, number of brands, and number of package sizes. In the Profile Analysis, the managers decide the number of determinants, and most importantly, it is a trade off between comprehensiveness and level of detail in the analysis, as described earlier.

In summery, the P/S-strategies identified in this article are similar to the strategies identified by Cooper. However, Cooper solely considers product characteristics as a determinant. On the other hand, Zinn and Bowersox consider a wider range of decision determinants, but do not include the possibility of employing postponement at the production plant level.[60] These similarities and contrasts make the key works by Cooper, Zinn and Bowersox, and the concepts presented in this article, mutually supporting, and thus together further operationalize the theory in a way that is useful to managerial decision making.

CONCLUSION

In conclusion, this article provides insight in three key areas. By using the P/S-Matrix, four generic supply chain P/S-strategies have been identified. The strategies do represent distinct and realistic supply chain P/S-strategies, as the empirical examples cited in the article indicate. Second, important P/S-decision determinants were proposed. Finally, a descriptive and normative tool (the Profile Analysis) was presented for selecting the most appropriate supply chain P/S-strategy. In short, the article provides managers with a framework of generic supply chain P/S-strategies, and a diagnostic tool to assist in the selection of a P/S-strategy for supplying products.

Many companies have identified a need to improve their processes for manufacturing and delivering products. One way of doing that could very well be to eliminate the inconsistency between the P/S needs and the P/S-strategy. Eliminating the inconsistency is not easy, but as Fisher stated "the reward - a remarkable competitive advantage that generates high growth in sales and profits - makes the effort worth it."[61]

NOTES

[1]Christopher Gopal and Gerard Cahill, *Logistics in manufacturing* (Business One Irwin, Homewood, Illinois, 1992), p. 68; and Martha C. Cooper, Douglas M. Lambert, and Janus D. Pagh, "Supply Chain Management: More Than a New Name for Logistics, *The International Journal of Logistics Management*, Vol. 8, No. 1, 1997, pp. 1-14.

[2]Donald J. Bowersox, "Lessons Learned from the World Class Leaders," *Supply Chain Management Review*, 1:1(1997), pp. 61-67.

[3]James C. Cooper, "Logistics Strategies for Global Businesses," *International Journal of Physical Distribution and Logistics Management*, 23:4 (1993), pp. 12-23; and Walter Zinn and Donald J. Bowersox, " Planning Physical Distribution with the Principle of Postponement," *Journal of Business Logistics*, 9:2 (1988), pp. 117-136.

[4]Global Logistics Research Team at Michigan State University, *World Class Logistics: The Challenge of Managing Continuous Change* (Oak Brook, IL: Council of Logistics Management, 1995).

[5]See e.g. Stanley H. Brewer and James Rosenzweig, "Rhochrematics," *California Management Review*, 2:3 (Spring, 1961), pp. 52-71; and R. Cox and C. S. Goodman, "Marketing of House Building Materials," *The Journal of Marketing*, 21:1, (July 1956), pp. 36-57.

[6]Wroe Alderson, "Marketing Efficiency and the Principle of Postponement," *Cost and Profit Outlook* 3 (September 1950).

[7]For a historical perspective regarding the concept of postponement, see e.g. same as references Notes 5 and 6, Wroe Alderson, *Marketing Behavior and Executive Action* (Homewood, IL: Irwin, 1950); Louis P. Bucklin, "Postponement, Speculation and Structure of Distribution Channels," *Journal of Marketing Research*, 2 (February 1965), pp. 26-32; Louis P. Bucklin, *A Theory of Distribution Channel Structure* (Berkeley, CA: IBER Special Publication, 1966). For further information regarding postponement, see e.g. same as Note 3; Donald J. Bowersox and David J. Closs, *Logistical Management: The Integrated Supply Chain Process* (New York, NY: The McGraw-Hill Companies, INC., McGraw-Hill Series in Marketing, 1996); Martin Christopher, *The Strategy of Distribution Management* (Butterworth and Heinemann, The Marketing Series, Professional Development, 1992); Renko I. Van Hoek, Harry R. Commandeur and Bart Vos, "Reconfiguring Logistics Systems Through Postponement Strategies," *Proceedings of the Twenty-Fifth Annual Transportation and Logistics Educators Conference*, October 20, (1996), pp. 53-82; Douglas M. Lambert and James R. Stock, *Strategic Logistics Management* (Homewood, IL: R.D. Irwin, 3'rd ed., 1993); Philip B. Schary and Tage Skjøtt-Larsen, *Managing the global supply chain* (Handelshøjskolens Forlag, 1996); and Louis L. Stern and Adel I. El-Ansary, *Marketing Channels* (Englewood Cliffs, NJ: Prentice Hall Inc., 4'th ed., 1992).

[8]Bucklin 1965, reference in Note 7.

[9]Bowersox and Closs, p. 472, reference in Note 7.

[10]Bucklin 1965, reference in Note 7.

[11]Logistics postponement is also referred to as geographic and/or time postponement, see e.g. Bowersox and Closs, p. 472-473, reference in Note 7.

[12]Bowersox and Closs, p. 473, reference in Note 7.

[13]Bucklin 1965, reference in Note 7.

[14]Same reference as Note 3.

[15]Bucklin 1965, reference in Note 7.

[16]Same reference as Note 3.

[17]With customer service we mean product availability and delivery time.

[18]Zinn and Bowersox reference in Note 3.

[19]This illustrative case is also based on Robert C. Camp and Dan N. Colbert, "The Xerox quest for supply chain excellence," *Supply Chain Management Review*, 1:1(1997), pp. 82-91; and a case-example in Christopher, p. 216-227, reference in Note 7, originally written by M. Stenross and G. Sweet of Xerox Corporation, USA.

[20]Bucklin 1965, reference in Note 7.

[21]Zinn and Bowersox, reference in Note 3.

[22]Schary and Skjøtt-Larsen, p. 86, reference in Note 7.

[23]Charles Scott and Roy Westbrook, "New Strategic Tools for Supply Chain Management," *International Journal of Physical Distribution and Logistics Management*, 21:1 (1991), pp. 23-33; and Bowersox and Closs, p. 472-474, reference in Note 7.

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OPERATIONS IN PRACTICE

Toyota

Seen as the leading practitioner and the main originator of the lean approach, the Toyota Motor Company has progressively synchronized all its processes simultaneously to give high-quality, fast throughput and exceptional productivity. It has done this by developing a set of practices that has largely shaped what we now call 'lean' or 'just-in-time' but which Toyota calls the Toyota Production System (TPS). The TPS has two themes, 'just-in-time' and 'jidoka'. Just-in-time is defined as the rapid and co-ordinated movement of parts throughout the production system and supply network to meet customer demand. It is operationalized by means of *heijunka* (levelling and smoothing the flow of items), *kanban* (signalling to the preceding process that more parts are needed) and *nagare* (laying out processes to achieve smoother flow of parts throughout the production process). *Jidoka* is described as 'humanizing the interface between operator and machine'. Toyota's philosophy is that the machine is there to serve the operator's purpose. The operator should be left free to exercise his/her judgement. Jidoka is operationalized by means of fail-safeing (or machine jidoka), line-stop authority (or human jidoka), and visual control (at-a-glance status of production processes and visibility of process standards).

Source: Alamy Images/Hannu Liukkar

Toyota believe that both just-in-time and jidoka should be applied ruthlessly to the elimination of waste, where waste is defined as 'anything other than the minimum amount of equipment, items, parts and workers that are absolutely essential to production'. Fujio Cho of Toyota identified seven types of waste that must be eliminated from all operations processes. They are, waste from overproduction, waste from waiting time, transportation waste, inventory waste, processing waste, waste of motion, and waste from product defects. Beyond this, authorities on Toyota claim that its strength lies in understanding the differences between the tools and practices used with Toyota operations and the overall philosophy of their approach to lean synchronization. This is what some have called the apparent paradox of the Toyota production system, 'namely, that activities, connections and production flows in a Toyota factory are rigidly scripted, yet at the same time Toyota's operations are enormously flexible and adaptable. Activities and processes are constantly being challenged and pushed to a higher level of performance, enabling the company to continually innovate and improve.'

One influential study of Toyota identified four rules that guide the design, delivery, and development activities within the company:[1]

- *Rule one* – all work shall be highly specified as to content, sequence, timing, and outcome.
- *Rule two* – every customer-supplier connection must be direct and there must be an unambiguous yes or no method of sending requests and receiving responses.
- *Rule three* – the route for every product and service must be simple and direct.
- *Rule four* – any improvement must be made in accordance with the scientific method, under the guidance of a teacher, and at the lowest possible level in the organization.

Source: Nigel, S., Alistair, BJ., Robert, J. 2013. Operations management. 7th ed. Harlow: Pearson. Pg. 465

McKinsey&Company

Supply Chain 4.0 – the next-generation digital supply chain

Supply Chain Management June 2016

Supply Chain 4.0 – the next-generation digital supply chain

Knut Alicke, Jürgen Rachor, Andreas Seyfert

"Supply Chain 4.0 – the application of the Internet of Things, the use of advanced robotics, and the application of advanced analytics of big data in supply chain management: place sensors in everything, create networks everywhere, automate anything, and analyze everything to significantly improve performance and customer satisfaction"

Over the last thirty years, logistics has undergone a tremendous change: from a purely operational function that reported to sales or manufacturing and focused on ensuring the supply of production lines and the delivery to customers, to an independent supply chain management function that in some companies is already being led by a CSO – the Chief Supply Chain Officer. The focus of the supply chain management function has shifted to advanced planning processes, such as analytical demand planning or integrated S&OP, which have become established business processes in many companies, while operational logistics has often been outsourced to third-party LSPs. The supply chain function ensures integrated operations from customers to suppliers.

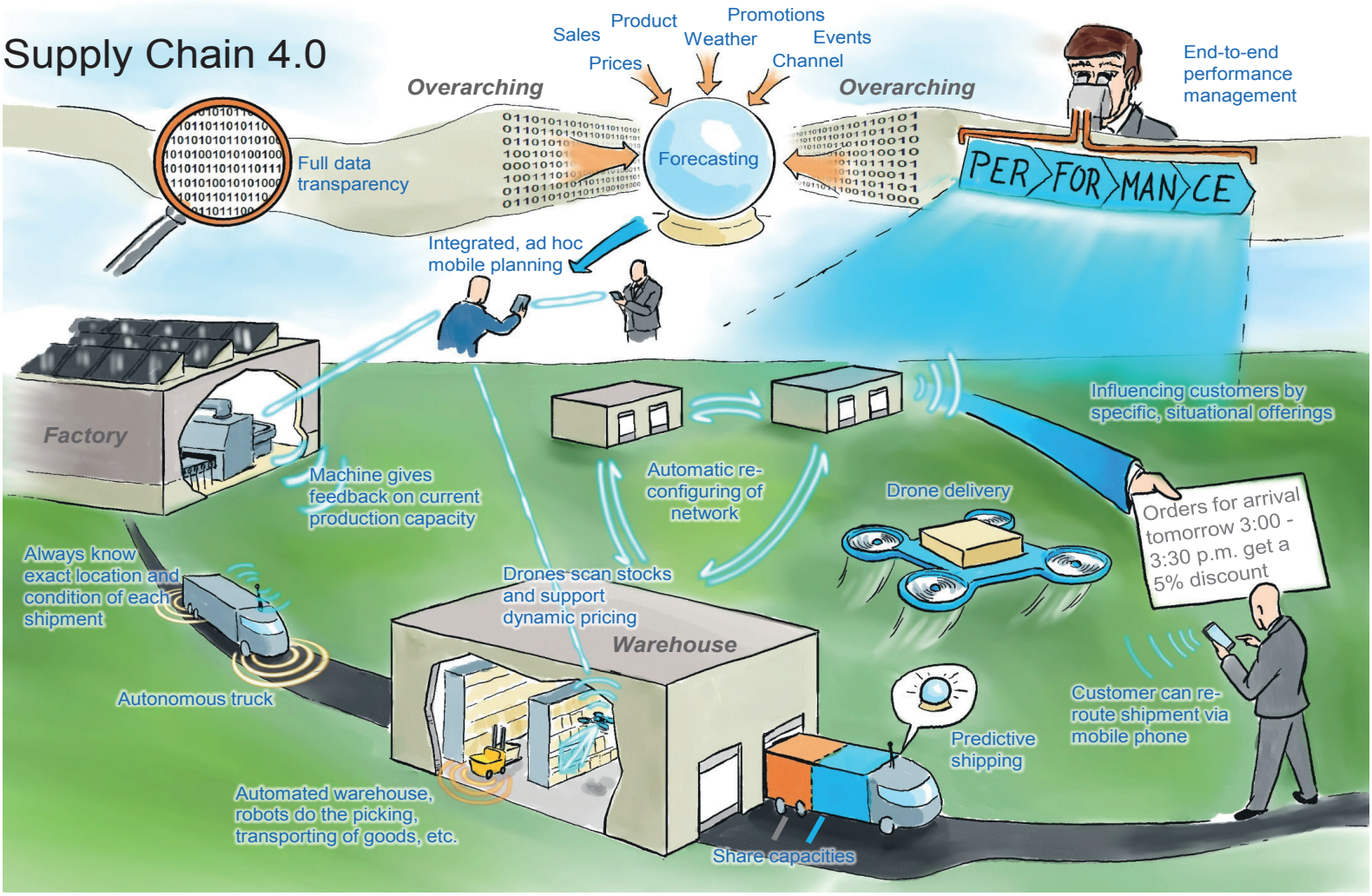
Trends in supply chain management

Industry 4.0 creates a disruption and requires companies to rethink the way they design their supply chain. Several technologies have emerged that are altering traditional ways of working. On top of this, mega trends and customer expectations change the game. Besides the need to adapt, supply chains also have the opportunity to reach the next horizon of operational effectiveness, to leverage emerging digital supply chain business models, and to transform the company into a digital supply chain.

Several mega trends have a heavy influence on supply chain management: there is a continuing growth of the rural areas worldwide, with wealth shifting into regions that have not been served before. Pressure to reduce carbon emissions as well as regulations of traffic for socioeconomic reasons add to the challenges that logistics are facing. But changing demographics also lead to reduced labor availability as well as increasing ergonomic requirements that arise as the workforce age increases.

At the same time customer expectations are growing: the online trend of the last years has led to increasing service expectations combined with a much stronger granularization of orders. There is also a very definite trend towards further individualization and customization that drives the strong growth of and constant changes in the SKU portfolio. The online-enabled transparency and easy access to a multitude of options regarding where to shop and what to buy drives the competition of supply chains.

To build on these trends and cope with the changed requirements, supply chains need to become much faster, more granular, and much more precise.



SOURCE: McKinsey

Vision of the future state

The digitization of the supply chain enables companies to address the new requirements of the customers, the challenges on the supply side as well as the remaining expectations in efficiency improvement. Digitization brings about a Supply Chain 4.0, which will be …

- **… faster.** New approaches of product distribution reduce the delivery time of high runners to few hours. The basis for these services is built by advanced forecasting approaches, e.g., predictive analytics of internal (e.g., demand) and external (e.g., market trends, weather, school vacation, construction indices) data as well as machine status data for spare-parts demand, and provides a much more precise forecast of customer demand. Forecasts are not carried out on a monthly basis, but weekly, and for the very fast-moving products even every day. In the future we will see "predictive shipping," for which Amazon holds a patent – products are shipped before the customer places an order. The customer order is later on matched with a shipment that is already in the logistics network (being transported towards the customer region) and the shipment is rerouted to the exact customer destination.

- **… more flexible.** Ad hoc and real-time planning allows a flexible reaction to changing demand or supply situations. Planning cycles and frozen periods are minimized and planning becomes a continuous process that is able to react dynamically to changing requirements or constraints (e.g., real-time production capacity feedback from machines). Once the products are sent, increased flexibility in the delivery processes allows customers to reroute shipments to the most convenient destination.

  New business models, such as Supply Chain as a Service for supply chain planning functions or transport management, increase the flexibility in the supply chain

organization. Supply chain can be bought as a service and paid for on a by-usage basis instead of having the resources and capabilities in-house. The specialization and focus of service providers allow them to create economies of scale as well as economies of scope and also attractive outsourcing opportunities.

For example, we will see an "Uberization" of transport: crowd-sourced, flexible transport capacity, which will lead to a significant increase in agility in distribution networks.

- **… more granular.** The demand of customers for more and more individualized products is continuously increasing. That gives a strong push towards microsegmentation, and mass customization ideas will finally be implemented. Customers are managed in much more granular clusters and a broad spectrum of suited products will be offered. This enables customers to select one of multiple "logistics menus" that exactly fits their need.

  New transport concepts, such as drone delivery, allow companies to manage the last mile efficiently for single and high-value dense packages.

- **… more accurate.** The next generation of performance management systems provides real-time, end-to-end transparency throughout the supply chain. The span of information reaches from synthesized top-level KPIs, such as overall service level, to very granular process data, such as the exact position of trucks in the network. This range of data provides a joint information basis for all levels of seniority and functions in the supply chain. The integration of data of suppliers, service providers, etc. in a "supply chain cloud" ensures that all stakeholders steer and decide based on the same facts.

  In digital performance management systems, clean-sheet models for warehousing, transport, or inventory are used to set targets automatically. To keep the aspiration of targets also in case of supply chain disruptions, systems will automatically adjust targets that cannot be achieved anymore to a realistic aspiration level. We will see performance management systems that "learn" to automatically identify risks or exceptions and will change supply chain parameters in a closed-loop learning approach to mitigate them. That enables the automatic performance management control tower to handle a broad spectrum of exceptions without human involvement and to only leverage the human planner for the disruptive events/new events – with this, a supply chain is continuously developing towards its efficient frontier.

- **… more efficient.** Efficiency in the supply chain is boosted by the automation of both physical tasks and planning. Robots handle the material (pallets/boxes as well as single pieces) completely automatically along the warehouse process – from receiving/unloading to putting away to pick, pack, and ship. Autonomous trucks transport the products within the network. To optimize truck utilization and increase transport flexibility, cross-company transport optimization is applied to share capacities between companies. The network setup itself is continuously optimized to ensure an optimal fit to business requirements.

  To create an ideal workload in the supply chain, various transparency and dynamic planning approaches are leveraged to drive advanced demand shaping activities (e.g., special offers for delivery time slots with low truck utilization).

Digital waste prevents supply chains from leveraging the potential of Supply Chain 4.0

In today's supply chains many sources of digital waste can be found (in addition to the existing waste) that prevent the potential of Supply Chain 4.0. It is crucial to understand the sources of waste and develop solutions to reduce/avoid it in the future state. The sources of digital waste can be classified in three types:

1) **Data capturing and management.** Often, available data is handled manually (data collection in a system, paper-based data handling, etc.) and not updated regularly, e.g., master data on supplier lead time that is entered once (sometimes even only dummy numbers) and then remains unchanged for years. Another example in warehousing is advanced shipping notifications, which are received but not used to optimize the inbound process.

   On top of these examples, it is typically not clear which additional data could be leveraged to improve processes, e.g., sensing of supply disruptions – if the lead time of a supplier is continuously increasing, a warning should be sent out to make planners aware of the situation and enable them to mitigate supply disruptions at an early stage. In current systems, this signal will not be recognized and will lead to a lower supplier service level reported at the end of the month. If the worst comes to the worst, the issue will cause trouble in the assembly line replenishment and operational problems.

2) **Integrated process optimization.** Many companies have started to implement an integrated planning process, but very often this is still done in silos and not all information is leveraged to achieve the best planning result possible. In addition, it can frequently be observed that automatically determined planning or statistical forecast data is manually overwritten by planners. Especially for parts moving at medium or high speed, the manual overwrites usually have a negative impact on the forecasting accuracy. Beside the intracompany optimization, the process optimization between companies has not been fully leveraged yet and improvement potentials created by increased transparency are not realized.

   To get to the advanced level of integrated process optimization, the organizational setup, governance, processes, and incentives need to be aligned within and between partners in the supply chain.

3) **Physical process execution of humans and machines.** Nowadays, warehousing, assembly line replenishment, transport management, etc. is often done based on gut feeling, but not leveraging available data, e.g., to improve pick paths in the warehouse. Warehouse operations are still managed in batches of one to two hours, not allowing the real-time allocation of new orders and dynamic routing. Also, opportunities arising from new devices, such as wearables (e.g., Google Glass) or exoskeletons, are not leveraged.

Increasing operational efficiency leveraging Supply Chain 4.0

Supply Chain 4.0 will impact all areas in supply chain management. We have developed the McKinsey Digital Supply Chain Compass (see figure on next page) to structure the main Supply Chain 4.0 improvement levers and to map them to six main value drivers. In the end, the improvements enable a step change in service, cost, capital, and agility.

The McKinsey Digital Supply Chain Compass maps Supply Chain 4.0 improvement levers to 6 main value drivers

SOURCE: McKinsey

Planning

The future supply chain planning will largely benefit from big data and advanced analytics as well as from the automation of knowledge work. Two example levers with significant impact are “predictive analytics in demand planning” and “closed-loop planning.”

Predictive analytics in demand planning analyzes hundreds to thousands of internal as well as external demand influencing variables (e.g., weather, trends from social networks, sensor data) with Bayesian network and machine learning approaches to uncover and model the complex relationships and derive an accurate and granular demand plan. These new technologies enable a significant improvement of demand forecast accuracy, often reducing the forecasting error by 30 to 50 percent. Also, the days of a “single truth” regarding the forecasting numbers are over – these advanced algorithms provide probability distributions of the expected demand volume rather than a single forecast number. This allows for targeted discussions, including upside potential and downside risks in the S&OPs, and advanced inventory management approaches.

Widely automated and fully integrated closed-loop demand and supply planning breaks the traditional boundaries between the different planning steps and transforms planning into a flexible, continuous process. Instead of using fixed safety stocks, each replenishment planning considers the expected demand probability distribution and replenishes to fulfill a certain service level – the resulting implicit safety stocks are therefore different with every single reorder. Another powerful feature of closed-loop planning is the integration of pricing decisions with the demand and supply planning; depending on the stock levels, expected demand, and capability to replenish, prices can be dynamically adapted to optimize the overall profit made and minimize inventories at the same time.

Physical flow

Logistics will take a huge step change through better connectivity, advanced analytics, additive manufacturing, and advanced automation. For example, as warehouses are being automated, we will see a significantly increasing amount of autonomous and smart vehicles, and 3-D printing changes warehousing and inventory management strategies completely.

The next generation of touch, voice, and graphical user interfaces and their quick proliferation via consumer devices facilitates a much better integration of machines in almost any process in warehousing operations. For example, the breakthrough of optical head-mounted displays, such as Google Glass, enables location-based instructions to workers, giving guidance for the picking process. Advanced robotics solutions have emerged for the improved picking of cases and single pieces, and the use of exoskeletons (that emulate the human physiology and can support straining manual movements) will have a major impact on warehouse productivity. In total, warehouse automations become much more holistic, with some warehouses being fully linked to production loading points, so that the entire process is carried out without manual intervention.

Autonomous and smart vehicles will lead to significant operating cost reduction in transportation and product handling and at the same time provide benefits regarding lead times and lower environmental costs. The use of self-guided vehicles in controlled environments (e.g., mines) or on-premise solutions (e.g., trains) as well as AGVs in warehouse environments are already operational and will further grow significantly in the near future. Autonomous trucks for use on public streets, however, are just being piloted in Europe and North America with promising results so far.

Besides the automation of warehouse processes, additive manufacturing will also have a significant impact on physical flows in the supply chain. For example, 3-D printing has become much more relevant for a broad range of business applications, such as local production of slowly moving spare parts or tools. This development is driven by an expanding range of printing materials, rapidly declining prices for the printers, and increased precision and quality. By now, the first production facilities that operate exclusively with 3-D printers have been established.

Performance management

Performance management is indeed changing tremendously. Whereas in the past, the generation of KPI dashboards was a major task and KPIs were only available at aggregated levels, now granular data is available in real time from internal and external sources. This moves the performance management process from a regular, often monthly process to an operational process aimed at exception handling and continuous improvement. For example, planners can be pointed to critical supply chain disruptions and further supported by an automatic handling of minor exceptions or potential solutions for the larger ones.

Automated root cause analyses are one approach for exception handling. The performance management system is able to identify the root causes of an exception by either comparing it to a predefined set of underlying indicators or by conducting big data analyses, leveraging data mining and machine learning techniques. Based on the identified root cause, the

system will automatically trigger countermeasures, such as activating a replenishment order or changing parameter settings in the planning systems, such as safety stocks.

Order management

Two examples of how order management is improved are no-touch order processing and real-time replanning, which lead to lower costs through automation of efforts, higher reliability due to granular feedback, and superior customer experience through immediate and reliable responses.

No-touch order processing is the logical next step after implementing a reliable available-to-promise (ATP) process. Through an integration of the ordering systems, linking to ATP, and through an enrichment with order rules, the system can be used to fully automate the ordering process. The goal is to have a complete "no-touch" process, where no manual intervention is required between order intake and order confirmation. Very stringent order rules that have to be followed, and continuously updated master data are prerequisites.

Real-time replanning enables order date confirmations through instantaneous, in-memory replanning of the production schedule and the replenishment in consideration of all constraints. Therefore the supply chain setup is always up to date, leading to a very reliable planning base. On top, additional services can be offered to the customers, e.g., a faster lead time for a certain premium fee, so the customer can see the feasibility and the updated dates at a glance.

Collaboration

The supply chain cloud forms the next level of collaboration in the supply chain. Supply chain clouds are joint supply chain platforms between customers, the company, and suppliers, providing either a shared logistics infrastructure or even joint planning solutions. Especially in noncompetitive relationships, partners can decide to tackle supply chain tasks together to save admin costs, and also to leverage best practices and learn from each other.

Another major field within collaboration is the end-to-end/multitier connectivity. Where some automotive companies have already started collaborating throughout the entire value chain (e.g., from the cow farmer to the finished leather seat in the car), other companies still need to close this gap. The collaboration along the value chain allows for overall much lower inventories through an exchange of reliable planning data, a step change in lead time reduction through instantaneous information provision throughout the entire chain, and an early-warning system and the ability to react fast to disruptions anywhere.

Supply chain strategy

Following the need for further individualization and customization of the supply chain, supply chain setups adopt many more segments. To excel in this setting, supply chains need to master "microsegmentation." The granularization of the supply chain into hundreds of individual supply chain segments based on customer requirements and own capabilities designed in a dynamic, big data approach allows to mass-customize supply chain offerings. Tailored products provide optimal value for the customer and help minimize costs and inventory in the supply chain.

Impact of Supply Chain 4.0

Eliminating today's digital waste and adopting new technologies is a major lever to increase the operational effectiveness of supply chains. The potential impact of Supply Chain 4.0 in the next two to three years is huge – up to 30 percent lower operational costs and a reduction of 75 percent in lost sales while decreasing inventories by up to 75 percent are expected, at the same time increasing the agility of the supply chains significantly.

How did we calculate these numbers? The impact numbers are based on our experience from numerous studies and quantitative calculations – the three performance indicators are highly correlated, e.g., an improved inventory profile will lead to improved service level and lower cost.

- **Supply chain service/lost sales.** Low customer service is either driven by a wrong promise to the customer (e.g., unrealistic lead times), a wrong inventory profile (ordered products are not available), and/or an unreliable delivery of parts. Lost sales in addition occur if the required products are not available on the shelf or in the system – customers will decide to switch to another brand. This is true for both B2C and B2B environments.

  By significantly improving the way we interact with the customer, by leveraging all available POS data/market intelligence, improving the forecast quality significantly (up to more than 90 percent in the relevant level, e.g., SKU), and applying methods of demand shaping in combination with demand sensing to account for systematic changes/trends, the service level will increase dramatically and with this lost sales will decrease significantly.

  We clearly need to keep in mind that industries like Pharma Rx, where the service level is often in the upper 90ies, will benefit less from the reduction of lost sales, but more from insights into the patient – and by providing individual service, they will be able to increase revenue.

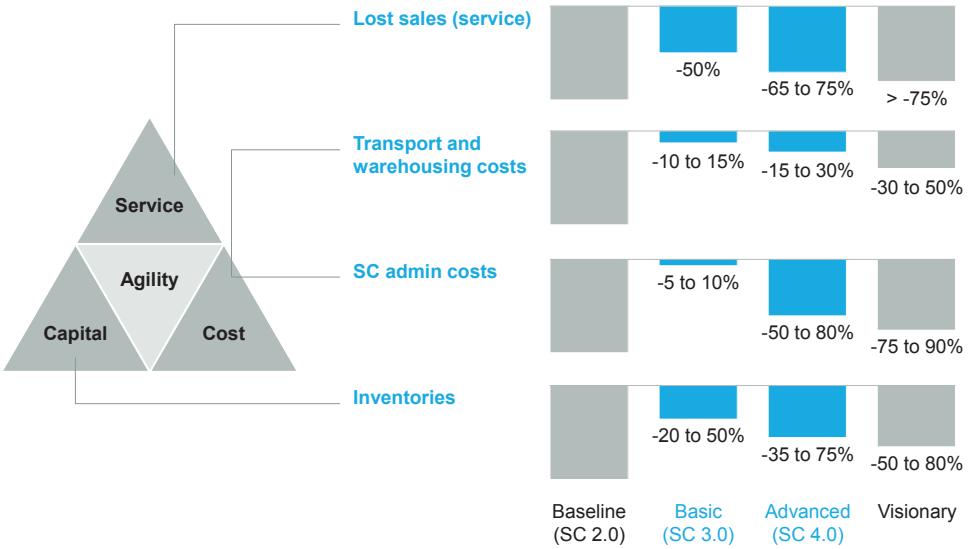
- **Supply chain costs.** Driven by transportation, warehouse, and the setup of the overall network, the costs can be reduced by up to 30 percent. Roughly 50 percent of this improvement can be reached by applying advanced methods to calculate the clean-sheet (bottom-up calculation of the "true" costs of the service) costs of transport and warehousing and by optimizing the network – the goal should always be to have minimal touch points and minimal kilometers driven, still meeting the required service level of the customer. In combination with smart automation and productivity improvement in warehousing, on-board units in transportation, etc., the savings potential can be achieved. The remaining 15 percent cost reduction can be reached by leveraging approaches of dynamic routing, Uberization of transport, leveraging autonomous vehicles, and – where possible – 3-D printing.

- **Supply chain planning.** The planning tasks such as demand planning, preparation of S&OP process, aggregated production planning, and supply planning are often time intensive and conducted mainly manually. With advanced system support, 80 to 90 percent of all planning tasks can be automated and still ensure better quality compared to tasks conducted manually. The S&OP process will move to a weekly rhythm and the decision process will be built on scenarios that can be updated in real

time. This accuracy, granularity, and speed has implications for the other elements, such as service, supply chain costs, and inventory. Systems will be able to detect the exception where a planner needs to jump in to decide.

- **Inventory.** Inventory is used to decouple demand and supply, to buffer variability in demand and supply. By implementing new planning algorithms, the uncertainty (the standard deviation of the demand/supply or forecast error) will be reduced significantly, making safety stock unnecessary. The other important variable to drive inventory is the replenishment lead time – with more production of Lot Size 1 and fast changeover, the lead time will be reduced significantly. Also, long transport time, e.g., from Asia to the EU or the US, will be reduced due to a significant increase in local-for-local production. In addition, 3-D printing will reduce the required inventory. We believe in an overall inventory reduction of 75 percent.

By applying Supply Chain 4.0 levers, huge potential can be unlocked in all supply chain categories



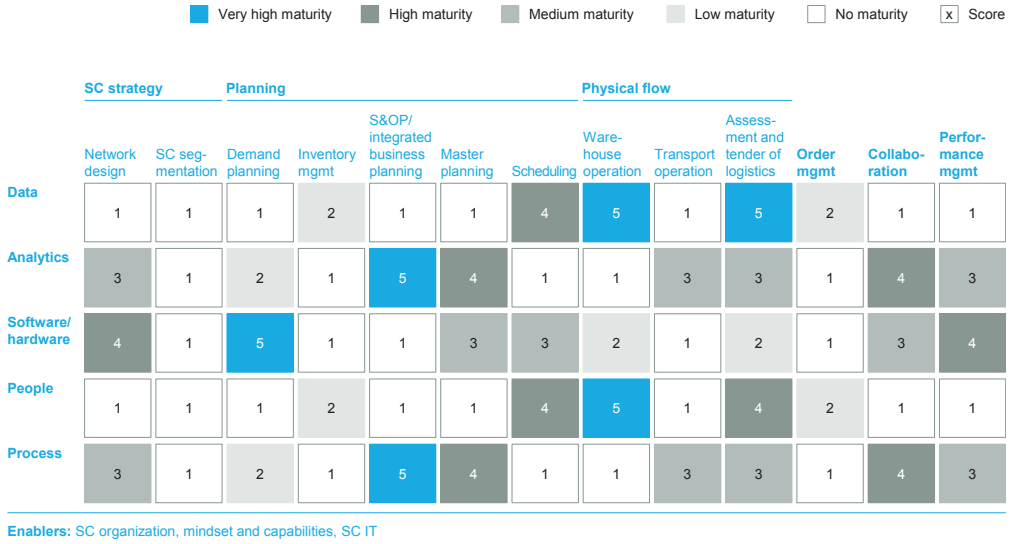
SOURCE: McKinsey

Capturing the value is a journey that can be started right away. Where it starts depends on the digital maturity of the current supply chain. The McKinsey digital walk-through helps companies appreciate the current digital maturity of the organization, create a sound understanding of the required levers to pull to reach the next performance level leveraging Supply Chain 4.0 tools to shape the road map for digitization, and estimate the potential impact.

The diagnostic tool assesses the supply chain systematically based on six value drivers and five assessment dimensions (e.g., data, analytics). It differentiates between three archetypes of maturity levels. Supply Chain 2.0 characterizes “mainly paper-based” supply chains with a low level of digitization. Most processes are executed manually. The digital capabilities of the organization are very limited and available data is not leveraged to improve business decisions. Supply Chain 3.0 describes supply chains with “basic digital components in place.” IT systems are implemented and leveraged, but digital capabilities still need to be developed. Only basic algorithms are used for planning/forecasting and only few data scientists are part

of the organization to improve its digital maturity. Supply Chain 4.0 is the highest maturity level, leveraging all data available for improved, faster, and more granular support of decision making. Advanced algorithms are leveraged and a broad team of data scientists works within the organization, following a clear development path towards digital mastery.

The digital walkthrough leads to a maturity assessment along the major SC 4.0 dimensions and concrete recommendations going forward



SOURCE: McKinsey

Transformation into a digital supply chain

The transformation into a digital supply chain requires two key enablers – capabilities and environment. Capabilities regarding digitization need to be built in the organization (see the chapter on capability building) but typically also require targeted recruiting of specialist profiles. The second key prerequisite is the implementation of a two-speed architecture/ organization. This means that while the organization and IT landscape are established, an innovation environment with a start-up culture has to be created. This “incubator” needs to provide a high degree of organizational freedom and flexibility as well as state-of-the-art IT systems (two-speed architecture independent of existing legacy systems) to enable rapid cycles of development, testing, and implementation of solutions. Fast realization of pilots is essential to get immediate business feedback on suitability and impact of the solutions, to create excitement and trust in innovations (e.g., new planning algorithms), and to steer next development cycles. The “incubator” is the seed of Supply Chain 4.0 in the organization – fast, flexible, and efficient.

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CHAPTER 5

Understanding Supply Chain 4.0 and its potential impact on global value chains

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ABSTRACT

The reorganization of supply chains using advanced technologies, such as the Internet of Things (IoT), big data analytics, and autonomous robotics, is transforming the model of supply chain management from a linear one, in which instructions flow from supplier to producer to distributor to consumer, and back, to a more integrated model in which information flows in an omnidirectional manner to the supply chain. While e-commerce is uniquely suited to many of these techniques, they also hold the promise of improving efficiency in brick-and-mortar stores. These technologies are generating enormous benefits through reducing costs, making production more responsive to consumer demand, boosting employment (employment in supply chain sectors where such technologies are most likely to be applied has grown much more rapidly than in other supply chain sectors and in the economy as a whole) and saving consumers' time. The impact of these technologies on the length of supply chains is uncertain: they may reduce the length of supply chains by encouraging the reshoring of manufacturing production to high-income economies, thus reducing opportunities for developing countries to participate in GVCs, or they may strengthen GVCs by reducing coordination and matching costs.

- Digital technologies are transforming supply chain management from a linear model in which instructions flow from supplier to producer to distributor to consumer, and back, to a more integrated model in which information flows in multiple directions (sometimes referred to as Supply Chain 4.0).
- Digital technologies offer huge benefits in terms of inclusive patterns of growth, innovation and entrepreneurial opportunities
- The impact of new digital technologies on GVCs is uncertain: they may reduce the length of supply chains by encouraging the reshoring of manufacturing production, thus reducing opportunities for developing countries to participate in GVCs, or they may strengthen GVCs by reducing coordination and matching costs.

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1. Introduction

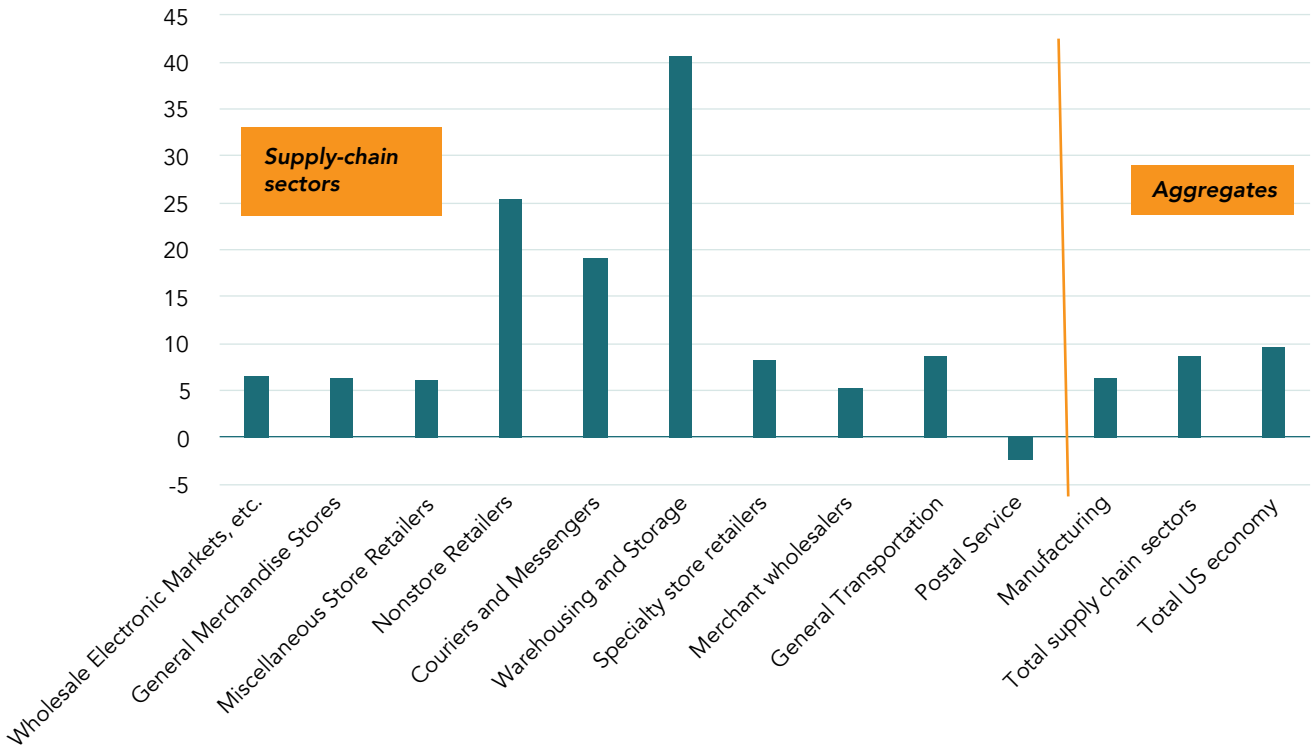
"Supply Chain 4.0" is the re-organization of supply chains – design and planning, production, distribution, consumption, and reverse logistics – using technologies that are known as "Industry 4.0". These technologies, which emerged in the 21st century, are largely implemented by firms that are at the frontier of supply chain management in high-income countries. Though, as we will argue, this classification is somewhat artificial, it does in fact capture certain prevailing ideas about what firms need to do, and are doing, in order to maintain competitive supply chains.

1.1 Supply Chain 4.0 is here already

While much of the literature we will review is forward-looking, and indeed has emerged only in the last two or three years, almost all of the technologies we discuss are being implemented today, at least by firms at the frontier of supply chain management, which by and large are in high-income countries.[1] With only one or two exceptions, everything described in this chapter is already being applied in actual supply chains, or is at least being piloted. While the literature includes many ideas for emergent technologies that might be available by 2030 (for example, vast fleets of self-driving delivery vehicles, or the "smart mirror" in the local clothing store that supposedly will allow you to virtually try on clothes just by scanning their bar codes), this argument does not depend on the deployment of technologies that do not really exist yet. The diffusion of already existing Supply Chain 4.0 technologies will already have a substantial impact.

When we say that Supply Chain 4.0 is here, we mean that it is here at the frontier of supply applications and being more widely adopted, not that it is universal. Even in high-income countries, the principles of Supply Chain 4.0[2] are unequally applied. Advanced supply management techniques are more likely to be observed in sectors such as electronics where earlier waves of management techniques took hold first, or in big-box retailers such as Walmart. As recently as February 2018, supply chain problems caused two-thirds of the 900 Kentucky Fried Chicken restaurants in the United Kingdom to close because they had run out of chicken.[3]

FIGURE 5.1 US employment by sector, supply chain sectors, manufacturing, transportation, post office and other, percent change (2011-2016)



1.2 It transforms business models, making supply more customer-driven

While Supply Chain 4.0 involves the deployment of such contemporary tools as the Internet of Things (IoT), big data analytics, autonomous robotics, and the like, it is not really about any of these things. It is about transforming the model of supply chain management from a linear model in which instructions flow from supplier to producer to distributor to consumer, and back, to a more integrated model in which information flows in an omnidirectional manner to the supply chain. While lead firms are increasingly analyzing this information through "supply chain control towers," the end effect of this development could be making the goods economy more responsive to consumer demand.

1.3 E-Commerce is ideally, but not uniquely, suited for Supply Chain 4.0

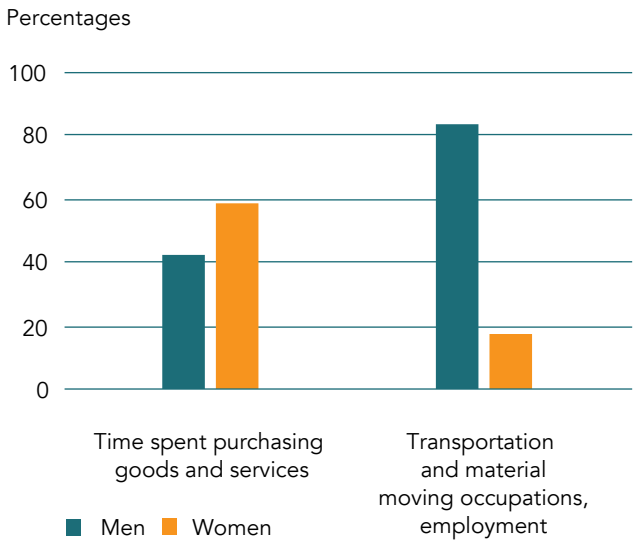
The ability to capture data in e-commerce empowers many of the data-driven methods we will discuss. In particular, older technologies (electronic data interchange) were already gathering large amounts of information in business-to-business (B2B) e-commerce, which can be used to improve supply chain performance. At the same time, most of the developments discussed here can be used to improve the performance of traditional brick-and-mortar stores, where the large majority of retailing still takes place, as well as in an e-commerce setting.

1.4 It generates jobs, which substitute for household labor and promote human well being

In an exercise using U.S. data gathered in the Occupational Employment Statistics of the Bureau of Labor Statistics, this study shows that employment in the most dynamic parts of the supply chain has grown at a rate substantially exceeding that of the overall economy since 2011. These sectors include warehousing and storage (used by all retailers, Walmart as well as Amazon), couriers and messengers (the sector including UPS and Federal Express, commonly known as "express carriers"), and non-store retailers (particularly electronic shopping and mail-order houses, the sector inhabited by Amazon and eBay) (see Figure 5.1). Most of the jobs being created involve moving goods around either in warehouses or delivery vehicles and have many of the characteristics of factory work. Though robots are used in many of these applications, they appear, at present, to be complementary with human labor.

Most importantly, e-commerce, powered by Supply Chain 4.0, involves a great substitution of market labor for household shopping time. Traditional shopping is a time-consuming and, for many, tedious activity. Because household time is an intrinsically scarce resource, Supply Chain 4.0 is already having profound impacts on human well-being. However, time saved as a result of e-commerce also has increased employment in the transportation and material moving occupations. As shown in Figure 5.2, men account for 42 percent of the time spent shopping, while women account for 58 percent, whereas men account 82 percent of employees in transportation and warehousing jobs, while women account for 18 percent. As discussed further in section vi below, these workers, concentrated primarily in warehouses and express delivery companies, are paid to do the picking, packing, and driving that would otherwise be done by household shoppers in the absence of e-commerce.

FIGURE 5.2 Shopping and e-commerce occupations, gender division (2017)



Source: BLS American Time Use Survey, BLS Current Population Survey, and authors' calculations.

1.5 It can transform the operation of global value chains

Whether conceived of as an advanced management practice, or simply as a cluster of technologies to be deployed by advanced management practices, Supply Chain 4.0 provides substantial opportunities for firms to enhance productivity, profitability, product quality, and performance in international trade. Because Supply Chain 4.0 diffuses at an unequal rate, it can also influence the size distribution of firms within industries as well as income distribution across countries. The enhanced ability to track both physical and financial information also has implications for activities of government which depend on highly disaggregated firm data, such as tax enforcement and monitoring of rules of origin in international trade.

2. The impact of Supply Chain 4.0 on firms

2.1 Technologies and management strategies

One way to approach Supply Chain 4.0 is to treat it as simply the application of Industry 4.0[4] to the supply chain.[5] And a common way to approach Industry 4.0 is to treat it as simply a bundle of technologies that have emerged, or are emerging, in the 21st century (see Figure 5.3). Then the task might be simply to map the technologies in Industry 4.0 to each of the steps of

the supply chain – design and planning, production, distribution, and consumption.

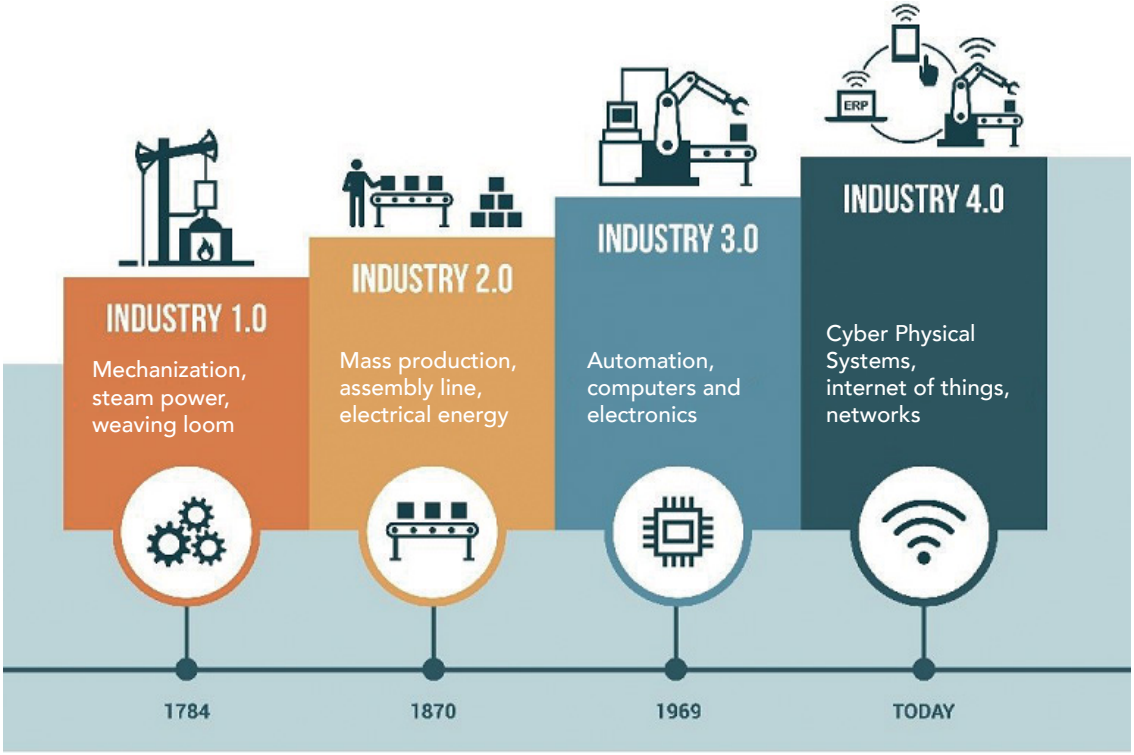
While each of the "industrial revolutions" is generally characterized by a cluster of typical technologies, the list of these technologies varies from one author to another. Cirera *et al.* (2017) identify 17 technologies that are said to characterize Industry 4.0 (see Figure 5.4), which are referenced two or more times in a corpus of underlying sources, of which the most frequently mentioned are the IoT; big data analytics; 3D printing; advanced (autonomous) robotics; sensor-using smart factories[6]; augmented reality[7]; artificial intelligence[8]; and cloud computing[9]. Pfohl *et al.* (2015) identify over 50 technologies associated with Industry 4.0, mind-mapped to such underlying attributes as "digitalization" (which applies to everything), "mobility", "modularization," "network collaboration," "autonomization", "transparency," and "socialization".

It is tempting, as noted above, to attempt to understand Supply Chain 4.0 as the application of Industry 4.0 to supply chains, and then to map each of the stages of the supply chain (planning and design, production, distribution, consumption, reverse logistics) to one or more of the iconic technologies said to be typical of Industry 4.0: the IoT, cloud computing, artificial intelligence, etc. The difficulty immediately arises that the application of technologies to sets of problems is fluid, and it takes a long time to determine what the most successful technologies will be in any given area. For example, during 1880-1920 it was not at all obvious how three available forms of energy, steam, electricity and gasoline, were to be applied to two areas of activity, factories and motor vehicles. Eventually a consensus emerged that factories ought to be run by electricity and motor vehicles by gasoline, but not before every other combination of power and activity had been experimented with extensively, and with some success (Freeman and Soete 1997 75-80, 139-140).

Fortunately, there is a more fruitful way to approach the problem, because the broad functional outline of how Industry 4.0 affects supply chains is already apparent.

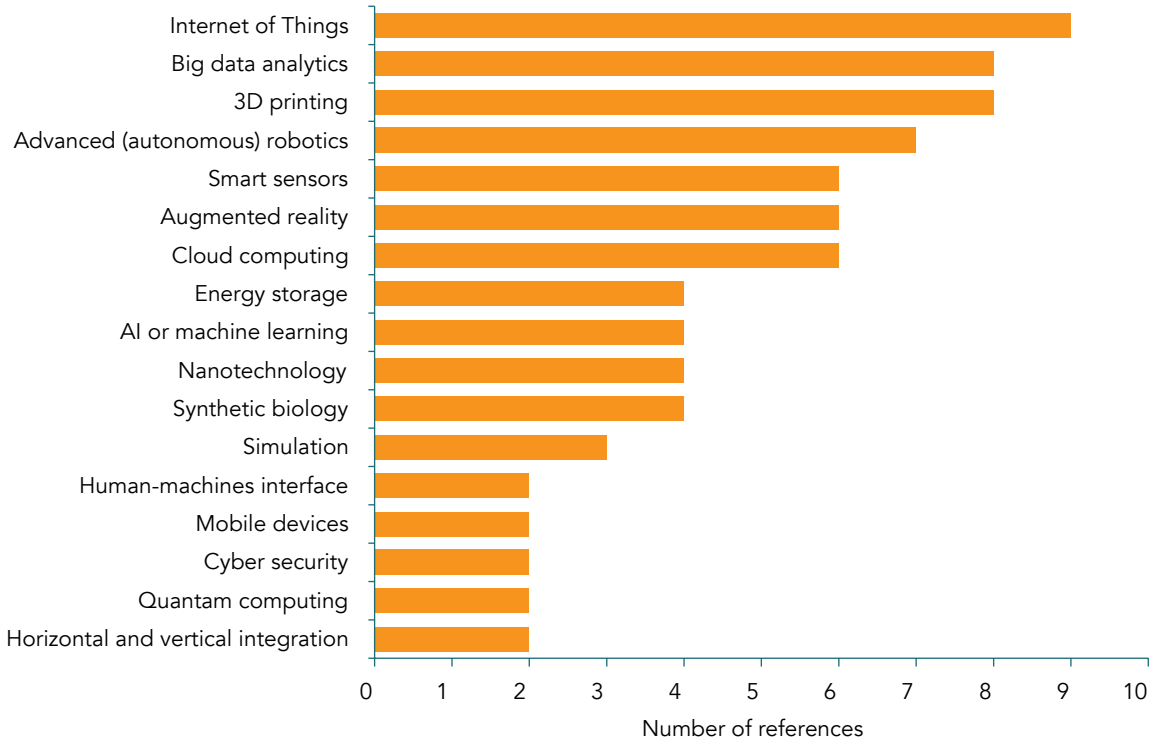
Supply Chain 4.0 fundamentally changes the way information flows through the supply chain. Traditional supply chains link suppliers to customers in a linear manner, with each firm sourcing inputs from suppliers and in turn delivering its products to customers (Figure 5.5). The planning process of each firm is designed to ensure that deliveries are coordinated with the customers' sourcing activities, and that sourcing activities are coordinated with the suppliers' delivery activities, and that returns of unwanted or unneeded products are accounted for (PWC 2016b). The processes by which this is done have been codified in the Supply-Chain Operations Reference (SCOR) model, originally developed in 1996 by the management consulting firm PRTM

FIGURE 5.3 The currently fashionable model of Industry 4.0 is over-simplified, but it reflects current thinking about what's happening now (2018)



Source: https://www.hammelscale.com/industry-4-0/

FIGURE 5.4 Industry 4.0 technologies, by relative emphasis in recent studies

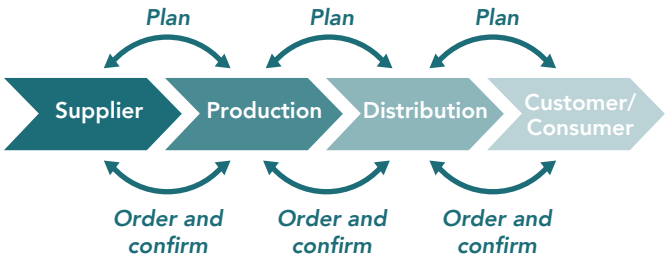


Source: Graphic from Hallward-Driemeier and Nayyar (2017).

(now part of PriceWaterhouseCooper) and AMR Research (now part of Gartner) (Lambert 2008, p. 305), and are now part of a de facto standard strategic, management, and process improvement methodology for supply chain management. The ideas behind SCOR, and their implementation, have been important for the development of global value chains and for supply coordination among networks of firms.

As successful as this method of supply chain management has been, it has limitations. Flows of information tend to primarily link each firm to its immediate suppliers and customers, not to firms further down the chain. In supply chains with multiple links, this leads to delays in the processing of information. In particular, changes in the system flowing from changes in final demand, which are often unpredictable, become distorted as they pass upstream, analogous to the old child's game in which a message whispered from one player to another becomes more and more different from its original content. Even with a lead firm acting as "impresario" of a network of firms, one actor is unlikely to have full information about everything that is going on in the supply chain. Managers at Walmart, planning for the fall apparel season, are in some sense leaders of their global supply chains (USITC 2011, 3-33 ff). But they are unlikely to actually know what is happening in button and zipper factories in Bangladesh which are part of their supply chain. That information is held by middlemen. Firms in Singapore, which ship small screws to manufacturers of

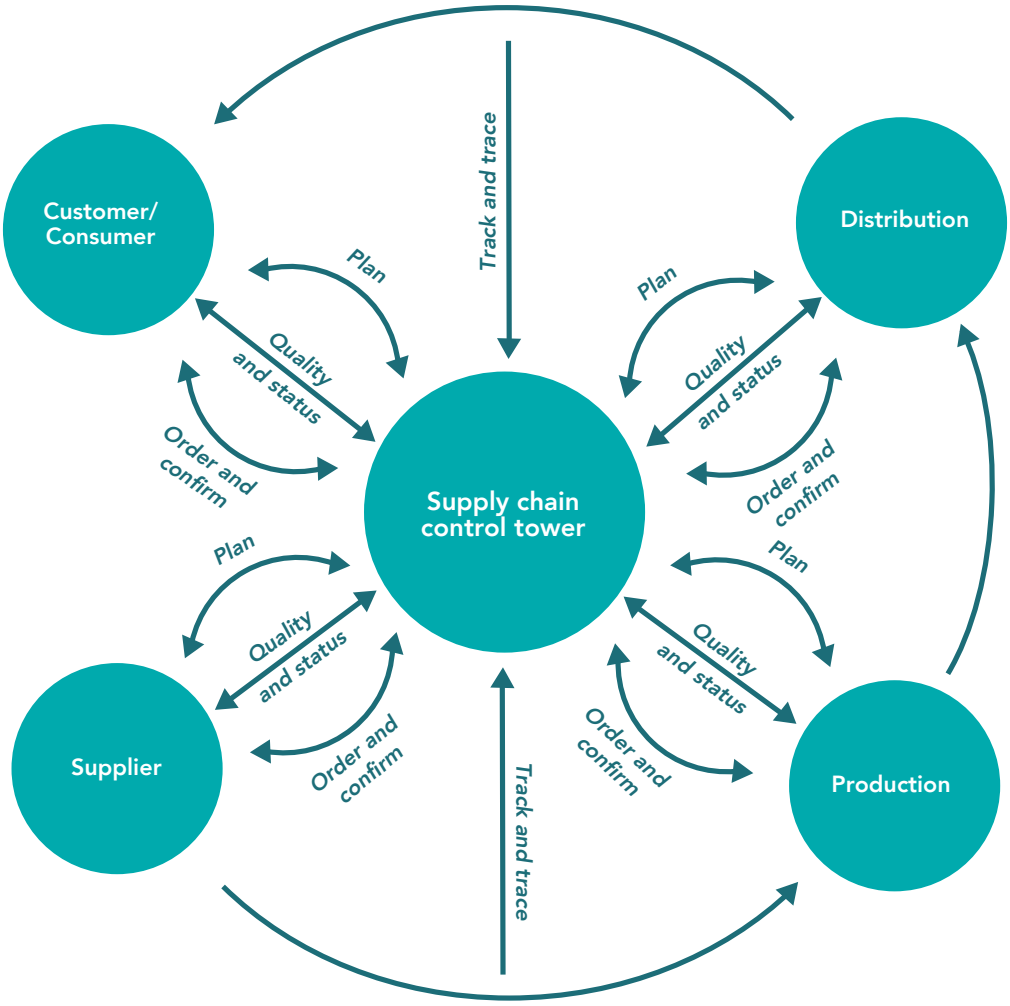
FIGURE 5.5 Traditional supply chain model



Source: PWC 2016b.

disk drives in Thailand, which are in turn shipped to assemblers of laptop computers in China, cannot see changes in consumer demand visible to Best Buy, a retailer in the United States (Hiratsuka 2005). The term Supply Chain 4.0 can be usefully applied to an integrated supply chain ecosystem, in which information flows in all directions, analytics enable adjustment throughout the supply chain, and response takes place in real time (PWC 2016b) (see Figure 5.6).[10] To rapidly assess and respond to changes in

FIGURE 5.6 Integrated supply chain ecosystem



Source: PWC 2016b.

customer demand, tracking and tracing throughout the supply chain is enabled through sensing technologies underlying the Internet of Things (IoT), including radio frequency identification (RFID), Bluetooth, and GSM (global system for mobile communication), which links maritime transport to satellites. In particular, changes in customer demand can be rapidly assessed and responded to. This technology has had a wide uptake. According to a recent PwC study on the rise of Industry 4.0, a third of the more than 2,000 respondents say their companies have started to digitize their supply chains, and fully 72 percent expect to have done so five years from now (PWC 2016a, p. 11).

2.2 Big data and supply chain analytics – running scenarios from a supply chain control tower

New technologies gather prodigious amounts of data. In the last decade, the cost of bandwidth has decreased by a factor of nearly 40 times, processing costs have declined almost 60 times, and many of the sensors used in IoT technology cost no more than 60 cents (CGI 2016). These data are only useful if they can be reduced to information useful for making decisions in real time that create business value. Big data analytics thus are about using data to drive useful business intelligence, answering the questions, "What just happened?", "Why did it happen?", and "What are we going to do next?". Specific applications of big data analytics include early warning algorithms (are we about to run out of something or hit a bottleneck? Did prices we care about just rise?), predictive algorithms (what is demand likely to look like next spring, or five years from now?), stock-keeping unit (SKU) rationalization (the decision about the optimal set of products, or SKUs, to offer to consumers at any given time), channel assessment (the decision about the optimal way to get product to end market, e.g. e-commerce/

distributors/company-owned outlets/large and small retailers/mail-order/etc.), and dashboards (user-friendly quick visualization in "supply chain control centers"). The ability to collect and analyze data gathered in the whole supply chain makes it possible to "run scenarios within the platform" (PWC 2016b), where the platform is conceived of as an overarching software solution within the supply chain control center.

The desire to collect and distribute data rapidly across a supply chain explains much of the recent enthusiasm for blockchain technologies in the context of supply chains (Petersen *et al.* 2017). Blockchain is a distributed ledger technology that allows multiple parties to maintain copies of the same information in different locations, either in an open manner or requiring individual entities' permission to access the network. Blockchain protocols encode information such as numbers or programs, time-stamp them, and enter them as a block into a continuous chain of previous blocks linked to the same transaction (Niforos, Ramachandran and Reherman, 2017). Such attributes make blockchain attractive for supply chain management, as well as for other uses such as fintech, cryptocurrencies, smart contracts, and security. Blockchain technology also has potential application in port logistics, improving tracking and tracing of containers and coordination among the diverse actors in ports such as carriers, ship agents, terminal operators, insurers, customs agents, financial institutions and inland transport (Weernink *et al.*, 2017). While there is a great deal of hype about blockchain and supply chains at the present moment, pilot projects involving establishing origin of Australian oats, preventing counterfeiting of Italian wine, combating fraud in diamond markets, and tracing the provenance of geological samples have demonstrated proof-of-concept (Petersen *et al.* 2017). It should be noted that many of these coordination functions can be performed by combinations of technologies that do not involve blockchain.

2.3 Smart factories/fractal factories/M2M communications/driverless programmable vehicles

Improved data gathering within the IoT, combined with analytics, enables process optimization within the factory as well, in order to enable timely business decisions. The application of Supply Chain 4.0 within manufacturing facilities is sometimes referred to as the "smart factory" (Pfohl *et al.* 2015). Embedded data collection units, using both automatic identification and data collection and radio-frequency identification (RFID) technologies, can be embedded in most pieces of factory equipment. The information can be passed from machine to machine (M2M) and handed to a supply chain control tower for decision making. Autonomous robotics simply refers to the control and reprogramming of robotics using bilateral and multilateral machine communication. Intra-logistics within factories includes the use of driverless vehicles to move materials based on externally-provided information.

One of the most important features of the Smart Factory is the ability to do predictive maintenance. The use of sensors to identify maintenance needs in advance of potential breakdowns reduces maintenance costs. (CGI 2017) For example, Microsoft and CGI developed a smart-sensor based solution for a company that maintains more than 1.2 million elevators worldwide. Information from the sensors is made available to service technicians and their supervisors through cloud-based dashboards. Manyika *et al.* (2015) estimate that predictive maintenance using IoT can reduce maintenance costs of factory equipment by 10-40 percent and reduce equipment downtime by up to 50 percent. Similarly, the use of predictive analytics and IoT can have a big impact on energy maintenance, both by using energy consumption data to detect potential equipment failures and by continuously modifying equipment settings and process parameters in real time (CGI 2017).

2.4 Smart logistics and the warehouse of the future

Smart logistics encompasses not only scheduling of transport, but also activities within the warehouse. It is within the warehouse that many of the most profound changes are already taking place. As noted above, one of the big changes is that the warehouse and the customer become more visible to each other, so that customer final purchases trigger not only product moves from the warehouse but also product moves from the manufacturer to the warehouse.

In e-commerce, the Internet makes the warehouse visible to the customer. A familiar example of this is the notice one encounters at Amazon.com, "Only three left! Hurry!", which can be used to influence both consumer behavior and trigger re-stocking. At Taobao.com, the giant Chinese e-commerce platform, customers are presented with both inventory and sales data for products. Alibaba is another platform that functions as the architect of an increasing complex eco-system, that includes designers/entrepreneurs, marketers, payments, financing (credit) logistics suppliers, integration of on- and offline retail, supply chains and manufacturing, all of which are complementary players in the eco-system interacting on the network, in rapid-response, data-driven, algorithm-guided mode (Spence, 2018).

The predictive maintenance techniques discussed above can reach into the warehouse as well, which can similarly optimize delivery of spare parts to factories. Indeed, with a flexible 3D printer, spare parts can be produced in the warehouse, triggered by demand. Some analysts project that 3D printers, which can be placed in any environment including delivery trucks, may make warehouses obsolete.

A traditional warehouse involves a good deal of "pick and pack" activity. Employees search around in the warehouse for products that have been ordered, take them off the shelves, and pack them. If the warehouse serves several firms, the packing may involve selecting packing materials marked with the logo of a particular firm. Clearly knowing where the products are located in a large warehouse, and moving through the warehouse in a time-minimizing manner, can speed up delivery time substantially and reduce errors. Within the warehouse, autonomous logistics and robotic transport can be employed to substantially improve pick-and-pack performance. Other technologies can be

used as well. Here's one example of the use of augmented reality in a warehouse:

"DHL recently conducted tests on an augmented reality system at a warehouse in the Netherlands owned by Ricoh, the Japanese imaging and electronics company. Equipped with smart glasses containing software from Ubimax, employees navigated through the warehouse along optimized routes via the glasses' graphics display, enabling them to find the right quantity of the right item much more efficiently, and with reduced training time. Over the three weeks of the test, 10 order pickers succeeded in fulfilling 9,000 separate orders by picking more than 20,000 items. The resulting productivity improvements and reduction in errors increased the overall picking efficiency by 25 percent" (PWC 2016b, p. 22)."

This example highlights a feature of many Supply Chain 4.0 technologies which will be important for understanding their employment effect. The use of new technology and human labor are often complements, rather than substitutes, especially in conditions where e-commerce is substantially increasing demand for certain goods. Rugaber (2018) reports that the online retailer Boxed in Edison, New Jersey opened up an automated warehouse in Union, New Jersey. Demand for goods was such that the firm ended up employing more humans, adding a third shift, as well as more robots. The new jobs are less physically demanding as well. Rather than taking thousands of steps a day loading items onto carts, employees can stand at stations as conveyor belts bring goods to them.[11]

2.5 E-Commerce is ideally, but not uniquely, suited for Supply Chain 4.0

As we have seen, many of the tools of Supply Chain 4.0 can be applied to traditional store-based retailing. The expansion of e-commerce, however, allows additional ways in which new technologies can be implemented. One obvious feature of B2C-commerce is that the process of purchasing involves electronic data entry on the part of the consumer. This enables information to be captured, preferences to be assessed, and strategies to target the consumer to be implemented, such as the ubiquitous pop-ups which now follow one around the Internet after having viewed a product in a given category.

Although most of the popular discussion of e-commerce is on B2C, nearly 90 percent of e-commerce is in fact business-to-business (B2B) (UNCTAD 2017, from which Table 5.1). This means by definition that it consists of links in supply chains – whether transactions between parts suppliers and assemblers, between distribution centers and retailers, or online purchases of services which in many cases support the supply chain. B2B commerce can be implemented either through websites, much like B2C e-commerce, or through electronic data interchange (EDI). EDI is a mature technology[12] through which the computer systems of the buyer and seller are directly connected using a common record format.[13] As an example of the pervasiveness of EDI, the United Kingdom's Office of National Statistics finds that a majority of all e-commerce in the U.K. consisted of B2B e-commerce conducted through EDI, as opposed to over websites that resemble B2C e-commerce (Table 5.2).

TABLE 5.1 Top 10 economies by total, B2B and B2C e-commerce, 2015, unless otherwise indicated

		Total		B2B		B2C
	Economy	$ billion	Share in GDP (%)	$ billion	Share in total e-commerce (%)	$ billion
1	United States	7,055	39	6,443	91	612
2	Japan	2,495	60	2,382	96	114
3	China	1,991	18	1,374	69	617
4	Republic of Korea	1,161	84	1,113	96	48
5	Germany (2014)	1,037	27	944	91	93
6	United Kingdom	845	30	645	76	200
7	France (2014)	661	23	588	89	73
8	Canada (2014)	470	26	422	90	48
9	Spain	242	20	217	90	25
10	Australia	216	16	188	87	28
	Total for top 10	**16,174**	**34**	**14,317**	**89**	**1,857**
	World	**25,293**	**-**	**22,389**	**-**	**2,904**

Source: UNCTAD Information Technology Report 2017.

TABLE 5.2 The United Kingdom reported that about 50 percent of e-commerce in 2017 was electronic data interchange B2B

Mode	Sector	Value in 2015 (billion UK £)	Grand Total (%)
All modes	**Total**	**560**	**100**
of which	B2B	400	71.4
of which	B2C	160	28.6
Electronic Data Interchange (EDI)	**Total (B2B)***	**281**	**50.2**
Website	**Total**	**279**	**49.8**
of which	B2B	119	21.3
of which	B2C	160	28.6

Source: UK Office for National Statistics.

* EDI can be explained as an automated transaction between businesses and therefore EDI sales are classed as business-to-business sales.

Transactions between businesses which take place without EDI involve multiple processes of transmission and re-copying of data. A customer creates an order manually, perhaps using a computer. The order is transmitted by telephone or fax. It is manually keyed into the vendor's computer system. When the order is fulfilled an invoice is created manually (with or without the aid of a computer). The invoice is sent back to the customer, who enters the data on the invoice manually.

Each of these steps in the process is time-consuming. Moreover, each step is a place at which error can be introduced into the system, leading not only to slow order fulfilment but to lack of fulfilment or mis-fulfilment. An EDI system causes an order created electronically by the customer to be instantly duplicated without error in the vendor's computer system, and the invoice to be similarly electronically duplicated in the customer's computer system.

Besides saving time and labor, and reducing errors, EDI enables a large amount of data capture about customer behavior. Thus, data captured in EDI can be the basis for supply chain analytics using either big data or "small data" techniques. One study of manufacturers in the Czech Republic finds that firms using EDI were also more likely to adopt advanced techniques of inventory management, such as consignment stocks, buffer stocks, and safety stocks[14] (Vrbová et al 2016). The same study reports that sectors with above-average use of EDI include auto parts, electronics, engineering industries, plastics, retailing and textiles. These are all sectors associated around the world with well-organized value chains, showing the use of EDI-driven data capture and analysis in value chains.

3. The impact of Supply Chain 4.0 on consumers – customer fulfilment increasingly resembles magic

In a traditional consumer supply chain, the final step is an in-store retail establishment. Consumers frequently experience the frustration of goods being out of stock, either goods that are usually on the shelves but are not there on the day the consumer is in the store, or goods that the consumer would like to buy and knows that they exist, but that the store does not carry. In such cases, the remedies are familiar. Do you have any more in the back room? May I speak to a manager? For a particularly vigorous consumer inquiry, the manager might be prevailed upon to call another store in the chain, or a regional warehouse or distribution center. By this time, the consumer may well have given up and not made the purchase at all, or gone to a competitor.

Applications of IoT are increasingly used to facilitate the management strategies of "customer-managed inventory" (CMI) or "vendor-managed inventory" (VMI). These strategies represent a revolution in supply chain management of comparable importance to the "just-in-time" revolution in manufacturing pioneered at Toyota and other companies in the 1960s. In such models, information is initially provided by a customer, for example by scanning a bar code associated with a purchase, and then transmitted up the supply chain to the warehouse/distribution center.[15] Technologies such as RFID tags then transmit information to the distribution center so that orders can be fulfilled. The information involved is mediated by EDI (see above under e-commerce). Since demand still cannot be fully forecast, models of inventory management such as scan-based trading or consignment distribute the risk between suppliers and retailers by enabling retailers to take physical possession of inventory while suppliers retain ownership, so that the sale between the supplier and retailer does not actually take place until the final consumer checks out at the register. More complex versions of this transaction are possible.

By mediating a series of linkages between retailers, warehouses, manufacturers, and suppliers of inputs to manufacturing, EDI-driven CMI minimizes forecasting errors along the supply chain. As a hypothetical example, a consumer checking out of an AT&T store in California with a newly purchased Samsung smartphone may, by the single act of purchase, trigger a chain of information going all the way back to a company that supplies Samsung with touch screens relatively quickly, with tight linkages between the "supply chain control towers" of Samsung and AT&T.

Future developments in in-store retailing, enabled by IoT technology, will enhance both the customer experience and the ability of stores to pursue advanced management strategies (Gregory, 2015). Using their cell phones, customers may be able to scan barcodes on items to obtain product information or identify other colors or sizes available on the retailer's website. VIP customers may be offered virtual coupons on entering the store. Smart mirrors may allow customers to "try on"

different clothing virtually. This experience, which immerses the customer in a retail environment with the aid of both mobile and in-store devices, may be known as the Internet of Me. From the management standpoint, smart price tags can be changed in real time based on demand or other needs, and "smart shelves" in store could detect low inventory, thus providing further support for CMI and VMI strategies. Of course, many of these same principles apply in markets for intermediate goods – B2B markets. In these markets, the ability to use analytics and advanced supply chain management to improve performance is in many ways more advanced than in business-to-consumer (B2C) markets, especially in sectors such as electronics, apparel, and motor vehicles where sophisticated supply chain methods have been in existence for an extended period of time. This is also discussed in the section on e-commerce.

4. The impact of Supply Chain 4.0 on workers

4.1 Physical labor in warehousing and driving substitutes for household time

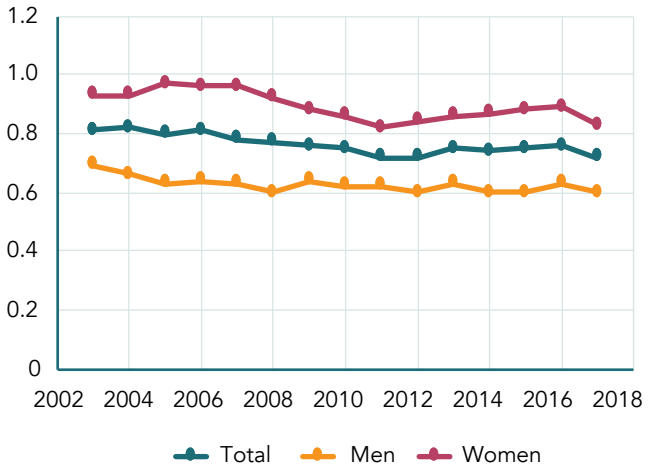
In an important recent contribution, Mandel (2017) demonstrates that U.S. sectors involved in supply chain activities associated with e-commerce have generated a significant amount of employment over the last decade – over twice as much as the reduction in employment in store-based retailing occurring at the same time. Moreover, the jobs involved are reasonably well-paying, and to some extent look like the old factory jobs in manufacturing which became less numerous during the period 1979-2010.

Specifically, Mandel finds that from December 2007 to June 2017, e-commerce jobs in fulfilment centers and e-commerce companies rose by 400,000, substantially exceeding the 140,000 decline in brick-and-mortar retail jobs. On a country by country basis, fulfilment center jobs pay 31 percent more than brick-and-mortar retail jobs in the same area.

Data from the American Time Use Survey (BLS) imply that in 2016, Americans age 15 and over spent 1.2 billion hours *per week* driving to the mall, finding a parking place, wandering around the aisles, checking out, and driving home. The number of hours spent by each such individual shopping per week declined from 4.9 in 2005 to 4.4 in 2012, recovering slightly to 4.5 in 2016. Due to online shopping, in the years between 2006 and 2012 each individual over age 15 spent 6 minutes fewer a day in the purchase of goods and services, which adds up to 11.8 billion leisure hours a year to spend on something else (see Figure 5.7). At the same time, the brick-and-mortar share of retail sales declined from 98 percent to 92 percent.

Thus, e-commerce is a mechanism for translating unpaid household shopping time (which has valuable alternate uses) to paid market time. Instead of consumers spending time shopping, workers in warehouses and on delivery trucks are picking goods off warehouse shelves and bringing them to the consumer's front door. Since time is a scarce resource,

FIGURE 5.7 Hours spent per day shopping in the U.S. (2002-2018)



Source: BLS American Time Use Survey.

particularly in an affluent society, the implications of e-commerce for social welfare are potentially profound. This includes implications for the gender distribution of labor. A reasonable hypothesis is that a further examination of the American Time Use Survey would reveal that the hours spent in shopping activities are disproportionately female, while the employment in supply chain activities are likely to be relatively more those of male mail workers. We leave this hypothesis for future examination.

4.2 Overall trends in supply chain employment

Data

We analyze a group of sectors particularly involved in the distribution of goods, including wholesaling (both traditional and electronic), retailing (both store-based and non-store based), couriers and messengers, and warehousing and storage (Table 5.3). We call the aggregate of these data the "supply chain sectors.' We then use data from the Occupational Employment Statistics (OES) of the U.S. Bureau of Labor Statistics to track sector-level employment as well as employment in individual occupations in each sector. For contrast, we compare the results with trends in manufacturing and in the U.S. economy as a whole.

We focus on the period from 2011-2016. Even though it is a very recent period, it corresponds roughly to the period during which the discussion of "Industry 4.0" (and thus, eventually, "Supply Chain 4.0") crept into the public awareness. This is a shorter period of time than covered in Mandel (2017). Moreover, we have a greater focus on the occupational composition of employment.

TABLE 5.3 Sectors of employment defined as U.S. "supply chain sectors"

	Total supply chain sectors:
423	Merchant Wholesalers (durable & non-durable goods)
425	Wholesale Electronic Markets and Agents and Brokers
441-8 & 451	Specialty Store Retailers
of which	motor vehicles and parts dealers; furniture and home furnishings; electronics and appliance;
	building materials and garden equipment and suppliers; food and beverage;
	health and personal care; gasoline stations; clothing and accessories;
	sporting goods, hobby, book and music
452	General Merchandise Stores
453	Miscellaneous Store Retailers (e.g. dollar stores)
454	Non-store Retailers
of which	Electronic Shopping and Mail Order Houses
493	Warehousing and Storage
481-4	General Transportation
of which	Air, rail, water, and truck transportation
491	Postal Service
492	Couriers and Messengers
	For comparison:
31-33	Total manufacturing
	Total supply chain sectors
	Total U.S. economy

Note: Sectors of employment defined using the Occupational Employment Statistics (OES) data from BLS from 2011-2016.

Supply chain sectors associated with e-commerce experienced rapid employment growth from 2011 to 2016. While employment growth in U.S. supply chain sectors as a whole (8.7 percent) was below that of overall employment (9.2 percent), employment growth was much higher in the subcomponents of warehousing and storage (28.9 percent), non-store retailers (20.3 percent), and couriers and messengers (16.0 percent). Within the subcategory of non-store retailers, employment in the category of electronic shopping and mail-order houses, which approaches most closely the usual conception of e-commerce, grew even more rapidly at 41 percent.[16] The time profile of employment increase shows that while jobs in the "couriers and messengers" sector grew steadily throughout the period, those at non-store retailers experienced an acceleration after 2013, while in warehousing and storage the acceleration kicked in after 2014 (Figure 5.8). In terms of absolute job gains in the supply chain sectors, these were mainly in specialty stores – that is, stores that specialize in one type of merchandise such as food, apparel, electronics, cars, or sporting goods (Figure 5.9). Such stores account for substantially more activity than general merchandise stores. Among the rapidly growing supply chain sectors, the largest job gains have been in warehousing and storage.

Types of employment increasing in supply chain sectors

The dominant category of employment that has expanded in the current supply chain boom is "transportation and material moving operations." Over 2011-2016, these occupations accounted for an increase in employment of over 350,000 in warehouses and courier services (Figures 5.10 and 5.11). These types of jobs involve a combination of physical and mental activity comparable to that of Industry 2.0, but less strenuous because of the effects of mechanization.

Among e-commerce firms proper (electronic shopping and mail-order houses), the greatest absolute growth in employment has been in office and administrative support occupations, with the second largest absolute growth (and largest percentage change growth) being in business and financial operations occupations) (see Figure 5.12). Among specialty stores, employment in many of the back-office occupations has declined, and the gains have come in customer-facing occupations – sales and related occupations, and health care practitioners and technical occupations (see Figure 5.13). The gain in health care workers can be attributed to a single category of specialty stores, pharmacies. Companies such as Walgreens and CVS are increasingly offering vaccinations and other basic health care services hands-on in their retail establishments, which carry many of the same items available in food stores and general merchandise retailers.

5. The impact of Supply Chain 4.0 on GVCs

Supply Chain 4.0 can be seen either as an advanced management practice, or as a cluster of technologies more likely to be adopted as the result of advanced management practices. As shown by recent survey-based research, improvement of management practices – such as may be associated with adoption of Supply Chain 4.0 – is likely to enhance productivity and profitability, lead to higher-quality outputs produced using higher-quality inputs (Bloom, Manova, Sun, Van Reenen and Yu 2018). Supply Chain 4.0 is designed to enhance key management competencies, such as effective target setting, collecting and analyzing data to monitor progress towards these targets, inventory management, coordination of targets/progress across production stages, and worker supervision and incentives.

Supply Chain 4.0 technologies may enable firms to reduce the number of stages in supply chains by reshoring routine labor-intensive activities in developing countries back to the developed countries. These technologies make undertaking some production stages in high-wage countries more profitable by reducing the amount of labor required, thus weakening the incentive for firms to locate in low-wage countries and reducing the importance of low labor costs in determining comparative advantage, providing instead an advantage to integrating multiple stages of production at a single automated location (Dachs *et al.* 2017).

FIGURE 5.8 **Employment growth in U.S. supply chain sectors and overall economy, index, 2011 = 100**

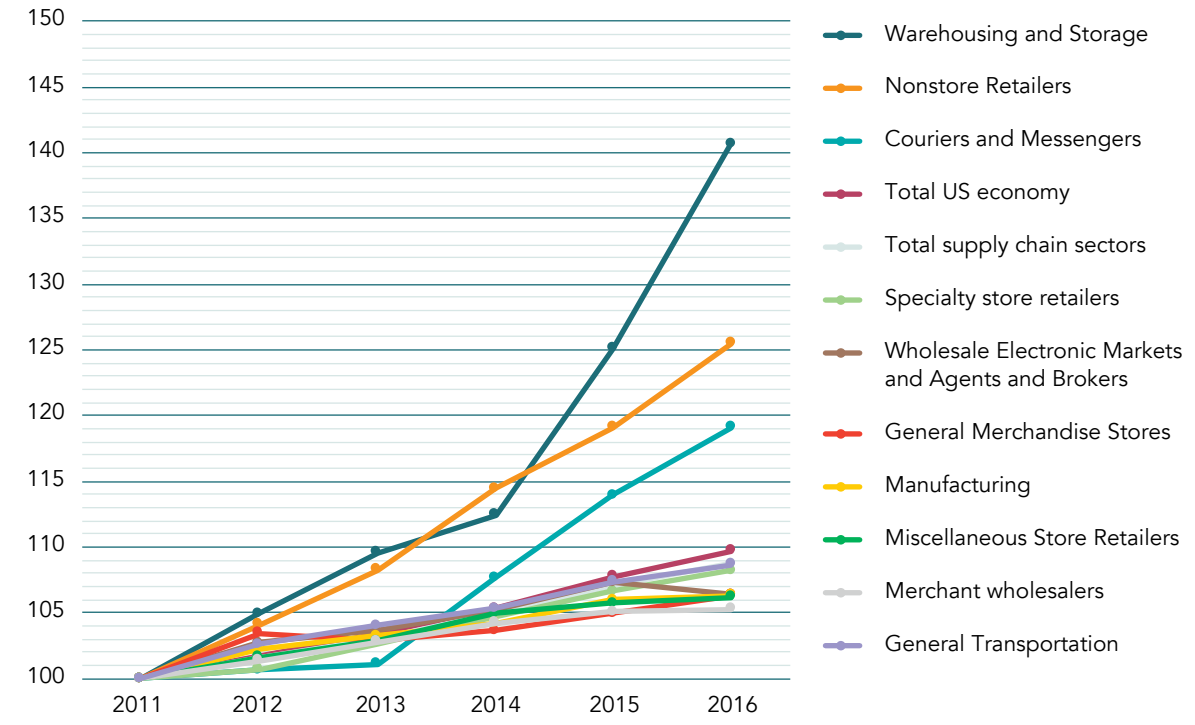


FIGURE 5.9 **Absolute changes in U.S. employment, supply chain sectors, and transportation (2011-2016)**

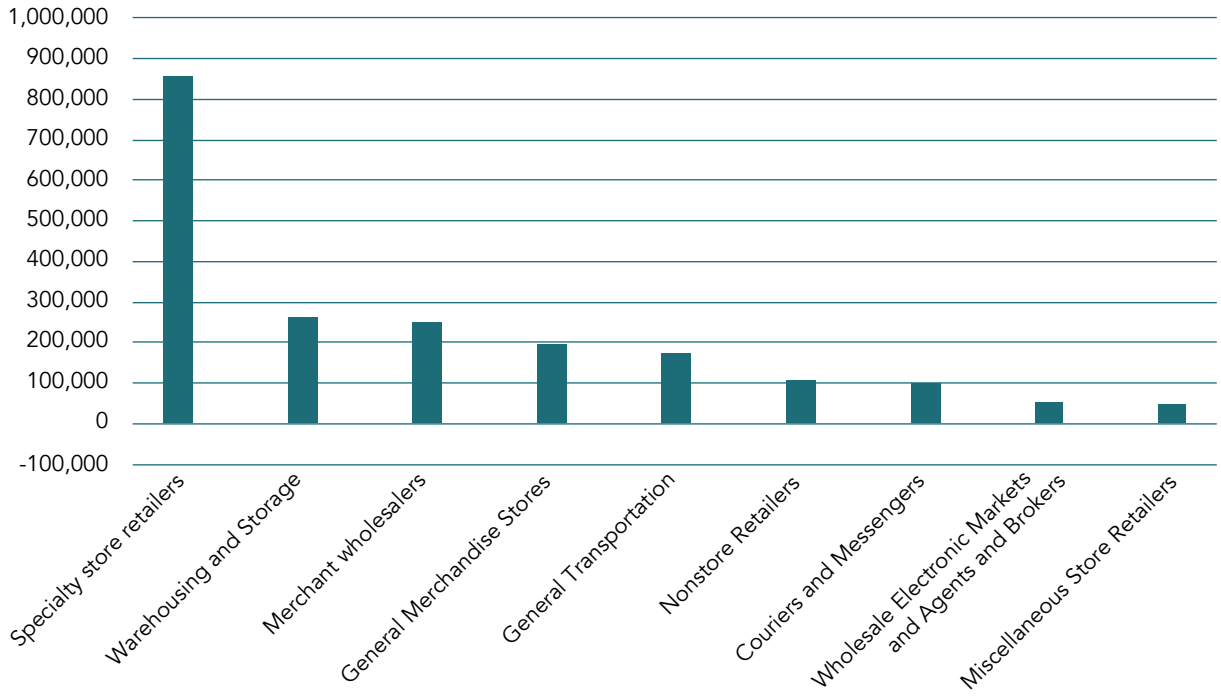


FIGURE 5.10 Warehousing and storage – changes in employment in selected occupations (2011-2016)

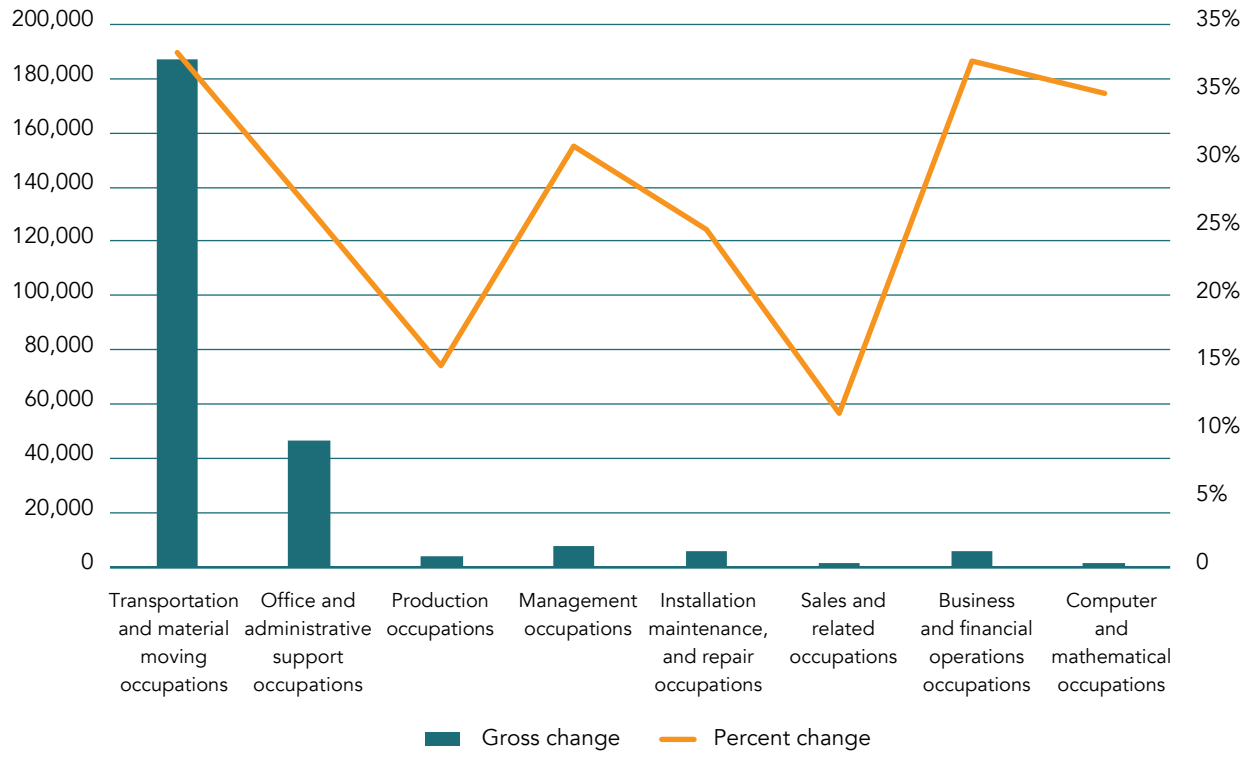


FIGURE 5.11 Couriers and messengers – changes in employment in selected occupations (2011-2016)

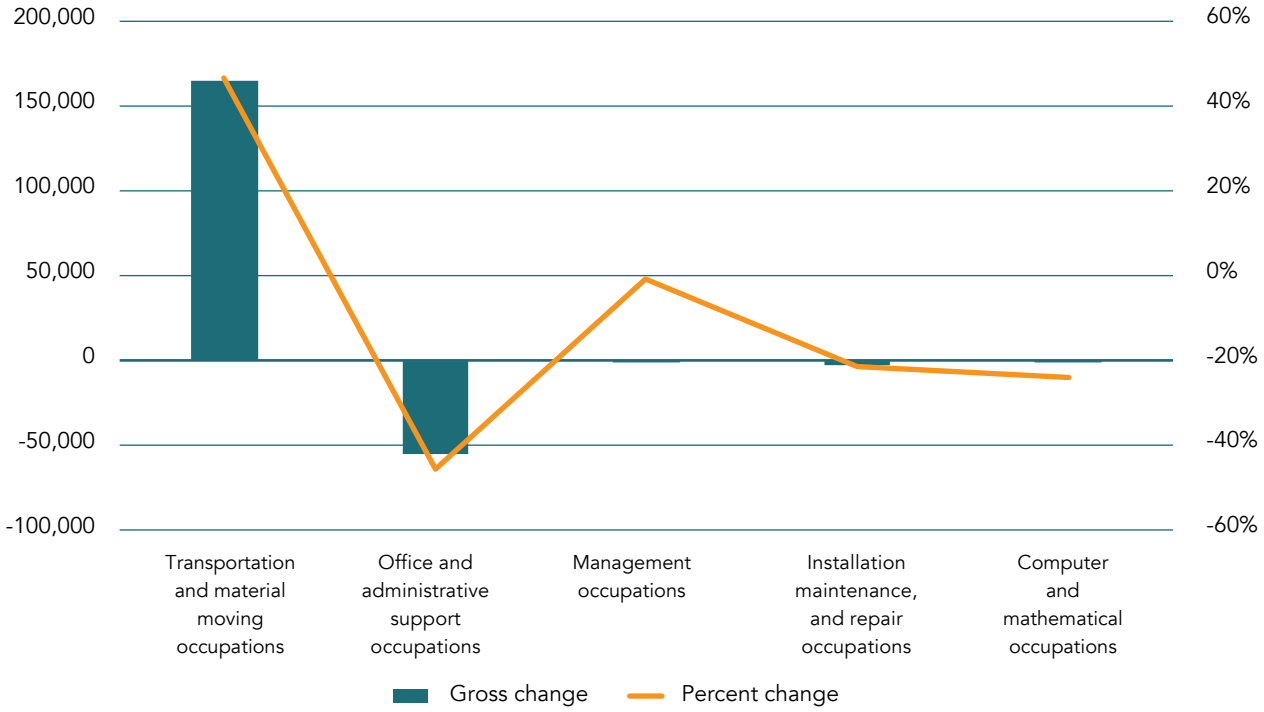


FIGURE 5.12 **Electronic shopping and mail order houses – changes in employment in selected occupations (2011-2016)**

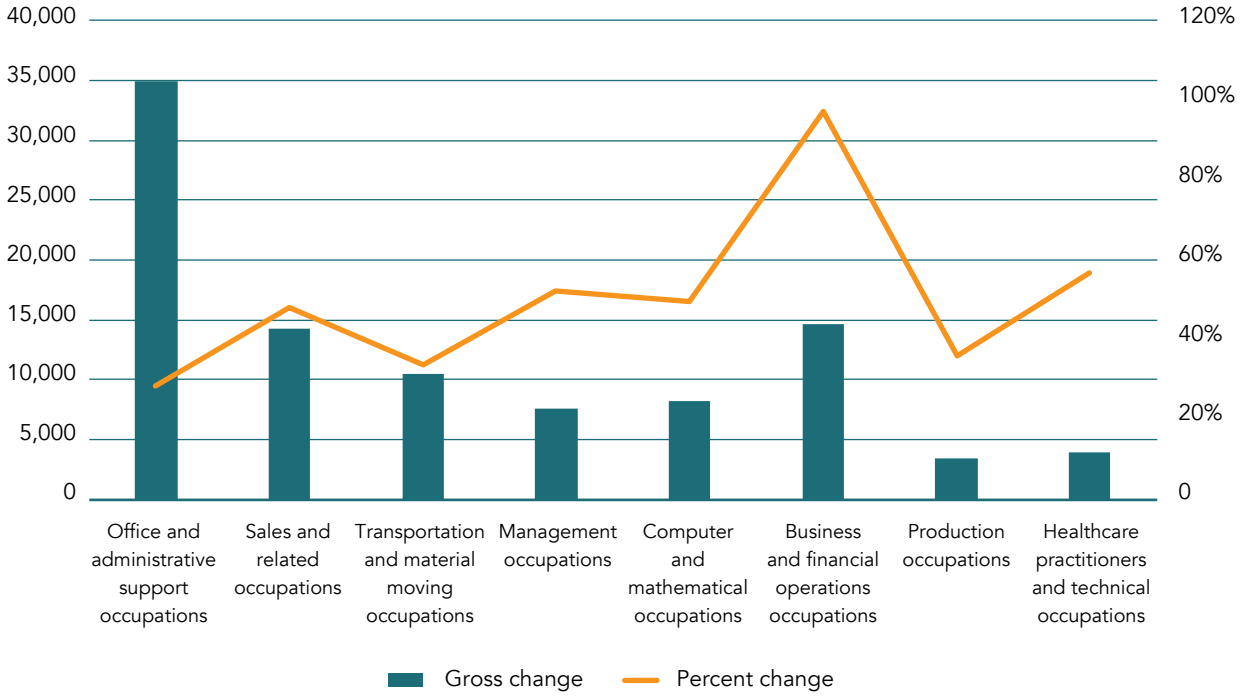
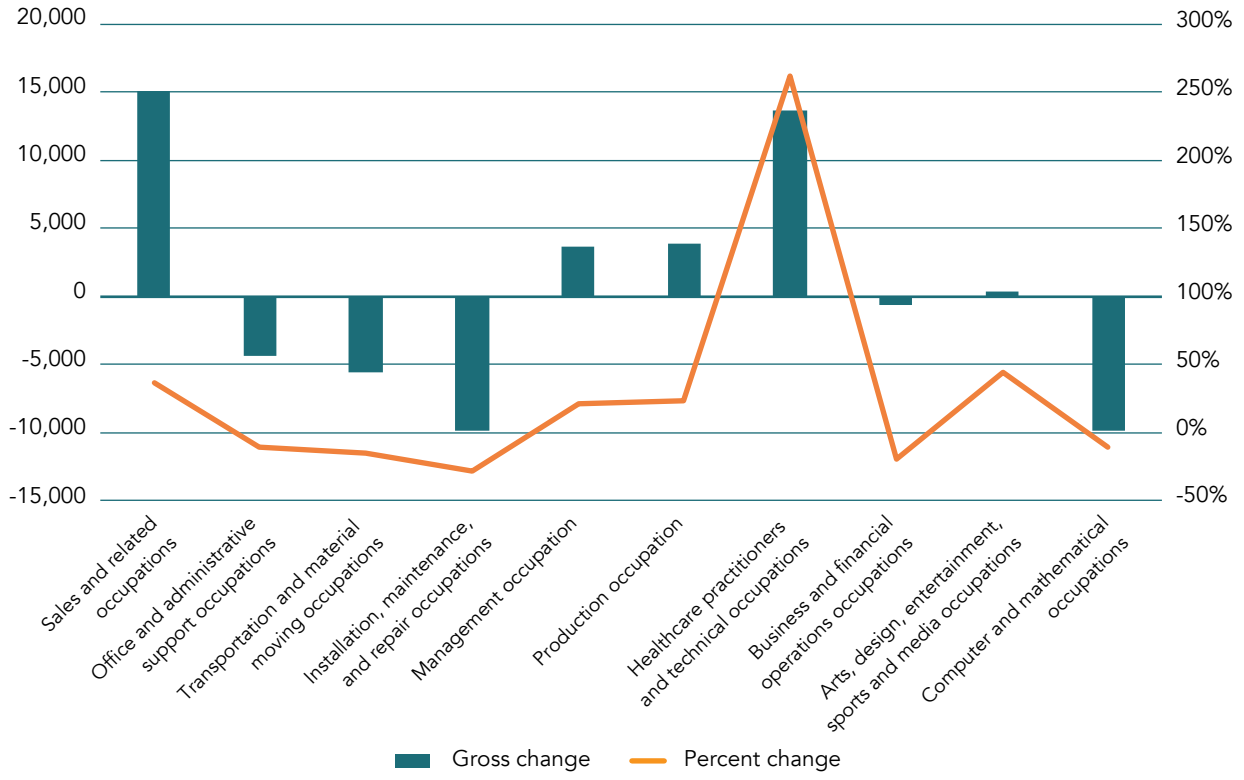


FIGURE 5.13 **Specialty stores – changes in employment in selected occupations (2011-2016)**



It has been argued that 3-D printing works in this way. According to one estimate it is expected that 3-D printing will disrupt between 4.6 percent and 14.9 percent of global trade flows (Arvis *et al.* 2017). By shortening GVCs, 3-D printing may eliminate the productivity benefits associated with international trade in manufactured goods by reducing the need for unskilled labor-intensive tasks. On the other hand, 3-D printing has actually been associated with increased trade in at least one sector – hearing aids – where the technology has been rapidly adopted (Freund, Mulabdic and Ruta 2018).

The new digital technologies are driving a revolution in the way firms are shaping the organization of their production processes. For example, in 2016, Adidas opened a fully-automated shoe factory using 3-D technology and robotics in Germany. The goal was to individualize its products and react more promptly to consumer needs by bringing manufacturing closer to its clients and speeding up delivery. The number of workers required in this factory is a fraction of the number of people working in emerging economies in the production of the same sportswear (Backer and Flaig 2017). Thus, this form of innovation may slow the growth of GVCs and increase the importance of skills development.

The reshoring of production by high-income countries could reduce demand for the products of manufacturing exporters and stifle the potential entry of newcomers into manufacturing GVCs (Hallward-Driemeier and Nayyar 2017). The higher and more specific investments in advanced production technology are, the greater the possibility to integrate manufacturing operations at one focal plant, favoring reshoring (Dachs *et al.* 2017). A report by Citigroup and the University of Oxford's Oxford Martin School finds that 70 percent of Citi institutional clients surveyed believe that automation will encourage companies to move their manufacturing closer to home, with North America having the most to gain from automation, followed by Europe and Japan. By contrast, the authors estimated that China, Association of Southeast Asian Nations (ASEAN) member countries, and Latin America have the most to lose from automation (Citigroup 2016). Hence, the increased use of labor-saving technologies will change the patterns of comparative advantage of manufacturing in the global market.

On the other hand, developments in the technologies such as IoT, big data and cloud computing can strengthen the current structure of GVCs by reducing the costs of tracking and monitoring the components of production, thus lowering coordination and matching costs. A survey of 152 decision-makers in automotive, aerospace, electronics, and industrial equipment manufacturing companies in Germany, France, and the U.S. finds that the biggest benefit of cloud computing is to reduce the cost of optimizing infrastructure (48.3 percent of respondents), followed closely by efficient collaboration across geographies (47.7 percent) and the ability to respond quickly to business demands (38.4 percent) (the Microsoft Discrete Manufacturing Cloud Computing Survey, Microsoft Corporation 2011).

The degree of adoption and diffusion of Supply Chain 4.0 processes is likely to vary across both firms and countries. As a result, in the medium run it could give rise both to more industrial concentration in sectors where it is important, and to increased income inequality across countries. Countries with higher internet penetration, firms and countries with greater digital entrepreneurial skills, and firms which have mastered previous generations of supply management practices (such as the SCOR model of the 1990s) are likely to have advantages in adopting Supply Chain 4.0 methods.

Conversely, attempts by developing countries to promote entry into new manufacturing sectors, particularly using strategies promoting domestic firms with subsidies, incentives, and special zones, might not take into account whether key players in the supply chain are using the most advanced technologies, and thus be at a competitive disadvantage relative to strategies which successfully attract FDI from firms which have mastered Supply Chain 4.0.

Differences in the rate of diffusion and adoption of Supply Chain 4.0 may not necessarily have negative impacts for poverty alleviation or income growth of people with lower incomes in developing countries. It depends on how the gains from the new management practices are distributed along the supply chain. For example, in some cases the application of advanced supply management practices to an agriculturally-based supply chain originating in developing countries could enable additional steps of food processing in those countries, while in other cases they could lead to increased export of raw materials. In the case of increased export, whether farmers capture any of the gains may depend on whether improved (likely foreign) management of the overall supply chain induces farmers to produce higher-quality produce at higher prices, or to have higher rejection rates. The effects of Supply Chain 4.0 on poverty and shared prosperity are thus likely to be contingent on a variety of local circumstances.

Another potential impact of Supply Chain 4.0 relates to the interactions between firms and governments. Improved supply chain management can lead to increased traceability of goods and financial information. This could make it easier for firms engaged in international trade to satisfy rules of origin by providing a comprehensive audit trail, and it could make it easier for governments to monitor some types of tax evasion.

6. Conclusion

It is dangerous to take a snapshot of recent history, whether of technologies, institutions, or economic trends, and project it very far in the future. Current developments in supply chains appear to be employment-generating, but this could reverse if developments in robotics advance in certain directions. The technology could evolve in entirely unpredictable ways. Or, more pessimistically, its diffusion could stall, limiting the application of Supply Chain 4.0 to already high-income countries and becoming another contributor to global income divergence, which may already be the case with Industry 4.0. Concerns about consumer privacy could easily cause governments to act to forestall some of the developments discussed here. For the present, though, jobs are being created in supply chains, and advances in supply chains are creating benefits for consumers. This can be taken as at least a small cause of optimism.

Notes

1. Or, likely as not, in China, though this chapter does not attempt to document that specifically.
2. Six principles of Industry 4.0 are: 1) Interoperability: the ability for plant equipment (i.e., workpiece carriers, assembly stations and products), humans or smart factories to connect and communicate with each other via the IoT and the Internet of Services; 2) Virtualization: a virtual copy of the smart factory created by linking sensor data (from monitoring physical processes) with virtual plant models and simulation analytics; 3) Decentralization: the ability of cyber-physical systems within smart factories to make decisions on their own; 4) Real-time capability: the capability to collect and analyze data and provide the derived insights immediately; 5) Service orientation: offering of services (of cyber-physical systems, humans or smart factories) via the Internet of Services; and 6) Modularity: flexible adaptation of smart factories to changing requirements by replacing or expanding individual models.
3. Available at: https://www.usatoday.com/story/money/2018/02/19/kfc-chicken-shortage-u-k-restaurants-close-amid-delivery-mishaps/350698002/,February 19, 2018.
4. The term "Industry 4.0" is of German origin. It arises from the German Government's High Tech 2020 strategy, an initiative launched in 2011 and conducted through the Ministry of Education and Research (BMBF) and the Ministry for Economic Affairs and Energy (BMWI) (European Commission 2017). As popularized, Industry 4.0 refers to the most recent in a sequence of "industrial revolutions" in historical time (e.g. Hallward-Driemeyer and Nayyar 2018, 40-41).
5. The definition by analogy to Industry 4.0 corresponds to the most common usage of "Supply Chain 4.0", e.g. Alicke et al. 2016, Asthana 2018. To our knowledge, nobody has attempted to provide historically-based definitions of "Supply Chain 1.0," "Supply Chain 2.0" or "Supply Chain 3.0."
6. A "smart factory" is a highly digitized and connected production facility of the type associated with Industry 4.0. The idea of a "smart factory" is still in its infancy and does not refer to a tightly standardized specification of operations.
7. "Augmented reality" refers to a technology that superimposes a computer-generated image on a user's view of the real world, thus providing a composite view. It includes as a subcategory "virtual reality," displays of information of a "3D" or "real" character mediated by such hardware as special headsets or gloves.
8. "Artificial intelligence" (AI) refers to the theory and development of computer systems able to perform tasks that normally require human intelligence, such as visual perception, speech recognition, decision-making, and translation between languages. It is closely related to the concept of "machine learning," i.e. computer systems that improve their performance with accumulated experience.
9. "Cloud computing" denotes the practice of using a network of remote servers hosted on the Internet to store, manage, and process data, rather than a local server or a personal computer.
10. Figures 5.5 and 5.6 portray a linear supply chain where goods are moved from one location to another sequentially – a structure often referred to as a "snake" supply chain. "Snakes" are contrasted with "spider" supply chains, in which parts and components are brought from dispersed locations to be assembled at a common location (cf. Hiratsuka 2005). The concept of a supply chain control tower applies equally well to "snake" and "spider" type supply chains. In a more elaborate chain, in which some lead firm orders major assemblies from Tier I suppliers, which in turn order sub-assemblies from Tier II suppliers, and so on, the flow of material may resemble a combination of "spiders" and "snakes". In such a complex supply chain, it might make sense for each Tier I supplier to have its own supply chain control tower, with information being further aggregated at the level of the lead firm.
11. Not every development in robotics is complementary to human labor. The development of prototype robots that can pick goods from shelves could lead to robots that would easily replace some workers. However, the dexterous movements of the human hand and arm have proved difficult to replicate mechanically. This replicates the experience of the first Industrial Revolution, in which there was approximately an 80-year gap between the development of mechanical spinning and the invention of the sewing machine (which still needed dexterous human labor). Gordon (2016) reports that in advanced robotics competitions, robots still have difficulty opening doorknobs.
12. International organizations began developing record formats for EDI as early as the 1960s (UN/CEFACT et al 2017). By the 1980s the use of EDI for firm-to-firm transactions, both nationally and across borders, was widespread.
13. The connection for EDI can either be a direct physical (hardwired) connection, or implemented over the Internet, or, more recently, take the form of a cloud-based solution.
14. According to Vrbová *et al.* (2016) in consignment stock the vendor, instead of the buyer, is in charge of managing the buyer's inventory and triggering replenishment orders; in *buffer stock* the placement takes place at a particular critical stage of supply chain; and in safety stock it is stored in the final stage of the supply chain.
15. This paper will use the older term "warehouse" and the more modern term "distribution center" interchangeably, as synonyms. Increasing use of "distribution center" in place of "warehouse" is associated with the spread of more advanced techniques of supply chain management.
16. Besides e-commerce, "non-store retailers" includes such firms as direct sales (i.e. door-to-door or house parties) and vending machines.

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