Learning to evolve

A review of contemporary lean thinking

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Abstract *The application of lean thinking has made a significant impact both in academic and industrial circles over the last decade. Fostered by a rapid spread into many other industry sectors beyond the automotive industry, there has been a significant development and "localisation" of the lean concept. Despite successful "lean" applications in a range of settings however, the lean approach has been criticised on many accounts, such as the lack of human integration or its limited applicability outside high-volume repetitive manufacturing environments. The resulting lack of definition has led to confusion and fuzzy boundaries with other management concepts. Summarising the lean evolution, this paper comments on approaches that have sought to address some of the earlier gaps in lean thinking. Linking the evolution of lean thinking to the contingency and learning organisation schools of thought, the objective of this paper is to provide a framework for understanding the evolution of lean not only as a concept, but also its implementation within an organisation, and point out areas for future research.*

Introduction

A brief history of lean

The origins of lean thinking can be found on the shop-floors of Japanese manufacturers and, in particular, innovations at Toyota Motor Corporation (Shingo, 1981, 1988; Monden, 1983; Ohno, 1988). These innovations, resulting from a scarcity of resources and intense domestic competition in the Japanese market for automobiles, included the just-in-time (JIT) production system, the kanban method of pull production, respect for employees and high levels of employee problem-solving/automated mistake proofing. This lean operations management design approach focused on the elimination of waste and excess from the tactical product flows at Toyota (the Toyota "seven wastes") and represented an alternative model to that of capital-intense mass production (with its large batch sizes, dedicated assets and "hidden wastes"). For a full account of these systems, methods, processes and techniques see Monden (1983). Much of the early work at Toyota was applied under the leadership of Taiichi Ohno to car engine manufacturing during the 1950s, later to vehicle assembly (1960s), and the wider supply chain (1970s). It was only at this latter point that supplier manuals were produced and the "secrets" of this lean approach were shared with companies outside Toyota for the first time. These manuals were written in Japanese, and it took almost another decade before the first English literature was available (e.g. Shingo, 1981; Schonberger, 1982; Hall, 1983; Monden, 1983; Sandras, 1989).

Still, the interest taken in lean by the western manufacturing community was limited until the performance gaps between Toyota and other carmakers were highlighted by the book *The Machine that Changed the World*, which also coined the term

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"lean production" (or "lean manufacturing") (Womack *et al.*, 1990). The exploration of the enterprise model, the infrastructure and practices that support lean production, promoted explicitly a thesis of "transference" and the ability of non-automotive and non-Japanese emulation based upon the premise that manufacturing problems and technologies were "universal problems" facing management (Womack *et al.*, 1990). Sparked by the superior performance achieved by lean producers over the performance of traditional mass production system designs, western manufacturers emulated the shop-floor techniques, the structural parts of lean, but often found it difficult to introduce the organisational culture and mindset. So many early lean efforts showed localised impact only, and fell short of their intended impact on the overall system's performance (Holweg and Pil, 2001). In this awareness period (up to 1990), the main weaknesses of lean manufacturing were its automotive manufacturing-based view and limited appreciation of how to handle variability in demand. The implementation was entirely tool-focused, and generally neglected the human aspects of the high-performance work system core to the lean manufacturing approach.

After 1990, there was a gradual widening of focus away from the shop-floor, a trend often ignored by omission, error or design by many detractors. This process of "extension" was also accelerated by the promotion of successful western case emulation by businesses in diverse sectors that had adapted their production systems to include a new design based upon "lean principles" (Womack and Jones, 1996). These principles involved the identification of customer value, the management of the value stream, developing the capability to flow production, the use of "pull" mechanisms to support flow of materials at constrained operations and finally the pursuit of perfection through reducing to zero all forms of waste in the production system (see Womack and Jones, 1996). This evolution may be summarised as a focus on quality during the literature of the early 1990s), through quality, cost and delivery (late 1990s), to customer value from 2000 onwards, as shown in Table I.

Also during the mid-1990s, the value stream concept evolved and was seen to extend beyond manufacturing or the single company, and stretch from customer needs right back to raw material sources (Hines and Rich, 1997; Rother and Shook, 1998). This provided the link between lean and the supply chain, as for the first time, the production "pull" was extended beyond the boundary of the single factory to include the up- and downstream partners.

The relationship between value and cost

A critical point in the lean thinking is the focus on value. Often however, value creation is seen as equal to cost reduction. This represents a common yet critical shortcoming of the understanding of lean. Therefore, let us examine the relationship between customer value and cost in detail.

In 1996, Womack and Jones crystallised value as the first principle of lean thinking (Womack and Jones, 1996). As such, lean had moved away from a merely "shop-floor-focus" on waste and cost reduction, to an approach that contingently sought to enhance value (or perceived value) to customers by adding product or service features and/or removing wasteful activities.

This was a key development, as value was linked to customer requirements, and no longer was simply define through its opposite, waste, on the shop-floor. Regardless of whether an activity appeared to be wasteful from a shop-floor point of view or be

Table I.
The evolution of lean thinking

Phases	1980-1990 Awareness	1990-mid 1990 Quality	Mid 1990-2000 Quality, cost and delivery	2000+Value system
Literature theme	Dissemination of shop-floor practices	Best practice movement, benchmarking leading to emulation	Value stream thinking, lean enterprise, collaboration in the supply chain	Capability at system level
Focus	JIT techniques, cost	Cost, training and promotion, TQM, process reengineering	Cost, process-based to support flow	Value and cost, tactical to strategic, integrated to supply chain
Key business process	Manufacturing, shop-floor only	Manufacturing and materials management	Order fulfilment	Integrated processes, such order fulfilment and new product development
Industry sector	Automotive – vehicle assembly	Automotive – vehicle and component assembly	Manufacturing in general – often focused on repetitive manufacturing	High and low volume manufacturing, extension into service sectors
Shingo (1981, 1988)	Shingo (1981, 1988) Schonberger (1982, 1986) Monden (1983) Ohno (1988) Mather (1988)	Womack *et al.* (1990) Hammer (1990) Stalk and Hout (1990) Harrison (1992) Andersen Consulting (1993, 1994)	Lamming (1993) MacBeth and Ferguson (1994) Womack and Jones (1994, 1996) Rother and Shook (1998)	Bateman (2000) Hines and Taylor (2000) Holweg and Pil (2001) Abbas *et al.* (2001) Hines *et al.* (2002)

costly, it is the customer that ultimately decides what constitutes *muda*[1], and what does not.

Figure 1 highlights the relationship between value and cost, and shows how products or services can be plotted with regards to their relative cost-value proposition to the customer. The further above the cost-value equilibrium a product/service can be positioned, the more attractive proposition it is to the customers. The cost-value equilibrium denotes the situation whereby the product provides exactly as much value, which the customer is willing to pay for, as the product costs. This migration from a mere waste reduction focus to a customer value focus opens essentially a second avenue of value creation:

- Value is created if internal waste is reduced, as the wasteful activities and the associated costs are reduced, increasing the overall value proposition for the customer.
- Value is also increased, if additional features or services are offered, which are valued by the customer. This could entail a shorter delivery cycle or smaller delivery batches, which might not add additional cost, yet add customer value.

Objectives

Lean as a concept has evolved over time, and will continue to do so. As a result of this development, significant confusion about what is lean, and what is not has arisen – a fact clearly observable at both academic and practitioner conferences in logistics and operations management. The key objective of this paper is therefore to provide a framework that explains the developments of the lean concept over time. The questions we seek to answer are:

- What are the key stages of the lean evolution?
- Within these stages, what are the key criticisms? And subsequently;
- Are these criticisms justified?

Overall, we seek to set a vision to help companies to see where they can evolve to in their lean thinking, as well as developing a framework to understanding this using organisational learning theoretical underpinning, in particular the framework suggested by McGill and Slocum (1993).

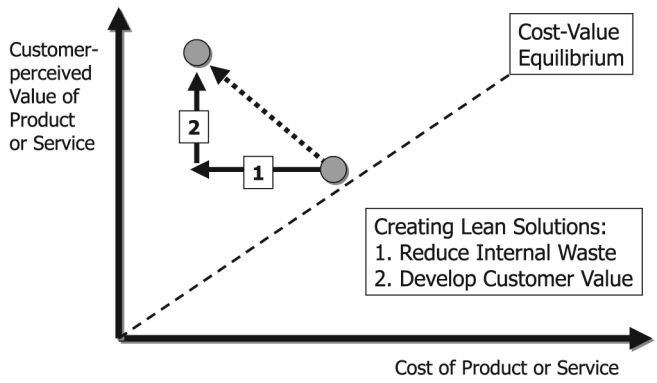

Figure 1.
Relation of value, cost and waste

Criticism of lean

Introduction

In its development over time, critics either from within or outside the lean movement have rightly pointed to various gaps in lean thinking. As lean thinking evolved however, these gaps changed. Table II gives a summary of the gaps in lean thinking and its main critics over time.

This evolution is largely driven because of the shortcomings of lean that surfaced as organisations progressed on their learning curve, as well as the extension of lean thinking into new sectors with different settings and constraints. Key aspects of this criticism are the lack of contingency and ability to cope with variability, the lack of consideration of human aspects, and the narrow operational focus on the shop-floor. Let us examine these in more detail.

Lack of contingency

There is still a general misunderstanding of the contingent nature required to apply lean thinking. Indeed, the otherwise excellent *Learning to See* publication from the Lean Enterprise Institute (LEI) failed in its first incarnation to have an appropriate focus on demand variability and quality issues (Rother and Shook, 1998). However, this lesson had been learnt by the time that the extension *Seeing the Whole* was published in 2002 (Jones and Womack, 2002).

This having been said, for many companies the major focus of lean implementation is still the shop floor and their search for competitive advantage has yet to rely on the more recent lean integrative approaches. Indeed, the car industry, the "mother of lean thinking", is still largely in this shop-floor dimension and has focused largely on optimising the car assembler and first tier supplier tier (Holweg and Jones, 2001). The paradoxical situation of piecemeal lean application is that the most productive car plants in Europe produce into the highest level of finished stocks in Europe.

What is needed in the car industry is an aligned supply that provides strategic value to the customer, by building cars to customer order (Holweg and Pil, 2001). Interestingly, this is a conclusion reached by Monden, who codified the Toyota production system in 1983. However, even Toyota in Japan has so far failed to produce more than two-thirds of their cars to real customer order[2]. The result of this "build-to-forecast" approach across Europe is that there are currently $18bn of unsold vehicles held in European markets, and 350,000 units in UK alone (see Fisher, 1997; Holweg and Jones, 2001; Holweg and Pil, 2001; Holweg, 2003 for more detail).

Human aspects

A further aspect that has attracted criticism is that lean production systems could be viewed through a Marxist lens as being exploitative and high pressure to the shop floor workers. Chief among the critics in this area are Garrahan and Stewart (1992) in their studies of the UK Nissan facility, a site that repeatedly has achieved the highest output of cars per worker in Europe[3]. In a similar vein, Williams *et al.* (1992) suggest that lean production is de-humanising and exploitative. Although such left-wing authors have failed to gain widespread support for their views, they have however raised an important point for those academics and practitioners interested in applying lean thinking, namely that lean should be regarded as more than a set of mechanistic hard tools and techniques and the human dimensions of motivation, empowerment

	1980-1990	1990-mid 1990	Mid 1990-1999	2000+
Key gaps	Outside shop-floor Inter-company aspects Systemic thinking Auto assembly only	Mainly auto Human resources, exploitation of workers Supply chain aspects System dynamics aspects	Coping with variability Integration of processes Inter-company relationships Still mainly auto Integrating industries	Global aspects Understanding customer value Low volume industries Strategic integration E-business
Main critics	Carlisle and Parker (1989) Fucini and Fucini (1990)	Williams *et al.* (1992) Garrahan and Stewart (1992) Rineheart *et al.* (1993)	Davidow and Malone (1992) Cusumano (1994) Goldman *et al.* (1995) Harrison *et al.* (1999) Suri (1999) Schonberger and Knod (1997)	Bateman (2000) Christopher and Towill (2001) van Hoek *et al.* (2001)

Table II.
The main gaps and criticisms of lean thinking

and respect for people are very important. Indeed, the present authors would argue that these elements are key to the long-term sustainability of any lean programme, regardless of the industry sector.

Scope and lack of strategic perspective

Linked to this last criticism is the almost complete lack of discussion of strategic level thinking in lean programmes as opposed to discussions of how to apply a series of different tools and techniques until quite recently. Again the current authors would argue that this gap has led to a lack of sustainability of many lean transformation programmes. In particular, the use of policy deployment and other strategy formation and deployment tools is of central importance (see for instance, Hines and Taylor, 2000; Hines *et al.*, 2002). Earlier references to such strategic thinking are either consigned to isolated academic papers (such as Tennant and Roberts, 2001) or Japanese texts (such as Akao, 1991), neither of which reached a mainstream lean readership.

Coping with variability

Another focal point of the criticism was the ability of lean production systems and supply chains to cope with variability, a key aspect of the lean approach. Indeed, in order to add value to the customer the lean approach seeks to find ways to manage variability and to create capacity by utilising assets more effectively than in traditional systems.

Various lean approaches, such as mixed model scheduling and level scheduling (also referred to as *heijunka*), had earlier been developed to do this. However, in the case of demand variability, these approaches have sought to flatten or control demand, as the original lean pioneers came from fairly stable demand environments industries, such automotive sector supply chains (at least downstream of the assembler). This high-volume and repetitive demand character suits the application of kanban pull-scheduling. However, such kanban-style solutions can be inflexible and thus have attracted criticism from authors such as Cusumano (1994) and Schonberger and Knod (1997).

As a result, many detractors confused pull and kanban, assuming that the latter tool was the only way of achieving customer-driven scheduling. In many other sectors though, demand variability was a main inhibitor to the implementation of lean in general, and kanban in particular. As a result, various contributors proposed agile solutions (*inter alia*: Goldman *et al.*, 1995, van Hoek *et al.*, 2001). The agile school introduced a greater emphasis on dealing with customer demand variability, flexible assemble-to-order systems, creating virtual supply chains and greater use of IT tools. Some of the main differences are summarised by Christopher *et al.* (1999) in Table III.

Learning steps – from prescription to contingency

Four stages of organisational learning

Lean has evolved considerably over time. The four stages of lean thinking defined here are indeed closely related to the stages of development of organisational learning. This will be demonstrated using McGill and Slocum's (1993) four type classification of organisational learning. The first type of organisation is what McGill and Slocum call the "knowing organisation". This type of organisation, as in the first lean awareness stage, believes that there is a best way of doing things that is well established and is closely associated with the scientific management of the likes of Max Weber (1964)

Lean	Agile
Satisfy the customer by adding value and eliminating waste	Satisfy the customer by configuring to order
Long-term relationships with supplier	"Fluid clusters" of suppliers, virtual supply chains
Measure output-criteria, e.g. quality, cost and delivery (QCD)	Measure customer satisfaction
Smooth workflow	Allow for unpredictability
Plan ahead	Face the unpredictable
Reduce stocks to a minimum throughout	Supply chain stock reduction is not the key

Source: adapted from Christopher *et al.* (1999)

Table III.
The main differences between lean and agile

and Frederick W. Taylor (1911). Within this type of organisation efficiency is key and firms tend to be bounded by an underlying philosophy of rationality. In the lean case, this rationality would include the mindset that waste is bad and should be removed, where waste is often defined with an introspective engineering definition of value. Such companies may also be described as "adaptive" or "single-loop", and can only be successful if competing in a mature and static environment (Argyris and Schon, 1978).

The evolution of the lean concept can be likened to organisational learning, both for the general lean movement and firms who progress along this four-stage lean maturity matrix. Here, organisational learning may be defined as "the process of improving action through better knowledge and understanding" (Fiol and Lyles, 1985, p. 803). Dodgson (1993, p. 377) describes organisational learning as:

> The ways firms build, supplement and organise knowledge and routines around their activities and within their cultures and adapt and develop organisational efficiency by improving the use of the broad skills of the workforce.

Such learning takes place through a phased process of information acquisition, information distribution, information interpretation and use, knowledge transmission and storage (Huber, 1991; Nevis *et al.*, 1995). The evolution of lean thinking along such a learning organisation spectrum is shown in Table IV.

Stage 1 – Cells and assembly lines

Turning firstly to the evolution from prescription to contingency, the awareness and quality stages of lean involved the highly prescriptive application of a set of tools and methods. These tools are well documented to include kanban, 5S (housekeping), "single minute exchanges of dies" (SMED – changeover time reduction) and cellular manufacturing (e.g. Monden, 1983; Schonberger, 1986; Harrison, 1992). However, even at this pre-1995 point in time, arguably the dominant paradigm in the field of organisational design and change had moved to a contingency approach (Child, 1977). Such an approach would suggest that there was no one correct "best practice" approach "that is highly effective for all organisations" (Donaldson, 1996, p. 51).

However, in order to understand what the lean movement was at this point it is important to make reference back to the industries in which lean thinking was primarily being deployed, namely the automotive industry and other discrete product or engineering sectors with very similar organisational environments in terms of volume produced, product variety and their nature of component assembly.

Table IV. The development of a contingent evolved lean approach

	1980-1990 Cell and line	1990-mid 1990 Shop-floor	Mid 1990-1999 Value stream	2000+ Value system
Prescription/contingency	Highly prescriptive tool-based approach	Highly prescriptive best practice approach	Lean principles Value stream mapping Prescriptive "one best way"; "Toyota is best"	Contingency involving: customer value, policy deployment, size, industry, technology
Organisational learning	Knowing organisation Single-loop learning Management by objectives	Understanding organisation Single-loop learning Management by objectives	Thinking organisation Single (and some often ineffective double) loop learning Management by fact	Learning organisation Double-loop (and some Deutero learning) Management by fact

As such, one might argue that as long as lean thinking was applied within these very similar environments its lack of theoretical contingency was of little importance. However, this view would be contradicted by many, as even this limited but relatively homogeneous range of firms would still face differences in environment (Burns and Stalker, 1961), organisational size (Child, 1975), organisational strategy (Chandler, 1962) and technology (Woodward, 1965).

Stage 2 – Shop-floor

McGill and Slocum's second type of organisation is the understanding organisation, which may be likened to the second "shop-floor" lean stage. Such organisations are governed by a set of core values and management practices that are designed to clarify, communicate and reinforce the company's culture. In this case, the lean quality stage has firms imbibed in a prescriptive best practice lean approach that is largely centred on the manufacturing area. As such they are often not open to further change and expanding their learning experiences. A typical response when discussing the application of lean with such firms is that "yes, we are doing lean", even if they are only applying it in limited islands of excellence on the shop-floor.

Stage 3 – Value stream

To counter this prescriptive "one best way" approach advocates of lean thinking in the third quality, cost and delivery (QCD) stage started to re-position lean thinking as based on a set of five key principles that it was claimed could be applied across a wide range of industrial settings (Womack and Jones, 1996). Indeed, a series of cases of this application were provided in this text. However, most of these cases are still drawn from component based manufacturing industries and involved the common application of *kaikaku* (i.e. improvement via breakthrough events, as opposed to *kaizen*, continuous improvement) events deployed by Japanese consultants Shingjutsu and their followers.

In spite of these shortcomings, there was the start of an awareness that individual value streams (or specific supply chains) should be individually mapped and contingent solutions found for their improvement (Hines and Rich, 1997; Rother and Shook, 1998). This having been said there was still a significant focus on the "one best way" which would typically be answered by the question "what would Toyota do?" This still largely prescriptive picture of lean thinking is well summarised in Womack and Jones's framework for the lean leap (Table V) which defines a "one best way" which, although containing a good deal of sensible advise, tends to ignore the various contingent features discussed above.

This third type of organisation is best described as the "thinking organisation", which typically focuses on a set of problem-solving management practices, as in the order fulfilment-focused QCD-stage lean firm. However, as in the thinking organisation, these solutions may be criticised as being piecemeal and providing discrete and identifiable solutions, but generally just within one business process. Typical the use of value stream mapping within the order fulfilment[4] process would be seen here. However, within this order fulfilment process, there would be a high degree of questioning and challenging of existing practices characterised by double-loop learning (Senge, 1990). Such a lean organisation typically ignores a range of other key processes such as new product development (NPD) and the development of

Phase	Specific steps	Time frame
Get started	Find a change agent Get lean knowledge Find a lever Map value streams Begin *kaikaku* Expand your scope	First six months
Create a new organization	Reorganize by product family Create a lean function Devise a policy for excess people Devise a growth strategy Remove anchor-draggers Instill a "perfection" mind-set	Six months through year two
Install business systems	Introduce lean accounting Relate pay to firm performance Implement transparency Initiate policy deployment Introduce lean learning Find right-sized tools	Years three and four
Complete the transformation	Apply these steps to your suppliers/customers Develop global strategy Transition from top-down to bottom-up improvement	By the end of year five

Table V.
Time frame for the lean leap

Source: Womack and Jones, 1996

new business opportunities. Such a company would typical rely heavily on a single process diagnostic tool such as Toyota's information and physical flow mapping tool popularised by Rother and Shook (1998).

Such firms also tend to assume that improvements should be based solely on improvements in quality, cost and delivery in the belief that in improving these areas it will create customer value. In some parts of mature industries, such as the automotive supplier sector, this may be a reasonable assumption but the current authors believe this is a dangerous assumption in most other instances. Indeed, in many or most other cases the customer values a wider and more complex range of tangible and intangible attributes such as brand, image, environmental issues and local production. As such, these types of organisation may be criticised for their limited scope and focus. Kiernan (1993) suggests that the linear approach adopted by this type of organisation virtually precludes the ability to step back and ask more fundamental, difficult and useful questions. Such questions may include: "should we be in the industry at all?" The result of this often poor strategic alignment is often a "scatter blast" approach of initiatives with many acting in conflict. Such organisations are unlikely to achieve sustainable improvement against customer desired value attributes.

Stage 4 – Value systems

The fourth value system stage of lean thinking involves a much greater degree of contingency, as it moves past the rhetoric of customer value to include approaches to the active capture of customer needs such as the value attribute approach described

in Hines *et al.* (2002). In addition, this is linked to the active use of contingent strategy deployment using policy deployment (Hines *et al.*, 2000). The application of policy deployment takes into account the various contingent factors impinging on an organisation such as their size, industrial sector, industrial dynamics and technology employed. As such, using this fourth lean value system stage, a unique contingent approach is created using a range of tools drawn from diverse management approaches such as the earlier lean manufacturing, six sigma, marketing, agile manufacturing, system dynamics, theory of constraints, and revenue management.

The last phase of McGill and Slocum's model is the learning organisation, here likened to the lean value system stage. Such organisations seek to maximise the learning opportunities of employees, suppliers, customers and even competitors. However, here each change is viewed as a hypothesis to be tested and by checking the results of the experiment, the learning organisation learns how to undertake the experiment better the next time. Within this context tools such as four fields mapping (see Dimancescu *et al.*, 1997 for details) would be employed within the lean value system firm within its contingently defined key core processes with bottom-up implementation plans validated by the catch balling process with the firm's policy deployment approach (Hines *et al.*, 2000; Hines *et al.*, 2002). Such an approach facilitates learning, and widespread double-loop learning could be expected.

Indeed, the various value stream maps from the different core business processes may also be the basis for what Bateson (1972) calls "deutero-learning" – involving the ability to "learn how to learn". The types of methods and approaches that one would expect to see to illustrate this would include supplier associations (for inter-company or network learning: see Hines and Rich, 1998), real-time strategy formation and policy deployment (for strategic and operational people alignment), attention a range of key business processes (Dimancescu *et al.*, 1997) and strong evidence of learning by doing activities rather than classroom training. The question that advocates of this level of lean would ask is "what should Toyota do?"

Conclusions and outlook

In this paper, we have reviewed lean thinking and its evolution over time, and after more than a decade after the seminal work *The Machine that Changed the World*, we have identified and outlined four key stages in its development. Lean as a concept has undergone a significant evolution and expansion beyond its origins in the auto industry, and its narrow definition around shop-floor improvement. Many critics thus were rightfully attacking lean at their respective time, yet often neglected the fact that lean has, and continues to develop. Such a process of evolution has maintained the adherence to the lean principles developed by Womack and Jones (1996) but has explored different applications and contingencies faced by organisations during the adaptation (the change process at existing rather than new facility designs) process. As such, this development is one of testing the boundaries of lean thinking and the contingent modifications of the approach (within sectors, across businesses etc.) rather than any fundamental change to the lean enterprise "design logic". Many critics' arguments still concern the subsystem of "lean production", as defined in the early 1990s, omitting the developments that have happened after that juncture. We also acknowledge that the development of lean has led to confusion with regards to what constitutes lean, and what does not. We thus have come to the following main conclusions:

- Lean exists at two levels: strategic and operational. The customer-centred strategic thinking applies everywhere, the shop-floor tools do not. This has led frequently to confusion, or led to misunderstanding as to where to apply lean. We therefore encourage the use of lean production for the shop-floor tools following Toyota's example, and lean thinking for the strategic value chain dimension[5].
- The second fact is that lean has evolved, which often is not acknowledged in the criticism. The shop-floor tools have largely been imitation of Toyota, nevertheless lean has evolved on the basis of its five principles, and long gone beyond a mere factory shop-floor application.
- Organisations that miss the strategic aspect (value creation, and understanding customer value) and assume that quality, cost and delivery equal customer value (a common mistake in shop-floor myopic implementations), only address the cost axis (c.f. Figure 1). This has lead to point optimisation in the supply chain. A particular example here is the "island optimisation" of vehicle assembly plant, yet a sub-optimisation of their complete supply chain (Holweg and Pil, 2001; Holweg, 2003).

Lean is one of the most influential new paradigms in manufacturing, and has expanded beyond the original application on the shop floor of vehicle manufacturers and component suppliers in the auto industry, ranging from "heavy" industries such as primary metals (notably Alcoa's production system see www.alcoa.com) to aerospace businesses (*Financial Post*, 1999; Womack and Jones, 1996). In particular when applied to sectors outside the high-volume repetitive manufacturing environment, lean production has reached its limitations, and a range of other approaches to counter variability, volatility and variety have been suggested. Here, the often quoted lean-agile debate is applicable, discussing whether an agile or a lean strategy, or even a hybrid approach is most suitable (Naylor *et al.*, 1999; Christopher and Towill, 2001).

From a strategic point of view however, you can integrate other approaches (particularly the tools they offer) without contradicting the core objective of lean – to provide customer value. In other words, any concept that provides customer value can be in line with a lean strategy, even if lean production tools on the shop-floor, such as kanban, level scheduling, or take time, are not used. And in fact, there are a range of complimentary approaches that can, and have been, used in conjunction with lean (see Figure 2).

In particular, we refer to the concepts considering production capacity, quality, responsiveness of the manufacturing system, demand variability, availability of production resources, and production control approaches. These concepts are not part of the lean production methodology, but can be used in support of a wider lean strategy. For example, a focus within lean thinking is to create capacity by removing waste with the application of improvements in overall equipment effectiveness (OEE), and subsequently, the overall supply chain effectiveness (OSCE) (Rich and Francis, 1998), and overall vehicle effectiveness (OVE) (Mason *et al.*, 2001). Added to these existing approaches is the need to increase process capability and attack wasteful bottlenecks. As such the contingent application of tools and methods from six sigma and the theory of constraints (TOC) are useful additions (Goldratt, 1990). Six sigma

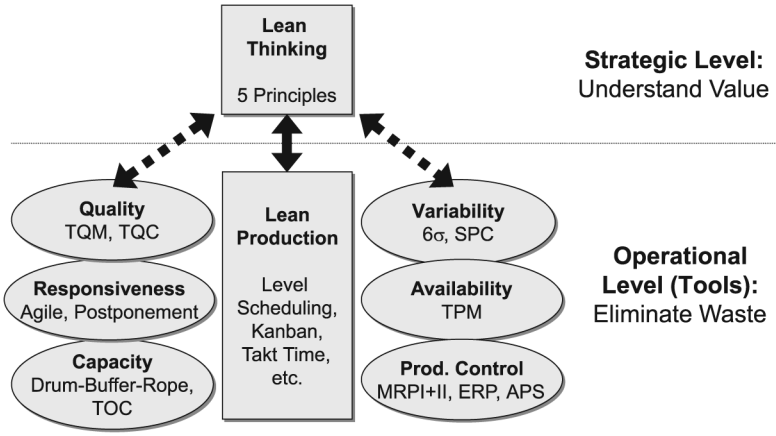

Figure 2.
Lean – A framework

attacks sources of variation by applying a rigorous set of quality tools, which are highly compatible with existing lean approaches (George, 2002). The thinking derived from the theory of constraints is also useful as it helps focus on capacity constraints – particularly where two or more capacity constraints collide in a value stream (Moore and Scheinkopf, 1999). These additional perspectives help to create a more rounded and focused tool-set for applying lean in order to create capacity at the constraint resources.

In conclusion, we found that the distinction of lean thinking at the strategic level, and lean production at the operational level is crucial to understanding lean as a whole in order to apply the right tools and strategies to provide customer value. Much of the discussion in academic circles about lean thinking still centres around the shop-floor, which exhibits a limited understanding of what contemporary lean approaches are about. To counter this lack of knowledge, we have attempted to summarise how the lean concept has evolved from production toolkit, through single supplier-customer focus dyad, to a strategic value proposition. The resulting lean value system encompasses a value-adding network of operations across companies, with the goal of providing a series of contingent value proposition to individual final consumers. This focus on the final customer is still missing in most lean supply chains, and least of all it is found in the auto industry where lean originates. The optimisation of such a networked system is determined by the value created to the customer, and not by localised performance measures within subsystems, such as the factory or the distribution channel.

In terms of moving this agenda forward, research is called for that looks at how lean value systems can be created in a "green-field" environment – rather than lean approaches just seeking to rectify the errors of earlier generations. In addition, the application of this approach will clearly require a contingent application, which very likely will be unique both to a particular value system and industrial sector. Further research is called for to see how this may be achieved in under-researched sectors, such as low-volume manufacturing and service environments like health care, which are still in early stages of their lean evolution.

Notes

1. *Muda* is the Japanese word for waste, in the sense of wasted effort or time.
2. The remainder of cars is generally made for export to Europe, the United States or elsewhere, and are used to buffer the build-to-order service to domestic customers.
3. Labor productivity in terms of hours per vehicle, or annual vehicle output per employee are the standard measures used in the auto sector, and were also used by Womack *et al.* (1990).
4. Order Fulfilment refers to the process covering all activities from the receipt of an order, its production scheduling, raw material purchasing, parts delivery, production, storage and distribution to the final customer.
5. An interesting corollary of this is that even though some observers staunchly hold the "to do lean you must apply kanbans" line, Toyota are now using a version of theory of constraints in Japan that they term "tie-tie".

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