Measuring Operations Performance

Andrea Chiarini
Pauline Found
Nicholas Rich *Editors*

Understanding the Lean Enterprise

Strategies, Methodologies, and Principles for a More Responsive Organization

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An Implementation Model for Lean and Green

Sophie M.C. David and Pauline Found

Abstract Most published articles on the adoption of Lean and Green (L&G) concepts in industry only address specific aspects, rather a holistic approach. Several levels of L&G internalisation are identified. Starting at the highest level, with the conceptual acceptance of L&G; although Green concerns are recognised as important, they are still perceived as costly and unrelated to Lean in the majority of companies. The key drivers of L&G implementations are contingent to the industry sector, geographies and the host organisation, regulations and a number of external influencers also affect growing pressure for Green improvement. It is only when L&G is reflected at strategic and decision-making level that it can be said to be internalised. Therefore this research, including literature review, interviews and survey, discusses how L&G can be internalised and adopted as a new strategic business model with a company and, in addition, the paper sets out to describe a method for a L&G operational implementation rollout.

Keywords Lean and Green · Lean · Green · Environmental sustainability · Business model

1 Introduction

Lean is a business management practice aiming to deliver greater value for customers with fewer resources. Lean, in the context of this article, refers to a wide range of lean activities, including operational, logistical and maintenance improvements, applied both locally, and throughout the value chain. Green and

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greening, refer to the reduction of environmental impact, and associated improvements. Environmental pressures and regulations, add to international, competitive threats and specific company challenges, competing for an organisation's limited resources. Finding synergies between the varied demands can help reduce this burden; whilst Lean addresses competitiveness, Lean and Green (L&G) combines Lean's operational improvement, with environmental benefits. Three conceptual debates, emerging from the literature, are key to framing the topic of lean and environmental sustainability (green).

Firstly, there is still a debate over the planet's ability to support existing and future levels of human activity, and absorb the consequences in terms of waste and resource depletion. The views vary from Gaian nonchalance (Lovelock 2002), and Solow and Romer's optimistic reliance on human ingenuity to solve environmental issues (Martin and Kemper 2012), to Malthusian catastrophic prediction (Martin and Kemper 2012). From these dissonant views, there is an increasing mandate to protect the environment, from Lovins (2011), Desrocher (2001), Florida (1996) and Hall (2009).

The second major debate concerns the justification of environmental benefits. Environmentalism had been widely considered as detrimental to business performance until Porter proclaimed the beneficial, operational and financial, impact of environmental improvements (Florida 1996). In the case study presented by Gordon (2001) and AME (2007), environmental initiatives are yielding significant improvements, and financial motivation is a clearly stated driver of such improvements.

The third debate concerns the consequence of Lean on environmental performance. Bicheno and Holweg (2009), Gordon (2001), EPA (2011) and AME (2007) clearly link the use of lean techniques with environmental benefits, even though they admit that these benefits may be unintended. It is logical that activities such as improving quality and first-pass yield, effective organisation of tasks, right-sizing and optimisation of machine performance in Total Quality Management (TQM), reduction of motion-associated waste, and indeed all other forms of waste, limiting stocks and producing what the customer desires, all lead to improved environmental outcomes, by reducing material and resource usage. But detractors claim that, in certain circumstances, lean can increase the need for travel when one-piece flow is introduced, since reducing batches involves more journeys, and hence a potential increase in transportation waste (Venkat and Wakeland 2006; Zokaei 2010), which would have a detrimental environmental impact.

This paper sets out to examine the concept of lean and green (L&G) to develop a framework model and a process for implementing a lean and green business model in an organisation.

2 Review of the Literature

The analysis of the literature identifies key topics, creating a hierarchy of themes, and summarising the content for each group, highlighting unexpected content and gaps. The grouping of emerging topics is key, to focus the analysis on a smaller

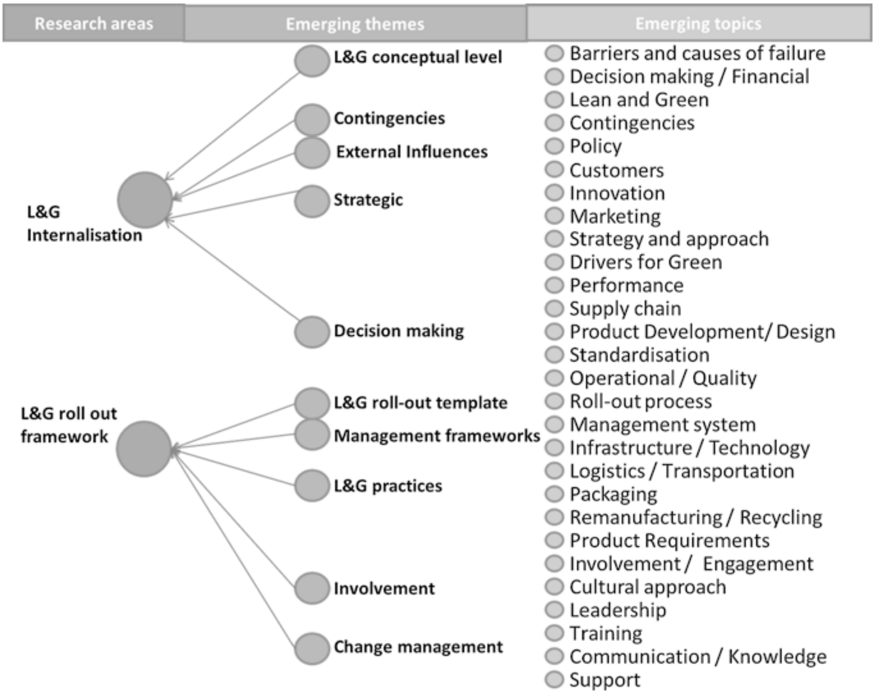

Fig. 1 Theme analysis

number of items that are as mutually exclusive and collectively exhaustive (Minto 2002) as possible, for future analysis. Figure 1 illustrates the complexity of creating such a hierarchy.

From the analysis two distinct grouping can be observed. Firstly, those topics related to the strategic level of implementing a lean and green decision support business model, termed "internalisation" for the purposes of the model, and secondly, those that relate to more operational elements that contribute developing an effective implementation framework.

Internalisation is defined as the adoption journey of new strategic concept from externally influenced to fully embed in an organisation's behaviour.

2.1 Internalisation

External policy and regulation, key influencers of Green commitment, are often created by local regulatory framework (Boira 2011; Florida 1996; Brown 2012; Simpson and Power 2005; Deif 2011; Hatcher et al. 2011). Europe is particularly proactive in driving environmental regulations (Gordon 2001; Gopalakrishnan et al. 2012; Ki-Hoon 2012).

Hopwood et al. (2005) recognise that whilst government intervention is not universally welcomed, there is a minimum need for supporting standard definitions for environmental behaviours and environmental measures; for example to balance the people, planet, and profit elements of the Triple Bottom Line (TBL) (Christofi et al. 2012). Hall and Lovins (2011), cited by Desrochers (2001), propose a deep structural intervention, challenging the fundamental notion of ownership as being unsustainable, whilst Hall (2009) proposes a revolutionary constitutional shift to reflect each individual's responsibility at a global level, and process valuation methods, which remain conceptual. Boira (2011) advocates a constant governmental influence, although less interventionist, to guide consumption behaviours by analysis of consumption patterns, and to influence the economy through "government procurement, subsidy reform, eco-taxes/shifting investment guidelines, socially responsible investment and financial institutions".

Even where governmental intervention is widely supported, Arana-Landin and Heras-Saizarbitoria (2011) warn about the timing of such interventions, citing the example of the current Spanish crisis as a poor economic environment for businesses to shoulder the burden of increased direct and indirect costs to implement environmental regulation. The type of encouragement is also key: if perceived as dictatorial, it may lead to minimal compliance, whereas benefit-driven encouragement tends to lead to deeper company commitment and long lasting improvements (Florida et al. 2001; Yap 2005). Hopwood (2009, p. 435) also cautions that the impact of lobbying can sometimes lead to situations where "nationalistic economics were given priority over environmental considerations, despite the underlying rationale for the scheme."

Although less common, self-directed environmental policy can also occur, when an organisation sees its vision as an extension of its environment, has fully internalised the need for change, or has understood the benefits of L&G initiatives (Klimley 2005). Whilst it is clear that regulations have a role to play, other influences over environmental policy and company behaviour need to be considered, including: customers, shareholders, corporate influence, employees, community, competitors, and the media (Ageron et al. 2012; Simpson et al. 2007; Hall 2011; Reichert et al. 2000). According to Christofi et al. (2012), ownership has a limited influence on the way legislation is deployed in the organisation, either as a short term, "tick-box" compliance exercise, or as long-term, sustainability standards to be exceeded.

There was no mention of the importance of industry associations in the literature review; an opportunity to be explored in the research project.

Contingency theory, initiated by Joan Woodward in 1958, states that there is no single, optimum way to structure organisations and their working, but different practices will best suit different organisations, and tailoring these practices is key to implementation success. Schoenherr (2012) and Law and Gunasekaran (2012), observe that local, industrial and specific, company, situational contingencies have a great impact on sustainability strategies.

Beyond the geographic applicability of regulatory framework, local differences exist between countries and continents, in attitudes towards Lean or Green initiatives, for example:

- Yap (2005) observes that China promotes a “conserver culture”.
- Schoenherr (2012) argues that the greatest benefits of environmental initiatives are possible in emerging economies.

Furthermore, financial viability of recycling, compared to landfill rates, is driven by the existence of a recycled product-market, waste recycling facilities, and their proximity to the plant considering recycling. These markets become increasingly important as raw materials become out of reach (Hall 2009).

Comoglio and Botta (2012), Wiengarten et al. (2012) and Marimon et al. (2011) highlight the dominance of sector-specific influences on the adoption of ISO standards, and recommend comparisons within a specific sector. Marimon et al. (2011) presents data that shows that aerospace is lagging ISO 14000 adoption, with decreasing numbers of certification since the peak in 2000. They also promote the comparison of practices in companies with an established ISO accreditation, rather than newly certified organisations, to ensure that compared practices are sustained ones rather than temporary certification fixes.

Reichert et al. (2000), Lozano (2012), Thourmy and Vachon (2012) and Florida (1996) observe that larger companies are more motivated to engage in Green programmes, since they are in the public eye. Furthermore, they tend to have the product replacement frequency to test Greener products, have significant research and development (R&D) budget, and advanced manufacturing techniques, which all support Green initiatives. Gunasekaran and Spalanzani (2012) also argue that a company strategy that is oriented towards shareholder value, tends to support environmental projects.

Whilst the literature describes generic geographical, industry and company level contingencies, the above findings do not represent an exhaustive list.

Once influences have raised the need for environmental improvement, it should then become part of a company’s strategy. There is abundant argument that successful environmental efforts are more successful if they are fully integrated into the strategy, not just as a line item, but interdependent with other goals (Balzarova et al. 2006; Boira 2011; Calia et al. 2009; Golicic et al. 2010; Nawrocka and Parker 2008; Sarkis and Sroufe 2004). Furthermore, environmental goals should be challenging (Klimley 2005), and need to recognise the prerequisites for success:

- Prior establishment of the root causes of environmental and sustainability concerns, in order to select the appropriate strategy (Gunasekaran and Spalanzani 2012).
- Adoption of an environmental standard to support analysis and on-going monitoring (Marimon et al. 2011).
- Pampanelli 2013 argues that Lean is a prerequisite for a Lean and Green Business Model (L&GBM) as the environmental intervention is using the same principles as Lean thinking, with a focus on flow performance (mass and energy flow) rather than product flow.

- Supplier strategic impact is so key that their involvement is recognised as mutually reinforcing by Soylu and Dumville (2011) and Ageron et al. (2012) argue that environmental concerns should be included in strategic partnering decisions. Benefits are superior when engagement of the end-to-end SC is secured (Rose-Anderssen et al. 2009; Varga et al. 2009; Gopalakrishnan et al. 2012), a practice already in place in the automotive industry (Ki-Hoon and In-Mo 2011).
- All value chain elements, enabling the change, need to be aligned, and the initiative is best rolled out as a bundle, covering: sustainable manufacturing and services, product/process design, sustainability in the SC, in production, in distribution, and in end-of-life and reverse logistics (King and Lenox 2001; Gunasekaran and Spalanzani 2012; Yang et al. 2012).

Some causes for environmental strategy failures are discussed, and should be considered:

- Focusing solely on environment aspects or ignoring operational improvements (Baas 2007).
- Existing success creates a myopia that prevents a company from recognising the strategic potential of environmental improvements (Gharajefaghic 1999, cited in Dervitsiotis 2004).
- "Standardization and enforcement of corporate socio-environmental disclosures" is lacking (Christofi et al. 2012).
- Hall (2009) cautions about the perverse effects of Intellectual Property (IP) protection strategies, leading to "dysfunctional tribalism" which prevents the required level of SC cooperation to co-innovate and ensure products complement each other.

Although the considerations for the inclusion of L&G in the strategic agenda are discussed above, the published literature makes little mention of methodologies used to create a compelling vision and strategy, based on competitive advantage.

Once environmental concerns are recognised at a strategic level, they need to be supported by the decision-making process, and satisfy financial requirements. Although, Hall (2009) recommends distancing the financial dimension from environmental considerations, since many of them are not financially quantifiable, the majority of companies have to demonstrate that they are wisely investing their owners' capital, some level of financial governance is necessary.

Current financial practices are not well adapted, in particular, cost accounting and the assumptions used in decision making are not appropriate (Hopwood 2009; Gunasekaran and Spalanzani 2012). Financial justification is particularly difficult in environmental SC improvements, where apportioning cost and benefits is extremely difficult. This represents a major barrier to such initiatives (Simpson et al. 2007; Varga et al. 2009; Hopwood 2009; Ageron et al. 2012). The time frame of investment and returns is also crucial, as most organisations are driven by short term expectations, whilst environmental improvements tend to yield long term results, and often require significant capital investment (Florida 1996; Brown 2012; Law and Gunasekaran 2012). Company size, resources, and environmental capability will also affect investment decisions (Marimon et al. 2011).

If the Triple Bottom Line (TBL) is used to assist stakeholders' sustainability decision making, as part of the Global Reporting initiative (GRI) (Ki-Hoon 2012), Van Hoek and Johnson (2010) argue that financial impact remains the most important part of decision-making, and even companies having adopted TBL show a bias towards financial considerations. Moreover, Christofi et al. (2012) argue that "that investors have neither rewarded nor penalized firms for adhering to or violating sustainability matters in their corporate decisions."

Too often still, environmental improvements are considered as risk mitigation, and their true value is not recognised (Ki-Hoon and In-Mo 2011). Hall (2011) and Ageron et al. (2012) recommend a change of value system to recognise the true importance of environmental matters, although this, too, is a tall order. Consequently, environmental change agents need to satisfy the criteria of business' decision making; to that effect, Gordon (2001, pp. 17–24) recommends a number of key considerations to communicate:

- "Tie improvement ideas to financial benefits",
- "Make a business case",
- "Transform emotion into business language",
- "Focus on biggest bank for buck",
- "Emphasise reduced risk".

To ground the Green decision-making process as a fact-based activity, Ki-Hoon (2012) promotes Carbon Footprint (CF) as a useful way to translate environmental improvements into financial savings. Despeisse et al. (2012) and Pampanelli (2013b) also promote an analysis of the flow of resources and energy, to identify losses. Liu and Muller (2012) recommend intense communication between policy making and analysts as part of the decision-making process. Other elements to consider are to review options at a system level, and choose the smallest bundle of supportive activities to deliver system-wide improvements (Lozano 2012). The system dimension is indeed crucial, to maximise overall savings instead of optimising each part, and to establish realistic saving estimates in a complex system, as "the maximum efficiency is influenced through a variety of sub-processes, which limit the economical implementation potential as a whole" (Enderle et al. 2012, p. 152).

Such recommendations assume that a structured decision-making process already exists, if this is not the case, this practice would have to be deployed first. Whilst improving decision-making concerning Green issues may be required, it can limit the scope of improvement to the environmental team's activities, and miss the opportunity for Greening all decisions, and engendering wider involvement. Instead, L&G considerations should be integrated in the normal decision-making process, leveraging the most appropriate Green decision-making advice from above, according to circumstances. There is limited practical advice in the literature on the creation of business cases to support Lean, Green or L&G initiatives. Another issue resides in the alignment and prioritisation of self-directed, L&G improvements, on the ground, with planned improvement portfolios that span the entire organisation.

2.2 Operationalization of L&G Rollout

In order to realise environmental improvements, the rollout of related initiatives requires careful design. As Hopwood (2009, p. 439) points out, organisations need to look "beyond abstract schemes for change and improvement to explore the actuality of their functioning and operations, and to use this knowledge for the more realistic design of approaches to changing both the significance which environmental and sustainability considerations play in the corporate sphere." Chriarini (2014) studied the applicability of specific Lean tools to reduce environmental impact in Italian motorcycle component manufacturers and quantified the results, proving the positive influence of Value Stream Mapping to identify environmental waste. Brown et al. (2014) and Diaz-Elsayed et al. (2013) confirmed these findings in multiple case studies from a range of industries.

As illustrated in Fig. 2, a five-stage rollout template emerges. The comparison of existing templates shows that authors do not explore the same number of stages, and disagree somewhat on the nature of these stages:

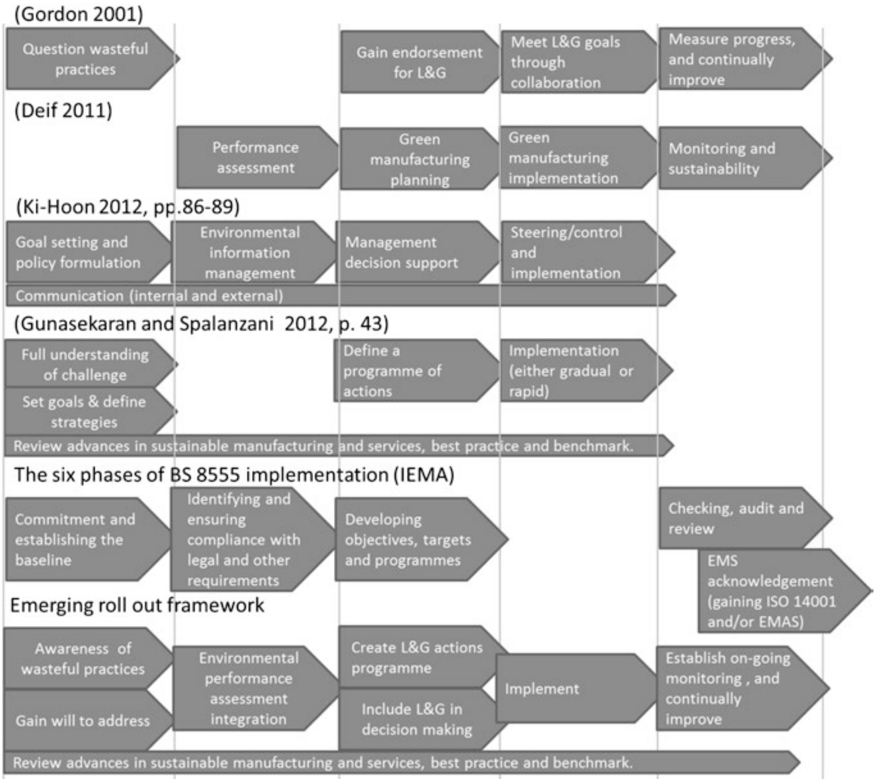

Fig. 2 Comparison of environmental roll-out templates

- Deif (2011) ignores initial awareness and challenge,
- Gordon (2001) and Gunasekaran and Spalanzani (2012) do not include the environmental management system,
- Ki-Hoon (2012) and Gunasekaran and Spalanzani (2012) do not explicitly include on-going monitoring which affects sustainability,
- The BS 8555 roll-out template assumes implementation activities, but it is not explicit, and is the only template specifically referring to compliance (IENA),
- Gunasekaran and Spalanzani (2012) also include knowledge management, supporting accelerated learning in a relatively new field for most staff involved.

The rollout templates available in the literature are linear models that don't embody the iterative nature of continuous improvement activities; this seems to be a significant gap for the research to develop.

The bundling of initiatives is highly recommended as these interact with one another (Florida 1996; Enderle et al. 2012), and Lozano (2012) even recommends specific sets of complementary initiatives. If a multi-discipline approach is essential (Enderle et al. 2012; Despeisse et al. 2012), these initiatives need to be coordinated in order to maximise synergies. Coordination mechanisms and governance are less clear; whilst Gordon (2001) promotes decentralisation, it is difficult to see how it would deliver the coordinated, system-wide changes required by Florida (1996) and Enderle et al. (2012). If system-wide improvements are beneficial, the inherent difficulty of managing large projects' complexity and scope (Thourmy and Vachon 2012), as well as a lack of resources and facilities, may drive towards a decentralised model. The advantages and concerns of each model will need to be understood to choose the most appropriate model, or a combination of several.

For an organisation embarking on an environmental improvement journey, an EMS is the first step (Arana-Landin and Heras-Saizarbitoria 2011; Florida et al. 2001; Galeazzo et al. (2014); Marimon et al. 2011; Sarkis and Sroufe 2004; Verrier et al. 2014). The key benefits supporting prioritisation of an EMS are:

- Encoded practices that support companies at the beginning of their journey (Baas 2007),
- Visibility is increasingly demanded by customers (Ki-Hoon and In-Mo 2011),
- The generation of internal improvement goals, as opposed to external stimuli, yields better commitment (Comoglio and Botta 2012), and
- Projects focussing on management systems rather than technology, tend to yield better results (Thourmy and Vachon 2012).

Having a Quality Management System (QMS) is a precursor to implementing an EMS; Balzarova et al. (2006) recommend that it is based on the ISO system, and, according to Laframboise and Reyes (2005), it is even beneficial to integrate them. As EMS implementation is key to its impact, QMS adoption lessons can generate key insight to ensure EMS success. Gordon (2001, pp. 78–80) recommends the following to ensure it is deployed effectively:

1. “First consider the areas of largest environmental impact,
2. Let employees know that the system was created because the organisation cares about the environment,
3. Embed EMS’s requirements into existing systems,
4. Identify locally the gaps between goals and the current state,
5. Use simple language,
6. Support usage of the EMS,
7. Match training style to company culture,
8. Get outside help to create the system,
9. Roll-out the system in phases,
10. Overestimate the time it takes”.

Despeisse et al. (2012) and Enderle et al. (2012) recommend that the EMS delivers an integrated view of material, energy, and waste, although Boira (2011) cautions against EMS over-complication. Balzarova et al. (2006) also list insufficient audit or lack of integration, as causes for EMS failure. There is indeed a real danger when an implementation is motivated by the desire for certification and compliance, rather than the pursuit of genuine improvement, that once the system is in place, sufficient monitoring and improvement efforts are not sustained.

There is substantial literature on the use of EMS, but only one article discusses their integration with other management systems. This requires further investigation.

Standardisation plays a key role in supporting the adoption of environmental practices. Performance measurement and expected benchmarks are lacking in ISO 14001 (Comoglio and Botta 2012), which poses an issue, although other standards are available, such as UNE 150301, which could be adopted (Arana-Landin and Heras-Saizarbitoria 2011). Standards are particularly important to ensure consistency when supporting SC environmental initiatives (Gopalakrishnan et al. 2012). Boys et al. (2004) cited by Balzarova et al. (2006) discuss the limitations of standardisation, and recommend sector-specific considerations, to leverage a standard and achieve excellence.

There is a debate in the literature over the measurement of Green improvements, and over the need for financial consideration. Measurement standardisation is required (Simpson and Power 2005; Comoglio and Botta 2012) to facilitate appropriate decision making, and since financials are key drivers, and despite Hall’s (2009) opinion, the standard measures need to easily translate into financials.

Lean is considered by Gordon (2001) and Pampanelli (2013) as having a positive environmental impact, since reducing inventory has an impact on reducing the volume of materials in the logistical pipeline. According to Azzone and Noci (1998), Golicic et al. (2010), Gunasekaran and Spalanzani (2012) and Sarkis et al. (2011), green logistical initiatives include:

- Review transportation network structure (reduce distances),
- Switch transport modes to more fuel efficient and greener ones,

- Use alternative fuels,
- Alter the fleet to reduce vehicle size and integrate less polluting vehicles where appropriate,
- Partner with lower-impact, transport firms,
- Improve tracking and information sharing for improved coordination of transport systems with transport needs,
- Recycle packaging.

Beyond these initiatives, circular systems or reverse logistics, which ensure the re-use of production waste and unwanted used goods, are also employed by the most proactive organisations (Azzone and Noci 1998; AME 2007), although coordination of such practices can suffer from a lack of integration and information.

Some logistical improvements, such as reduction of business travel using video conferencing, and reducing employee commutes, impact employees directly (Golicic et al. 2010; Gopalakrishnan et al. 2012) and the way they interact with their employers.

The operational aspects of environmental improvement come under the banners of Lean, Pollution Prevention, Re-use and Re-cycle, and Enterprise Resource Planning (ERP) implementation. When looking at the practices described under each heading, there is significant overlap between categories, even when the activities have a different name, as illustrated in Fig. 3. This not only reflects the

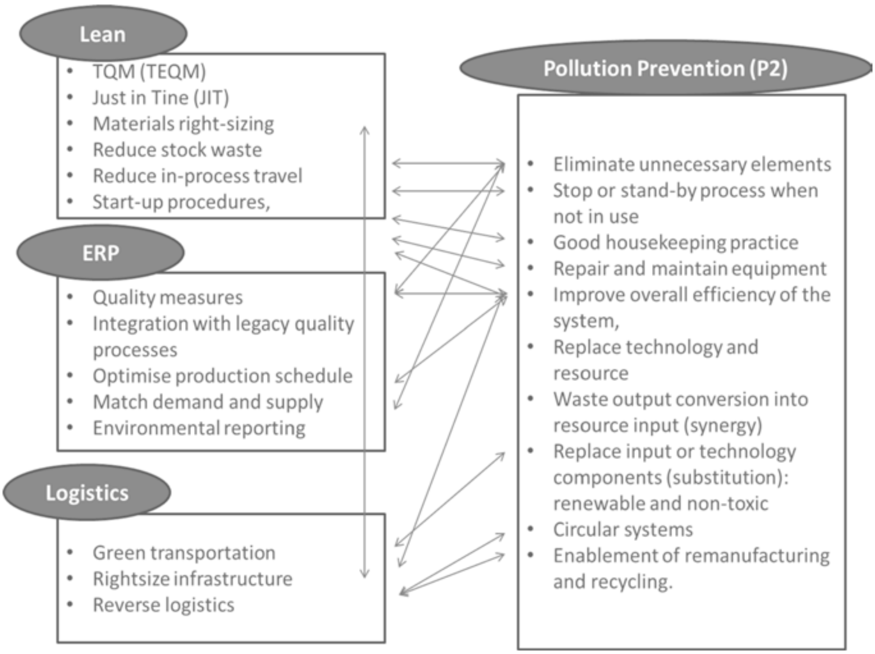

Fig. 3 Practices listed by method

synergies between multiple endeavours, to improve performance, but also implies that coordination is necessary to avoid wasting resources on repeating a given activity.

Ki-Hoon and In-Mo (2011) and Calia et al. (2009) identify some limitations to the dissemination of environmentally friendly operational practices:

- End-of-pipe solutions are mainstream whilst pollution prevention (P2) ones aren't,
- Companies encounter difficulty implementing new technology,
- Market access to cleaner technology is limited.

These challenges are partly due to a lack of knowledge with which to inform the decision-making process, which reinforces the need for a knowledge management activity during the rollout.

If existing facilities constrain lean, environmental, and logistical improvements opportunities, due to lack of flexibility; new facilities may offer significant benefits (Laframboise and Reyes 2005), such as:

- Environmental climate management and air systems best practice,
- Water usage management at system-wide level, and
- Reducing need for harmful chemicals, such as pesticides and some cleaning products, thanks to design features.

Another aspect of infrastructure planning concerns IT, particularly for highly outsourced operations; sustainability relies increasingly on information systems integration (Ageron et al. 2012). According to Laframboise and Reyes (2005), system-wide improvement initiatives, such as Lean and quality suffer from being implemented without a holistic approach, or adequate integration with other business imperatives, like IT upgrades.

The impact of infrastructure, beyond building constraints, affects success when an improvement relies on timely communications of performance, corrective actions and good practices, as this underpins organisational learning. Communications become increasingly critical when the end-to-end value chain involves remote locations and other organisations. Therefore, whilst infrastructure can significantly impact the results of organisational change, it is not systematically mentioned in the published literature discussing Lean and Green implementations, presenting a noticeable omission to be addressed.

A product's environmental impact covers its whole life cycle, although most current initiatives apply to manufacturing, the later stages are now becoming increasingly important (Boira 2011; Gunasekaran and Spalanzani 2012; Hatcher et al. 2011; Herva et al. 2011; Presley et al. 2007). The Extended Producer Responsibility, embedded in increasingly stringent regulations, began in the European Union and is now being adopted more widely. Although the end-of-life regulation affects mostly, to date, automotive (since 2003) and electronics (since 2006) in Europe, the environmental benefits can be realised in other industries.

One aspect of end-of-life consideration is re-manufacturing, which involves re-using part of, or the entire, product, to produce a new one against an agreed quality standard. Remanufacturing relies on effective reverse logistics, the development of a secondary market, and improved information sharing (Soylu and Dumville 2011; Hatcher et al. 2011; Gunasekaran and Spalanzani 2012).

If environmental improvements are mostly envisaged at operational level, they also require support function involvement: sales and marketing, design, and, as they all influence the value chain. To be successful, visibility is key throughout the value chain, from customer to suppliers (Florida 1996). Three main non-functional groups were mentioned in the literature; the potential for additional groups, such as HR, and even all employees, to be involved is not covered. Wider involvement, when considered for a specific function only, misses the strategic nature of system-wide involvement, and the benefit of cross-functional working. This issue merits further investigation.

2.3 Change Management

According to Lozano (2012), the least addressed element is the organisational system, which is crucial to ensuring sustainability beyond initial compliance. According to the authors' experience, the people change approach should address leadership, engagement, culture, training, communications, knowledge and support, in a coordinated and mutually reinforcing manner.

Lack of sustained management support over time and employee engagement, are key reasons for failure of an environmental initiative (Florida 1996; Balzarova et al. 2006; Baas 2007; Boira 2011). Engagement can be difficult to start, and Baas (2007) cautions the reader against assuming that "ethical and economic benefits are motivators for changing routines". To address the former, Baas (2007) and AME (2007) recommend including environmental awareness as part of leadership development. Furthermore, as per lean leadership, environmental leadership should be encouraged at all levels in the organisation, and the foci of leaders should include: vision, communications, accountability, succession planning, and establishing a dialogue with employees (Gordon 2001). Without engagement, an environmental initiative is not sustainable and employees' knowledge is not leveraged (Florida 1996; Boira 2011; Thourmy and Vachon 2012).

Although authors agreed on the importance of leadership contribution, only Hall (2009) develops further the leadership traits that are expected to maintain the vigorous learning discipline, even though it is unclear how the ownership is ensured.

Hall (2009, p. 205) cautions about the self-reinforcing nature of cultures, therefore moving away from the omnipresent "monetary incentives and financial logic" requires intensive efforts which represents a huge shift in mind-set. The influence of culture, on the change, needs to be considered. Balzarova et al. (2006) recommend changing the culture to fit the change culture, as a one-step approach, which is not realistic in the author's experience. In contrast, Gordon (2001) recommends changing the initiative to leverage the culture, which may ignore the need for change. Azzone and Noci (1998), Gordon (2001), Rose-Anderssen et al. (2009), Hall (2009), Martin and Kempe (2012) and Pampanelli (2013) recommend some initiatives for increased cultural alignment:

- Participation in supplier collaboration,
- Peer pressure,
- Build on an existing quality culture to establish a L&G culture,
- Recruit people who appreciate environmental implications,
- Daily reinforcement.

Further to leadership education programmes, training should also be offered to the rest of the organisation, in order to establish awareness (Golicic et al. 2010) and build internal expertise (AME 2007; Baas 2007). In particular, Pampanelli (2013) and Baas (2007) recommend learning by doing, instead of classroom training, to support behaviour change and a continuous improvement culture.

Communication has a key role to play in engaging employees; it should be regular, use varied media, include dialogue, and address both the need for change, and progress realised (Balzarova et al. 2006 and Boira 2011). Communication language should keep a business-like style, and translate environmental benefits in financial terms (Gordon 2001).

Lack of knowledge can be a major barrier to internalisation of an initiative, engender mistakes, and drive inaction (Baas 2007; Ki-Hoon and In-Mo 2011). It should, therefore, be proactively shared (AME 2007; Baas 2007). The importance of support for adopting the change is only recognised by Balzarova et al. (2006), this represents a significant gap in the published literature.

A two-part L&G adoption model, further defined in this section, emerges from the literature review, represented by the systematic framework illustrated in Fig. 4. This model informs the structure of the analysis.

2.4 Conceptual Lean and Lean Business Model Derived from the Literature

A L&G model, composed of two elements, emerges from the literature: the internalisation level and the operational rollout framework. The levels of internalisation reached by an organisation helps to assess the level of commitment and sustainability of an organisation's L&G intentions, beyond marketing claims. The extent of the rollout framework refers to the breadth of adopted practices, and their coordination into integrated bundle, to create a self-supportive rollout framework.

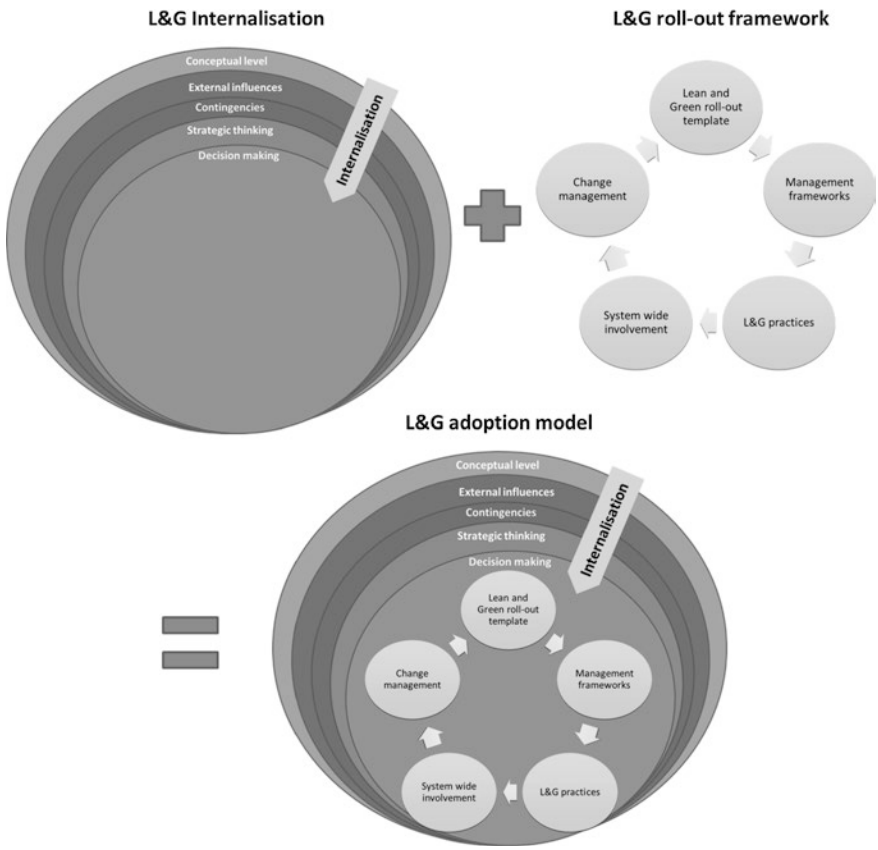

Fig. 4 L&G systematic adoption framework

3 Model Validation

3.1 Research Questions

The research questions are constructed to validate the model illustrated in Fig. 4 and address some of the gaps and contradictions from the literature as illustrated in Fig. 5.

Five levels reflect the different stages of L&G internalisation; the first three are not controlled by the organisation, whereas the last two are internal:

1. **Conceptual level**—the acceptance of environmental concerns, environmental improvement financial viability, and the synergies between Lean and Green as valid conceptual considerations,

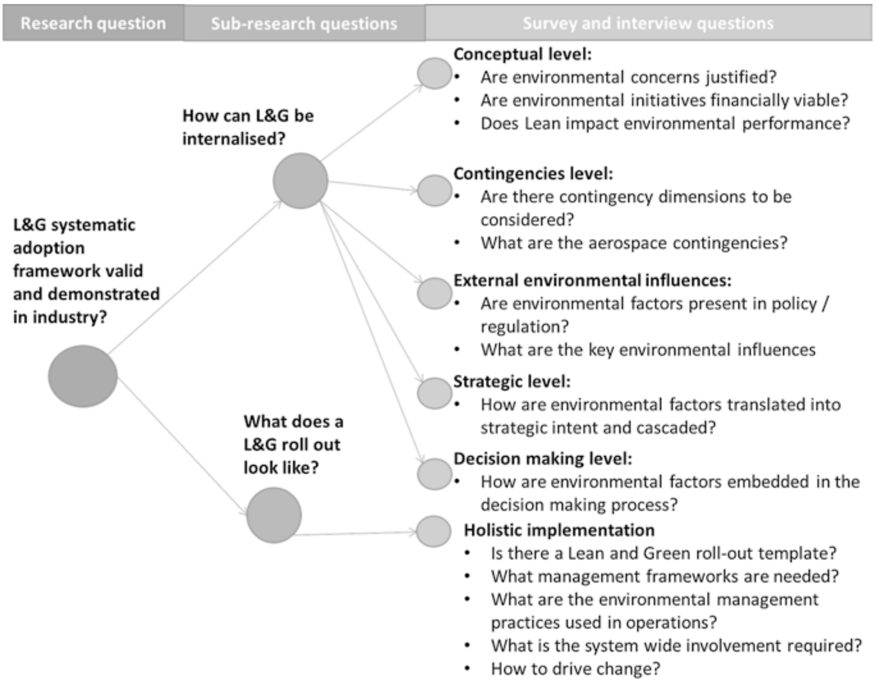

Fig. 5 Research framework

2. **External influences**—the influences encouraging Lean and Green adoption, including policies and regulations, and also key stakeholders,
3. **Contingencies**—specific considerations follow next, in view of geographical, sector and company contingencies,
4. **Strategic thinking**—the first level to reflect that L&G is internalised is the strategic one, L&G objectives are set, cascaded, managed and monitored through the organisation's strategic processes,
5. **Decision-making**—integration of L&G as part the decision-making process and the on-going improvement programmes.

The second part of the L&G adoption model describes an L&G rollout framework, comprised of five distinct activities,

An **L&G operational template** is used to identify the most appropriate L&G activities, and ensure synergies,

1. **Management frameworks** need to reflect the Green agenda, and leverage integration with Lean improvements, and with other systems, throughout the value chain,
2. **Specific L&G practices** are recognised as a benchmark, they need to be included and integrated in the programme, to maximise system-wide benefits,

3. Depending on the programme reach, **system-wide involvement** beyond operational teams, needs to be carefully thought through, engaged and aligned to support such activities,
4. **Change management** maximises programme success, and ensures improvements are sustained beyond the project phase; often under-estimated, it represents a key investment in leadership, communication, training, knowledge management and support.

3.2 Research Methods

To avoid the pitfalls of undertaking a long-term project (Kearns and Gardiner 2011); a structured plan was developed at the outset of this study, as summarised in Fig. 6. The first iteration of the literature review supports subject discovery, followed by topic refinement, and research questions. The analysis of the literature first identified key emerging topics (Fig. 1), creating a hierarchy of themes, and summarising the content for each group, highlighting unexpected content and gaps (divergent process). This was followed by grouping of emerging topics to develop a number of emerging themes, to focus the analysis on a smaller number of research areas that are as mutually exclusive and collectively exhaustive (Minto 2002) as possible, for future analysis (convergent process).

- The following iterations support further knowledge acquisition, and constitute the basis for the literature review, the L&G framework, and the research questionnaire.
- The semi-structured interviews validate the model.
- A survey also validates parts of the model.
- Finally, analysis generates conclusions from the findings.

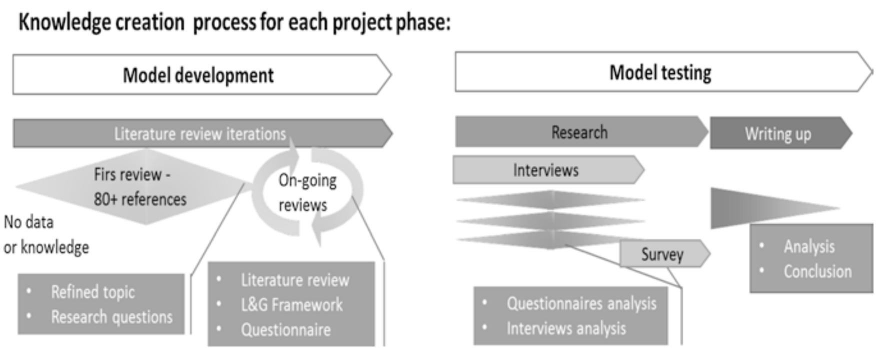

Fig. 6 Summary of research method and knowledge creation process

The research consisted of a series of 11 in-depth interviews. Two distinct groups of practitioners were interviewed: practitioners of Lean, and of L&G, with direct responsibility and involvement in continuous improvement. This group offers an internal and practical view of Lean and L&G implementation in an organisation, and represented different levels in the organisation. The observers have less direct involvement in specific implementations, but have witnessed several Lean or L&G implementations and can therefore offer more objective perspective and reflection, linked to their roles in the academic and consulting worlds, compared to practitioners who are embedded in a specific organisation. Five practitioners and six observers were interviewed. Practitioners' locations are exclusively European, split between the UK and France, whereas observers were based in the UK, USA, and South America, reflecting a more international view of L&G implementation.

A survey was conducted where survey respondents were purposively selected from a database of Lean and Transport Systems Technology alumni, where they were known to have specific knowledge of Lean and of manufacturing operations management. The respondents were individually invited by e-mail, and sent a common link to ensure anonymity. Over 180 people were invited to take part in the survey, 85 opened the survey, and 57 completed it. In total, 28 aerospace, six automotive and 23 respondents from other industries took part. Due to the small sample size, the automotive industry responses were amalgamated in the other industry category. Most of the participants are based in the UK or France, apart from one individual, based in China. Company head office locations, where a large part of the strategic decision making takes place, were shared between Europe (80 %) and North America (20 %), no companies head-quartered in Asia or other regions took part in the survey.

4 Findings

4.1 Internationalisation

Observers supported the increased prevalence of environmental concerns, worldwide and across industries, and that the voice of protractors is mostly limited to political agendas.

The level of motivation of companies to address such issues does not match the level of awareness, this results in part from the wide spread belief that Green, as was previously the case for quality, costs more. This view can be explained by lack of integration with other improvements, counterproductive financial practices, and the difficulty of assessing environmental savings. Although, most managers tend to balance their perception of short-term costs and benefits for each activity, a higher financial pressure is emerging at institutional investor level to drive a longer-term investment view. Increasing numbers of investors are demanding organisations to adopt sustainability measures to improve long-term financial outcomes. Therefore, financial justification of Green investments requires a longer-term view and a new approach, this is what the observers, who hold academic and consultancy positions, have developed to help companies overcome these problems.

Although all interviewed practitioners accept the synergy between Lean and Green benefits, most had not previously thought about it. Observers have pointed out that in some cases, a Lean improvement may be environmentally detrimental, therefore the lack of awareness, and potential isolated experience of such detrimental impacts, may explain why Lean and Green synergies are not universally recognised. As Lean has been a mainstream business activity for 20 years, whilst Green is still developing as a business standard, most survey answers sequenced Lean before Green (Fig. 7). Although the literature highlights that Lean builds a supportive engagement and systemic platform to facilitate environmental activities, the author, supported by survey results, believes that it isn't a pre-requisite. Green can also lead to Lean by using the EPA (2011) L&G toolkit, providing an opportunity to implement a selection of Lean techniques for environmental purpose.

The research supports the findings of Pampanelli et al. (2013a, b) and confirms that, although a Green regulatory framework sets the context, it is only when the need for Green is recognised and demanded by large organisations, controlling extensive value chains, that the Green agenda can be systematically adopted. In addition, regulation rollout needs be associated with financial consequences, to leverage the dominant financial driver, including incentives (Florida et al. 2001; Yap 2005) as well as punishments Boira (2011).

Although regulations drive environmental performance compliance, a number of external influences also have an impact. Survey and interviews confirmed the influence of end-customers, industry associations, media and to a lesser extent, suppliers. The role of investors, disputed in the literature, is becoming increasingly influential, as recent events, particularly in the banking sector, are strengthening the need for sustainability in the way organisations are lead. Additional influencing forces were uncovered by the research: competition, recruitment, and the political arena.

Answer	Bar	Responses	%
Lean first then green		24.00	58.54%
Lean and green simultaneously		13.00	31.71%
Green first, calling upon lean techniques		4.00	9.76%
Total		41.00	100.00%

Fig. 7 Sequence of Lean and Green initiatives

As previously discussed, the Green regulatory framework is not homogenous, world-wide; as the value streams of aerospace organisations tend to be international, different parts of the value stream will be impacted by different regional requirements. The treatment of value chains spanning regulatory frameworks is notably absent from the reviewed literature.

The research confirms that industry contingencies need to be taken into consideration, to maximise benefits and reduce risks.

The company size dimension, mentioned in the literature, was not explored in the research since all respondents work for large companies that can support the R&D effort required for L&G adoption. Had the survey included smaller companies, R&D might have been a concern.

Observers confirm the strategic dimension of L&G, and the need for recognition at that level, due to: end-to-end value chain implications, information requirements for decision making, and the level of integration required with other systems. They also echo the strong warning concerning setting environmental targets independently of other sustainability measures, in particular, financial objectives. The gap identified in the literature review concerning the provision of tools to create a compelling vision and economic assessment is addressed by observers, who also work as consultants, using a maturity matrix to reflect current position, and a comprehensive list of options for future and associated expected benefits.

The inclusion of Green considerations in the decision-making process is confirmed as essential by observers. They point out that, even when the decision-making process involves TBL considerations, it remains dominated by financial considerations or risk mitigation, rather than an environmental improvement philosophy. From a practical stand point, the authors recommend adopting the organisation's existing standards, presenting Green decisions in a formal manner, to build initial management buy-in, and that improvement proposals need to be accompanied by financial impacts. They also confirm the need to challenge the assumption made by literature, concerning the suitability of the existing decision-making processes, as they often treat non-core issues, such as Green considerations, as 'tick-box'. They also point to the poor fit with common financial practices; this last point is particularly important in aerospace companies, since the benefits of L&G improvements are frequently not recognised appropriately. An additional insight from observers' interviews concerns the inclusion of environmental considerations in the day-to-day informal decision making, through role and responsibility, and the individual, performance-management process. This incentives model is debatable, in the view of intrinsic motivation theory (Pink 2011), and may be more appropriate to certain cultures, such as in North America, where the observers who put this idea forward are based.

There is a gap in the literature review, which is not addressed in this research, concerning the reconciliation and alignment of formal decision making with incremental, self-directed improvements. From a technical perspective, end-to-end solutions yield most benefits, and as per Lean, Green initiatives are subject to sub-optimisation risks when locally initiated; to mitigate this risk, L&G requires a level of top-down guidance. The engagement of staff requires giving them greater freedom over the choice of improvements to be carried out locally, as they are best placed to identify them. The top-down approach and the bottom-up one are exclusive, and affect the decision-making model, which in turn drives the rollout framework. In the author's experience, both approaches need to cohabitate, and alignment starts with a clear vision, embedded through the strategic process (Table 1).

Table 1 Conceptual level findings

Conceptual level	Findings
Green concerns	• All interviewees confirmed that Green concerns are increasingly important to all sectors of industry
	• Green concerns are key to transport companies, and reducing the environmental impact is mostly embedded in product development rather than in manufacturing
	• An observer pointed out that, looking at the life-cycle environmental impact of transport products, emissions during product life cycle are mostly linked to product operations through fuel consumption rather than during the manufacturing phases
Financial viability of Green initiatives	Observers dominate the reflection on this topic:
	• They concur on the financial viability of Green improvements
	• They also recognize that there is still a myth that Green, like quality, costs more due to the short-term financial practices, a view that is confirmed by practitioners
	• They point out that sustainability is becoming increasingly important to investors, particularly institutional investors
Synergy between Lean and Green	• Although observers state a high level of synergy between Lean and Green for a majority of lean improvements, they recognize that some Lean activities can be detrimental to Green
	• Observers also recognize that the synergy is not widely appreciated by either, Lean or Green practitioners in industry, only one of the interviewed aerospace companies has established a link between Lean and Green improvements
	• Practitioners recognized some shared benefits between Lean and Green, mostly linked to waste removal and quality improvements, although Green improvements generated by Lean initiatives are not planned or purposefully measured

4.2 Implementation Model

Whilst the content of the L&G rollout template is fundamentally valid, the model requires redesign to accommodate both the coordination effort required for EMS implementation, and system-wide, environmental changes, whilst encouraging local engagement. It also needs to consider on the current state, envisaged future state, and fit the activities required to close the gap. On reflection, the rollout template emerging from the literature is mostly derived from EMS implementations, and assumes that the organisation is right at the very beginning of their journey. Proposed changes to the L&G rollout template are sketched, at high level, in Fig. 8.

The bundling of activities, which reinforces the systemic dimension of L&G rollout, and the need for a system-wide decision-making and deployment mechanism, identified in the literature, is not validated by the research, as it would have required very detailed focus on this section. Hence, there is potential for further research in this area.

Observers confirm the importance of supporting L&G with an EMS, and also validate the risk and cost of solely focusing on implementation or certification. Although the efficiency of integrating management systems is identified in the literature, and by observers, they miss the more important, effectiveness benefit mentioned by one practitioner. His organisation has integrated QMS and EMS, due to noticing that quality and green issues could be different symptoms of the same root cause; the effectiveness benefit, of resolving issues common to EMS and QMS in a single intervention, far outweigh the efficiency benefit, of having a single audit visit or a shared software solution for several management systems.

The adoption of ISO 9001 and ISO 14001 quality and environmental management systems is tested for the following: ISO 14001, a generic environmental management

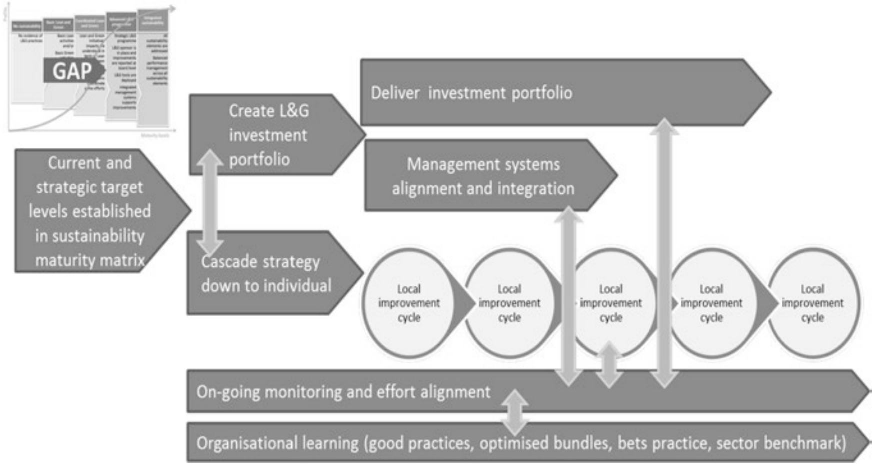

Fig. 8 Proposed new L&G rollout template

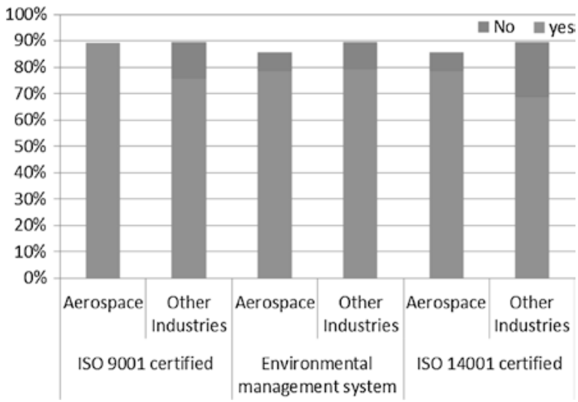

Fig. 9 Adoption of quality and environmental management systems

system and ISO 9001, a generic quality management system. The results are shown in Fig. 9. Overall, circa 92 % of respondent's companies are ISO 9001 certified, 88 % have an environmental management system and 82 % are ISO 14001 certified. 82 % of respondents working for companies with ISO 14001 certification represent a very high percentage, since in 2010; fewer than 1600 companies were certified across France and the UK (Marimon et al. 2011).

The aerospace industry, due to high regulatory demands, has the highest rate of standard adoption.

Observers echoed the literature recommendations concerning the need for performance management systems alignment, and for standardisation. Therefore, data used for benchmarking in the current climate may not be adequate.

The improvement methods presented under the Logistics, Lean and Green banners were all validated as relevant by interviewees. All interviewees confirm the synergy between the Green, logistics and Lean tools, although several practitioners recognise that they had not made the connection prior to the interview, which could explain why some survey respondents didn't think that there is much synergy between Lean and Green. All observers confirm this lack of awareness in the continuous improvement (CI) and environmental communities, beyond the minority of companies who have implemented L&G. Outside of system-wide activities, the additional dimension of product life cycle needs to be added.

Observers validate the recommendation for end-to-end value chain involvement beyond traditional organisational boundaries in L&G, as well as the need to establish clear ownership of initiatives to ensure success.

Practitioners and observers validate the importance of, and highlight the current lack of change support for technical subjects, such as Lean, Green and L&G. They also confirm the detail of the proposed change management interventions. Although the research focuses on the Lean and Green components of sustainability, the importance of people factors to implementation success reinforces the need to address the three dimensions together.

5 Conclusions

Although there are a significant amount of published articles on specific aspects of Lean and Green, there is a lack of a L&G systematic adoption framework, with the majority of written work in the form of books. These gaps in the published literature can be explored by the following research questions:

1. *How might L&G be internalised (adopted as a new strategic business model) within a company?*
2. *What does a L&G implementation rollout look like?*

5.1 How Might L&G Be Internalised in a Company?

Taking a systemic view, several layers of L&G internalisation were identified during the literature review, three are external, and exert influence on the organisation, whilst two are internal, and reflect how the organisation responds to external influences.

At the highest level, three relevant conceptual topics emerged during the literature review: the acceptance of green concerns, the financial viability of environmental improvements, and the synergy between Lean and Green. As confirmed during the research, Green concerns are increasingly recognised in industry. The interviews further pointed out that although some companies are realising extensive savings through reducing environmental waste, Green initiatives are still perceived as costly by a large number of organisations, due to narrow investment assessment practices, whilst Green practices benefit from longer-term investment and a broader consideration of benefits, which consultants have begun to explore. The last point reflects the observers' experience that there is a lack of awareness of the synergy between Lean and Green; many lean initiatives improve environmental performance, but a lack of focus, and inadequate metrics fail to demonstrate the cross-benefits. The interviews also confirm that some industries prioritise product pollution over operational impacts due to life-cycle considerations, and the direct link to customers' operating costs (Teehan and Tucker 2014). Environmental improvements are frequently regarded as costly, and with varied levels of Lean maturity, most companies don't recognise the synergies between Lean and Green.

The next level of L&G internalisation focuses on external influences that support Green improvements. A key Green driver is the development of the regulatory framework, which is becoming increasingly stringent in order to protect the environment. But the literature identifies that current legislation compliance alone has limited improvement potential; both the survey, and interviews, identify that other influences also play a key role in encouraging the shift of Green considerations onto the strategic agenda, such as customers, competitors, suppliers, industry associations, and even talent recruitment pressures.

The impact of contingencies of geographic and sector natures on L&G internalisation is also explored. Financial management, task prioritisation, leadership, culture and knowledge are key constraints validated in the survey. Market readiness and a lack of appropriate performance management, are cross-sector contingencies, also raised during interviews. Although some contingencies are supportive, most industries have contingencies that slow down L&G adoption, these need to be considered during the L&G implementation.

The first aspect of L&G internalisation inside a company, and a good basis for assessing the deployment of L&G, is the strategic level. To implement L&G, the strategic process needs to include operational improvement targets and Green objectives, as well as cascade them through the organisation. For this to happen, the financial assessment framework needs to accommodate the integration of L&G targets with strategic financial objectives. The strategic process needs to be cognisant that the bulk of the environmental impact may be realised in the SC, and that a certification objective alone tends to yield limited improvements. Lean and Green are rarely represented at strategic level in organisations; of all the organisations polled only one company demonstrates such strategic objectives, fully cascaded across its operations, although Lean and Green were not explicitly integrated. When considering decision making, the survey respondents identified a number of decisions involving Green issues, but the interviews pointed out that the nature of these are generally linked to compliance rather than motivated by environmental improvement.

5.2 What Does a L&G Operational Rollout Look like?

Also applying a systemic view to the creation of the L&G roll-out framework, five key topics require consideration: the L&G roll-out template, the management systems, the selection of L&G practices, the level of system-wide involvement, and change management support. The proposed L&G rollout template, is based on a formal decision making process, and is project based. It requires significant rework to reflect the iterative nature of L&G: self-directed, decision-making and implementations, through cycles of experimentation. Whilst engagement is important, the interviews show that changes of processes in regulated industries require specific controls due to certification, and the literature highlights that a project-based approach is also necessary to retain, to ensure end-to-end optimisation. Therefore, the rollout needs to accommodate self-directed improvements and formal project control. This research does not detail how this should be implemented.

The literature highlighted that management systems also play a key part in the roll-out, as they provide the information framework to support L&G improvement and decision making; unfortunately they are all too often used merely as compliance tools. The interviews show that, amongst the surveyed organisations, even if organisations are certified against environmental and quality standards, these systems are only exceptionally exploited as a basis for improvement.

A high proportion of the literature focused on Green and L&G tools that are often used at an operational level; the plethora of tools can be overwhelming for organisations, and a number of tools are very similar, even though they relate to different functions. This overlap, and the integration of such tools by observers, confirms the high synergistic potential between Lean and Green, once awareness of L&G has been established. The interviews also identify that several industries tend to display a low Lean maturity level and have seldom implemented L&G.

The next part of the L&G rollout framework is the level of system-wide involvement required to support L&G. The contributions of all functions in L&G, and the danger of isolation of such an initiative, are highlighted by observers. The survey highlighted that Lean initiatives tend to generate wider non-operational involvement than Green ones, so the integration of Lean and Green should support wider engagement in Green improvements. Observers all stated that ultimately, L&G needs to be owned by all employees and be part of their role and responsibility.

Change management represents the last part of the L&G rollout framework. The research confirms that it is often poorly delivered in many organisations. The change management approach requires the alignment of leadership vision and behaviours, training, communication and knowledge, culture, and finally, support structures. The importance of people involvement and management, through the L&G adoption process, supports the adoption of L&G as part of a balanced sustainability implementation.

This paper makes several contributions to the Lean and Green community. In terms of knowledge, research on a L&G systematic adoption framework, and the level of adoption of L&G in the manufacturing sector, represent topics which were not found in published literature. Although, there is abundant literature on specific aspects of L&G, the creation of an integrated and systematic model is particularly beneficial to understanding the breadth of activities, and the coordination effort, required. The model can also contribute to practice as it is generic enough to be used by companies in many sectors, when starting on a L&G journey. Organizations, which have to obey stringent regulatory frameworks can particularly benefit, whilst other companies need to review the contingencies for application in their industry. Finally, the model also contributes to L&G policy, in maintaining a system view throughout its development, implementation and impact monitoring.

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Lean and IT—Working Together? An Exploratory Study of the Potential Conflicts Between Lean Thinking and the Use of Information Technology in Organisations Today

Kate Maguire

Abstract The main objective of this paper is to carry out an initial investigation into the relationship between Lean Thinking and the use of business applications in contemporary organisations. Although both are arguably critical to business success today, traditionally the two fields have often been thought to be in conflict. A review of the available literature identified a number of potential Lean-IT conflicts, and a survey was used to validate if those conflicts exist in organisations today, if they have an impact on successful lean transformation, and whether or not the relationship is changing. The research findings indicate several potential relevant conflicts between Lean and IT. Those conflicts having the most impact on lean transformation all relate to business process management, and include: the introduction of too much complexity, automating processes where it does not make sense, and the automation of poor processes. Conflicts where improvement effort should be focused were also considered, based on a combination of high impact and poor current state. The top areas highlighted in this category were again the need to avoid complexity, the need to ensure that automation does not inhibit learning, and the importance of adopting an incremental rather than a 'major event' change culture. The objective of understanding whether the situation is improving or otherwise generated only limited findings.

Keywords Information technology · Business applications · Lean IT · Lean thinking

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1 Introduction

> The many benefits of electronic information systems are often offset by the waste they generate (Bell and Orzen 2011, p. 53).

It is an inescapable fact that Information Technology (IT) is critical to most if not all businesses today. Over the decades since computers were introduced into the workplace, their role has evolved from merely automation of transaction processing to much more that of strategic enabler. Bell (2013, p. 18) advises that 'we live in an age where skilful application of IT is an essential component of the value proposition for every enterprise'. He provides three reasons: IT capabilities are integrated in virtually every product and service delivered to our customers, IT competency allows us to serve our customers better, and IT knowhow enables us to better understand the voice and behaviour of our customers. The role of IT is arguably even more important in the service sector, where information does not just support the product, it *is* the product. 'In the knowledge worker space, information isn't metadata such as project status or scheduling—it is the process—and IT needs to be a critical part of it' (Gonzales-Rivas and Larsson 2011, p. 117).

Lean Thinking is a well-established business system relating to flow, value, and waste. Its value has been demonstrated, initially in many manufacturing organisations, and subsequently also in the service environment (Bicheno 2012). In recent years the term 'Lean IT' has become more widespread in the business world (e.g.: Bell 2006; Bell and Orzen 2011; Cunningham and Jones 2007; Schrader and Murphy 2012). McKinsey and Company state that 'IT is the next frontier for the application of Lean in business' (www.mckinsey.com), and an annual European Lean IT Summit, introduced in 2011, is now well established. However, the term is yet to be formally recognised within the academic community. Further, it is interesting to consider if it encompasses a broader scope than just a Lean IT Function. The discussion on 'What is Lean IT?' will be revisited at the end of this paper.

Traditionally Lean and IT have been in conflict (e.g.: Piszczalski 2000; Bell 2006; Crabtree and Astall 2006). A number of the reasons for this are due to fundamental differences. For example, lean thinking advocates simplicity, but the use of computer systems introduces great opportunity for complexity. Other conflicts, such as the opposing views of 'push' and 'pull', are due to how the disciplines have evolved. Historically, many IT systems based on MRP logic have worked on the philosophy of 'pushing' product through the manufacturing process. This is not aligned with the fourth of Womack and Jones' original five lean principles, namely 'let the customer *pull* value from the producer' (Womack and Jones 2003, p. 10). These and other conflicts raise the question: *does the use of IT in an organisation support a lean transformation, or are the two objectives more often pulling in different directions?* The aim of this research is to begin to address this question, and several potential Lean-IT conflicts are explored in more detail throughout this paper. Such an understanding is important as, since both Lean and IT are arguably critical to the success of businesses today, an organisation needs to be able to embrace both Lean Thinking and the use of IT and enable them to complement rather than work against each other. Further, it is important to recognise that the two fields of Lean and IT are both changing very rapidly. The pace of change of technology has exceeded all predictions, whilst Lean, as a relatively new field, continues to evolve. A current state study of Lean-IT interaction, which is simply a snapshot in time, is therefore missing a key element. In recognition of this, an objective of understanding if the relationship between Lean and IT is changing has been included in this study.

The research undertaken involved two phases. The literature review not only provided an understanding of what has already been written in this area, but also uncovered a number of potential Lean-IT conflicts. The second step was to survey the Lean Practitioner community to enhance understanding of the potential conflicts identified. The objectives of the survey were to validate if the identified conflicts exist in organisations today, if they present a barrier to successful lean transformation, and also to understand if the situation is improving or otherwise. This third objective was approached by asking respondents to consider whether or not the current state has changed over the last two years. Despite some limitations, a survey approach was considered appropriate for this research as the objective was to understand the current state across a broad range of organisations, so a resource-intensive qualitative approach was impractical. Since the survey data is based on respondents' opinions, analysis has avoided complex statistical techniques and is restricted to descriptive statistics only.

It is important to clarify the scope of both Lean and IT for the purpose of this research. Although the origins of Lean Thinking were in the manufacturing environment (Womack et al. 1990), its application has since expanded into service and administration (e.g.: Swank 2003; Bicheno 2012; Suárez-Barraza et al. 2012) and evolved to consider an enterprise-wide approach (Womack and Jones 1994). This study is not restricted to manufacturing organisations, it recognises the broader applicability of Lean Thinking and its relevance in all businesses today. From an IT perspective, the scope has been restricted to business applications only, defined as 'any application that is important to running your business' (Microsoft Technet). The IT Function is relevant to this work, but this study encompasses a broader scope than just consideration of the IT Function. Where mentioned, the term IT refers to the technology rather than the function within an organisation. Figure 1 provides a visual illustration of a broader view of IT, and clarifies the scope for this study.

The next section reviews the literature available on Lean-IT interaction and also highlights the Lean-IT conflicts identified during the literature review. Section 3 provides more detail on the research methodology, and the survey results are presented and discussed in Sect. 4. Conclusions are provided in Sect. 5, and Sect. 6 provides a discussion on the limitations of this study and opportunities for further research.

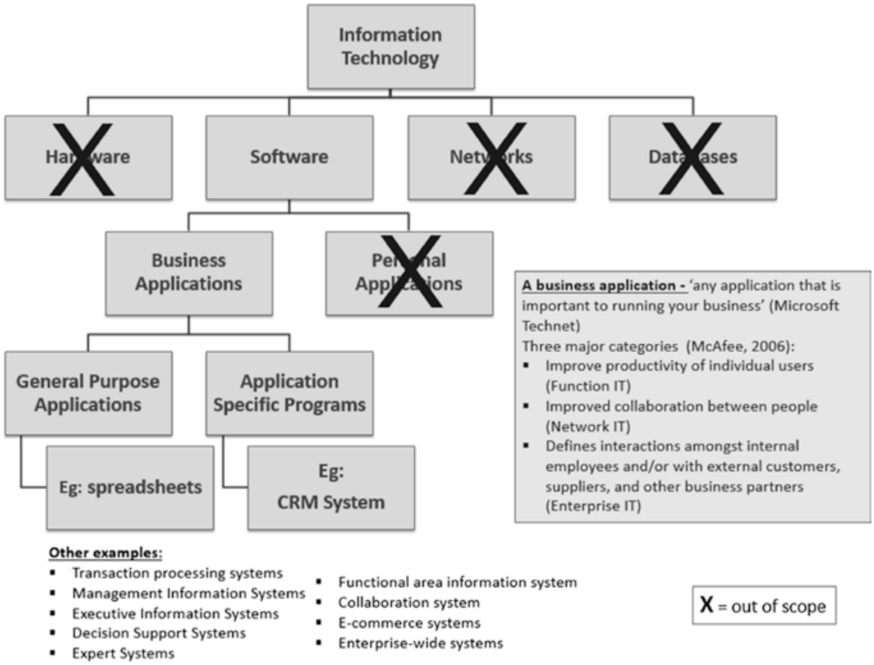

Fig. 1 Scope of IT for this research. *Source* Author

2 Literature Review

Two related areas of Lean-IT interaction that have been well researched and published are those of Lean and Enterprise Resource Planning (ERP), and Lean Software Development. A brief summary of literature in these areas has been provided, however this study then considers Lean and IT in a broader context.

A major element of IT in the current business environment is ERP, a term now used to represent enterprise-wide systems. MRP and MRP II (Materials Requirements Planning and Manufacturing Resource Planning respectively), the precursors of ERP, were based on a 'push' philosophy, developing a production schedule based on forecast demand, and 'pushing' product to the line to support that schedule. This is in contrast to the lean 'pull' approach, one of Womack and Jones' original five lean principles (Womack and Jones 1996). The early view that Lean Manufacturing and IT were in competition was driven largely by this push-pull disconnect. Several authors have commented on this relationship (e.g.: Carroll 2007; Deis 2006; Crabtree and Astall 2006). However more recent thinking has evolved to suggest that Lean and ERP can be implemented concurrently, that ERP implementation can 'behave as a catalyst for lean implementation' (Powell et al. 2013, p. 324), and together they can be an enabler for competitive advantage (Powell 2013). Powell et al. (2013) point out the value of a combined approach due to reduced time and resource requirements. They propose an approach for an ERP-based lean implementation.

The concept of agile software development was first introduced in 2001 with the development of four values and the 12-point Agile Manifesto (www.agilemanifesto.org). It was introduced to address the challenges of 'rapid changes in competitor threats, stakeholder preferences, software technology and time-to-market pressures' (Ramesh et al. 2010, p. 449), and its use has 'grown dramatically in recent years' (Wang et al. 2012, p. 435). The key objective is the 'ability to efficiently and effectively respond to user requirement changes' (Lee and Xia 2010, p. 88). Several of the Agile Manifesto principles are closely aligned to Lean Thinking, for example the need for simplicity, and learning through experimentation. At a similar time, Poppendieck (2001), introduced the concept of Lean Programming, stating that methodologies such as agile were in effect applying lean principles to software development. Further, she aligned ten Lean Manufacturing rules with software development practices as shown in Table 1. These principles reinforce the need for iterative development (a Plan-Do-Check-Act approach) and the ability to accommodate uncertainty and changing requirements. These concepts were subsequently discussed at length in the Lean Startup (Ries 2011). Ries introduces the concept of the Minimum Viable Product (MVP), and discusses the many advantages of launching an MVP into the market as quickly as possible and then refining it. The iterative approach reflects the spiral model of software development first outlined by Boehm (1986).

At a broader scope of IT than that of ERP and software development, a review of the available literature identifies three sources of Lean IT thinking. Figure 2 illustrates the three sources with associated key themes, showing similarities and differences.

As can be seen from Fig. 2, some themes are common to all three sources. These are: the challenge of recognising Information Waste due to its intangible nature, the need to accommodate changing customer requirements, and the importance of avoiding complexity. It is also of note that the annual European Lean IT Summit, introduced in 2011 and attended by many current Lean IT Thinkers (Bell, Orzen,

Table 1 Lean manufacturing rules applied to software development

Lean manufacturing rule	Applied to software development
• Eliminate waste	• Eliminate waste
• Minimize inventory	• Eliminate intermediate artifacts
• Maximise flow	• Drive down development time
• Pull from demand	• Decide as late as possible
• Empower workers	• Decide as low as possible
• Meet customer requirements	• Now and in the future
• Do it right the first time	• Incorporate feedback
• Abolish local optimisation	• Sub-optimised measurements are the enemy
• Partner with suppliers	• Use evolutionary procurement
• Create a culture of continuous improvement	• Create a culture of continuous improvement

Source Adapted from Poppendieck (2001)

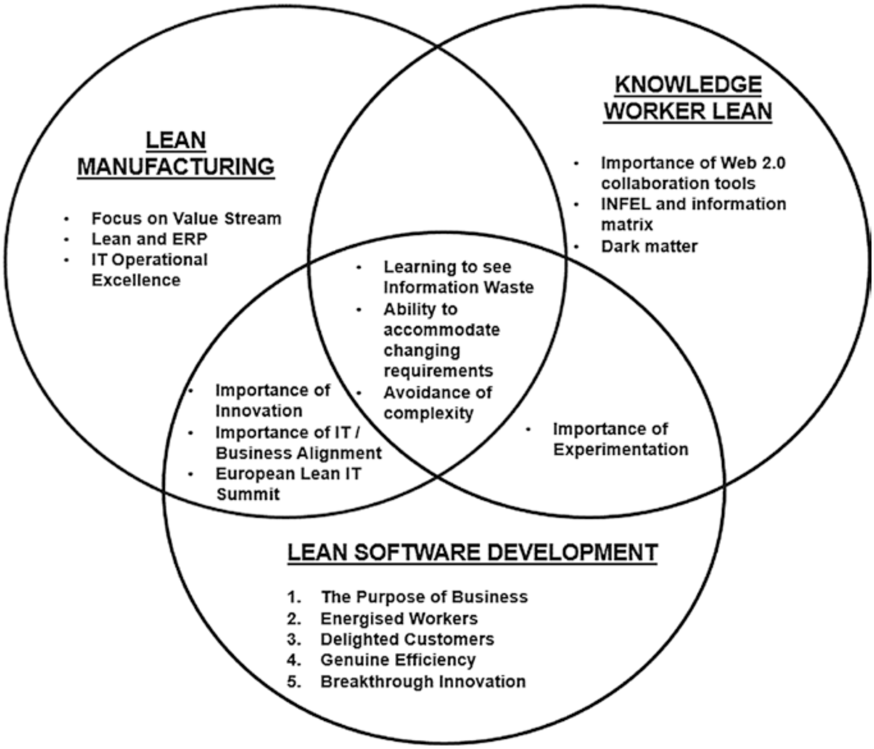

Fig. 2 Lean IT thinking—from three sources. *Source* Author, using: Bell (2006), Bell and Orzen (2011), Bell (2013), Gonzales-Rivas and Larsson (2011), Poppendieck and Poppendieck (2014)

Jones, Cunningham, Poppendieck), illustrates that two of the three sources are coming together. Further, the Lean-Agile discussion session that took place at the 2013 summit highlights that the relationship between these two areas is of interest.

Bell (2006) was the first to publish on Lean IT as a broader subject than just ERP or software development. His earlier work (2006) focused primarily on supporting lean manufacturing through IT, but his recent book (2013) takes a broader view, discussing innovation in detail and highlighting the need to balance managing current IT operations with funding innovation. He also states that aiming to align IT and 'the business' should no longer be required, as they should be as one. 'There is no "IT value" separate from business value. And in this new and often disruptive information age, there is increasingly limited business value separate from IT' (Bell 2013, p. xxxi). There is a strong focus on understanding and managing the value stream throughout Bell's work. Powell's work, on the relationship between lean manufacturing and ERP, also fits into this category (Powell 2013; Powell and Strandhagen 2011; Powell et al. 2013).

Poppendieck and Poppendieck have written extensively on the subject of lean software development, although their latest book, *The Lean Mindset* (2014), covers a wider scope. Two key themes from this book relating to software development

Table 2 Information management journals reviewed

Journal title	ISSN number
Communications of the ACM	0001-0782
IEEE Transactions on Software Engineering	0098-5589
Decision Support Systems	0167-9236
Journal of Information Technology	0268-3962
MIS Quarterly	0276-7783
Information Processing and Management	0306-4573
Information and Management	0378-7206
Journal of Management Information Systems	0742-1222
Expert Systems with Applications	0957-4174
European Journal of Information Systems	0960-085X
Journal of Strategic Information Systems	0963-8687
Information Systems Research	1047-7047
International Journal of Human-Computer Studies	1071-5819
ACM Transactions on Computer-Human Interaction	1073-0516
International Journal of Electronic Commerce	1086-4415
INFORMS Journal on Computing	1091-9856
Information Systems Journal	1350-1917
Information and Organisation	1471-7727
Journal of the American Society for Information Science and Technology	1532-2882
Journal of the Association of Information Systems	1536-9323
R and D Management	0033-6807
Technovation	0166-4972
Journal of Product Innovation Management	1540-5885

Source Author

are the importance of iteration to solve complex problems, and the value of innovation, including the need to understand and deliver what will really add value for customers. They discuss the potential of isolating innovation effort, particularly in larger companies that may be risk-averse. The themes of iteration and understanding customer requirements relate to two of the Lean-IT conflicts identified.

Gonzales-Rivas and Larsson's book, *Far From the Factory* (2011), approaches Lean IT from a different perspective. The focus is on Lean for the Knowledge Worker, beginning with a discussion on information, which leads naturally into consideration of the technology that supports it. The authors caution against taking the factory lean analogy too literally in an information environment, and use the example of 5S—'a tidy workflow strikes us as more relevant than a tidy storage room' (2011, p. 4). They propose that the challenge in the information world is to fully understand constantly evolving information flows, by making the 'invisible visible'.

The literature review included a review of the major Information Management journals, in order to understand topical subjects in the IT community. Details of the journals reviewed are shown in Table 2. All articles published between January

2010 and September 2014 were included in the review. It is notable that, of all the journals reviewed, there were only three articles found where *Lean* was included in the subject term, in each case as part of the phrase *Lean Manufacturing*. This suggests that, although Lean IT is a fast-moving emerging field in the business environment, it is not being widely discussed or acknowledged within the academic community and there is as yet no Lean IT body of knowledge. Twenty-one articles were found with *Agile Software Development* as a subject term, suggesting a higher level of recognition in this area. As agile can be considered to be the application of lean practices to software development (Poppendieck 2001) this means that arguably lean practices are being discussed in the IT community, but under a different name.

2.1 Potential Conflicts Between Lean and IT

Several authors have commented on the uneasy relationship between IT and Lean. For example, Piszcsalski (2000, p. 26) refers to 'two opposing camps' and suggests that the lean movement has been 'almost anti information systems in its stance'. Bell (2006, p. 11) refers to a 'curious tug of war', and the 'natural state of conflict between the paradigms of IT and Lean practitioners'. The literature review has identified a number of possible conflicts between IT and Lean Thinking. These conflicts divide into three different categories as listed in Table 3, and are discussed further below. Validating if these conflicts are real and impacting lean transformation in businesses today is the objective of this research.

Firstly, the use of IT introduces a number of risks to a lean approach. Lean advocates simplicity, whilst IT solutions provide opportunity to introduce complexity (Piszcsalski 2000; Bell 2006; Bell and Orzen 2011; Jones 2012; Plenert 2012). Two examples of such complexity are excess process automation (Cunningham and Jones 2007; Plenert 2012; Bell 2014) and unnecessary software functionality (Bell and Orzen 2011; Poppendieck and Poppendieck 2014; Seddon 2005; Gonzales-Rivas and Larsson 2011). Secondly, IT solutions present a risk of valuable data being hidden, in contrast to the lean approach of keeping status fully visible (Gonzales-Rivas and Larsson 2011; Mann 2010). Further, several authors comment on the need to avoid the automation of poor processes, which, once automated, become much more challenging to change and therefore improve (Hammer 1990; Bell 2006; Bicheno and Holweg 2009; Seddon 2005; Bell and Orzen 2011). Also the lean philosophy of respect for people is challenged by both the risk of technology, such as excessive email usage, weakening relationships (Schonberger 2007; Gonzales-Rivas and Larsson 2011), and the risk of process automation stopping 'learning by doing' and thereby inhibiting operators from truly understanding how processes work (Crabtree and Astall 2006).

The second category relates to conflicts between Lean Thinking and traditional IT thinking. Lean advocates the use of cross-functional teams, whilst IT has traditionally adopted a 'silo' approach to working, not only between IT and

Table 3 Lean-IT conflicts identified from literature review

Category		Lean	IT
Risks introduced by the use of IT	1	Simplicity	Complexity
			• Over-automation of process
			• Unnecessary software functionality
	2	Keeping status visible	Automation hiding visibility
	3	Ongoing process improvement	Automation of poor process
	4	Respect for people	• Technology weakens relationships
			• Automation inhibits learning
Conflicts between lean thinking and traditional IT thinking	5	Cross functional teams	Working in silos
			• Between IT and 'the business'
			• Within IT
	6	Pull	Push
	7	Culture of experimentation	IT control and compliance
			• Overly restrictive IT security
			• Over-standardisation
	8	Incremental approach to change	'Major-event' approach to change
	9	Everyone involved	Only experts can make changes
Conflicts between lean thinking and IT current practice	10	Focus on the voice of the customer (VOC)	Insufficient understanding of the VOC
	11	Understand demand to drive flow	Poor demand management
	12	Measure the things that matter	Inappropriate IT metrics

Source Author

the rest of the organisation (Bell and Orzen 2011; Seddon 2005; Markus and Keil 1994; Poppendieck and Poppendieck 2014), but also within the IT Group between different IT functions (Orzen 2011). Secondly, a fundamental concept of a lean approach is 'pulling' demand through the system. The advent of IT systems supporting pull production (Powell et al. 2013) means the original Lean/IT conflict may be less of a concern. However the pull-push conflict is potentially still valid as IT solutions have traditionally been 'pushed' out to users (Seddon 2005; Plenert 2012). Also, a lean culture is one of experimentation and learning, whilst traditional IT thinking adopts a control and compliance approach. Two such examples are overly restrictive IT security (Gonzales-Rivas and Larsson 2011; Cunningham 2012; Bell and Orzen 2011), and over-standardisation of process (Gonzales-Rivas and Larsson 2011; Hopp and Spearman 2008; Jones 2012), both of which are in conflict with an experimentation approach. A third conflict in this category is that between the lean approach of incremental change, and the traditional IT philosophy of 'major-event' change (Poppendieck and Poppendieck 2014; Ries 2011; Gonzales-Rivas and Larsson 2011; Orzen 2011; Bell 2006; Cunningham and Jones 2007). Finally, Jones (2012) highlights the 'everyone versus experts' conflict—lean aims to involve everyone in creating value and improving their work, whereas in the traditional IT world, often only 'experts' can design and implement changes.

The third and final category of conflicts considers differences between Lean Thinking and current IT practice. A key Lean concept involves understanding the voice of the customer (VOC), whilst in many cases the IT Group does not sufficiently understand either their internal or external customers (Jones 2012; Bell and Orzen 2011; Seddon 2005; Markus and Keil 1994). Also, a lean approach involves understanding demand, as well as supply, in order to enable flow, but poor IT demand management is often a problem (Gentle 2007; Bell and Orzen 2011; Poppendieck and Poppendieck 2014). Finally, the right metrics are key to an effective lean approach, but inappropriate metrics are often used in an IT environment (Markus and Keil 1994; Spitzer 2007; Jarrett 2012; Bell 2013).

3 Methodology

The author has adopted a pragmatist philosophy, which avoids the need to take one of the opposing positions of positivism or interpretivism. As Saunders et al. (2012, p. 130) state, pragmatists recognise that there are many ways of interpreting the world, and they will use whichever method or methods that will 'enable credible, well-founded, reliable and relevant data to be collected that advance the research' (quoting Kelemen and Rumens 2008). The aim of the research was to develop a theory of possible conflicts based on the available literature, and then test it by asking Lean Practitioners for their opinions on related questions. Whilst this is a deductive approach usually associated with a positivist philosophy, the data gathered in this case is opinions rather than facts, fitting better with the interpretivist end of the continuum.

The process used to gather the opinions of Lean Practitioners was through an online survey. Although a qualitative approach may initially be considered more appropriate for opinion data, in this case a survey was used. This is because of the need to gather a sufficient volume of responses, as one aim of the research is to understand the current state in a broad cross-section of organisations. Use of a resource-intensive qualitative interview technique would not have accommodated the collection of a sufficient volume of data within a reasonable timescale.

Aside from some initial demographic and concluding open text questions, the survey asked for respondents' opinions on the potential Lean-IT conflicts identified in Table 3. In order to design a survey to achieve the research objectives, one or two related *statements* and *objectives* were developed for each identified conflict. For clarification, the label *conflict* is used for the initial potential incompatibilities between Lean and IT, as identified in the Literature Review. Asking respondents how strongly they agreed or disagreed with each *statement*, using a Likert scale, provided information on the current state of each conflict. The aim of asking respondents how much impact they thought achievement of each *objective* would have on lean transformation was to gather data on the impact of resolving each conflict. An example is illustrated in Fig. 3.

The research constitutes a cross-sectional study, as the objective was to understand the current state at one point in time regarding Lean-IT conflicts. As both fields are moving rapidly, it is recognised that this analysis may quickly become obsolete. Each survey question was therefore followed with a subsequent question which aimed to capture respondents' views on whether the situation is improving or otherwise. This was to address the research objective which sought to understand how the relationship between Lean and IT is changing, in recognition of the fast-changing landscape. A time period of two years was selected as appropriate for this objective, so respondents were asked to identify if the situation was better, worse, or unchanged since June 2012. Three questions for each conflict were therefore included, with the objectives of understanding: whether or not the conflict exists in the respondents' organisations, if the situation has changed over the last two years, and if that conflict has an impact on lean transformation. The survey questions took one of three forms in line with these objectives, as illustrated in the example in Fig. 4. Careful consideration was given to the design of the statements and objectives relating to the conflicts, since opinion questions 'are harder

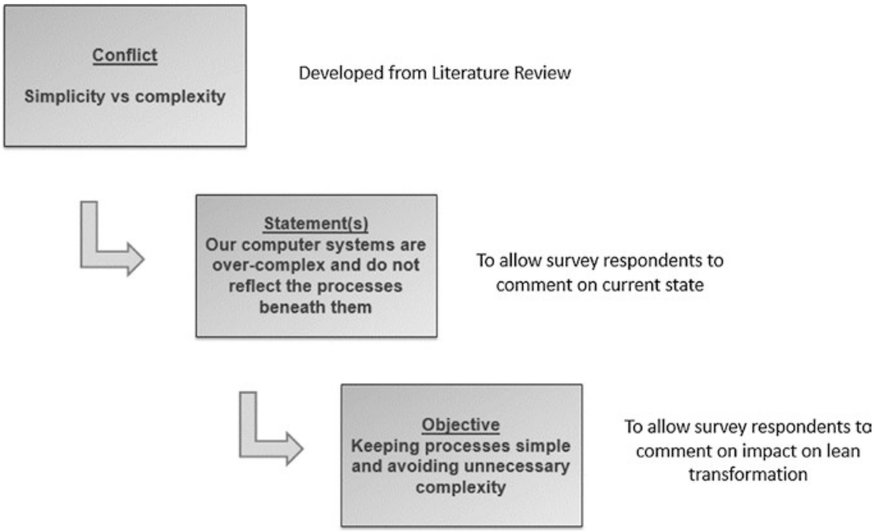

Fig. 3 Relationship between conflicts, statements and objectives. *Source* Author

15. Risks introduced by the use of Information Technology **Please choose the answer that states how much you agree with each statement, when considering the current situation in your organisation**					
	strongly disagree	disagree	neither agree nor disagree	agree	Strongly agree
• Our computer systems are over-complex and do not reflect the processes beneath them	○	○	○	○	○

16. Risks introduced by the use of Information Technology **Please choose the answer that specifies whether or not you think the situation in your organisation has changed from where it was two years ago (June 2012)**					
	Better	No Change	Worse	Don't know	
• Our computer systems are over-complex and do not reflect the processes beneath them	○	○	○	○	

21. Please choose the appropriate answer that specifies how much impact you think the objective stated will have on successful lean transformation for an organisation **4 – high impact (if we get this right it will really help the lean journey)** **1 – no impact (it doesn't matter whether or not this changes)**					
	1 – no impact	2 – minimal impact	3 – some impact	4 – high impact	Don't know
Keeping processes simple and avoiding unnecessary complexity	○	○	○	○	○

Fig. 4 Examples of survey questions. *Source* Author

to construct as they are much more sensitive to small changes in question wording' (Chatfield 1988, p. 212). Also, both positive and negative statements were included to ensure the respondent had to consider their response rather than just selecting the same answer for every question.

The finalised online survey, distributed in June 2014, was circulated in two different ways. An email invitation to complete the survey was sent to: University of Cardiff M.Sc., in Lean Operations Alumni, University of Buckingham M.Sc., in Lean Enterprise current students, and Lean Practitioner contacts known to the researcher. In addition a discussion requesting people complete the survey was posted on several LinkedIn groups: Systems Thinking and Lean, Lean Thinking, Lean Debate, Lean Enterprise Academy, Lean Offices. This is a convenience sampling approach. Clearly this may generate some concern as the sample was not random, which raises the question of how much it can reasonably be used to generalise findings across a population. However there are justifications for such an approach in this case. Firstly, identifying, accessing, and soliciting responses from a truly random sample would be extremely challenging. Also, this is an initial exploratory study only, and, as such, is seeking to provide general rather than detailed findings. A more rigorous sampling approach could be considered for subsequent more detailed research if appropriate.

4 Discussion

It is not possible to determine a survey response rate, as the use of LinkedIn Groups meant that the survey was available to an unknown number of people. However a total of 82 people viewed the survey, with 66 completing it. This response total should generate valid conclusions as it is more than the small sample definition of 30 responses (Bock and Sergeant 2002). Further, 87 % of the respondents stated that they either had, or were working towards, a qualification in Lean. It is therefore reasonable to assume that the majority of responses are based on a comprehensive understanding of lean principles and practices. Figures 5 and 6 provide further demographic data about the respondents. These figures highlight that this analysis will represent a European perspective as the majority of respondents (close to 80 %) are based in Europe, and also that more than 50 % of respondents are based in very large organisations.

The survey data analysis has been kept very simple, and not ventured into complex statistical analysis due to the nature of the raw data and the recognition that it is based on opinion only. Two simple measures were used to assist in drawing some conclusions. Firstly, for the questions asking for respondents' views on the impact of each objective, an Impact Index was calculated. This is a weighted average, calculated as shown in Step 1 in Fig. 7. Two differing weighting approaches were explored but the difference in results was minimal. The objective of calculating a number is for comparison purposes only rather than because of any significance of the number itself.

A second measure was developed with the aim of addressing the further objective of understanding on which of the conflicts identified should improvement effort be focused. This requires identifying which conflicts are both in a

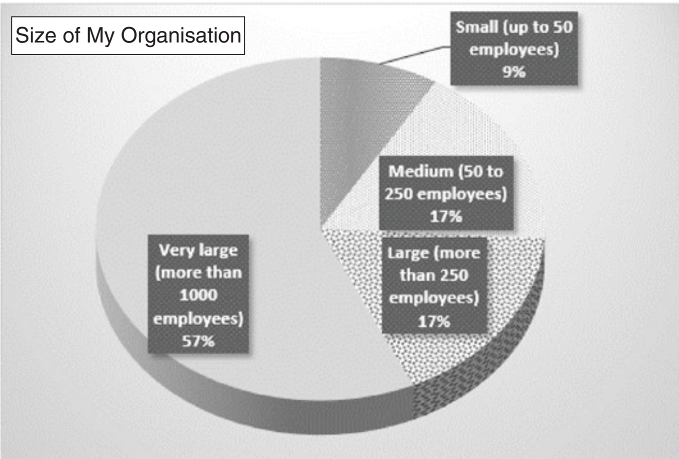

Fig. 5 Size of respondents' organisation. *Source* Survey data

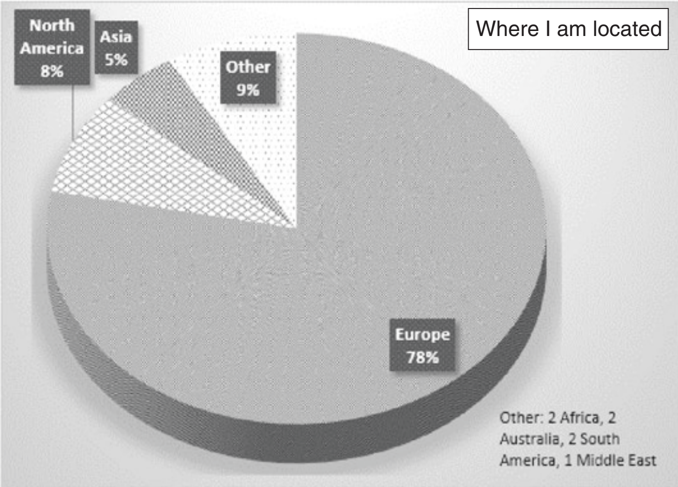

Fig. 6 Location of respondents. *Source* Survey data

Step 1 – Calculation of Impact Index

Answer Options	1 – no impact	2 – minimal impact	3 – some impact	4 – high impact	Don't Know	Respons e Count
Weighting	0	4	7	10	-	-
Keeping processes simple and avoiding unnecessary complexity	0	0	6	60	0	66

Impact Index = ((0*0) + (0*4) + (6*7) + (60*10))/66 = 9.73

Step 2 – Calculation of Impact – Current State Index

Percentages	Strongly disagree	disagree	Neither agree nor disagree	agree	Strongly agree	% 'good'	% 'bad'
Our computer systems are over-complex and do not reflect the processes beneath them	4%	20%	13%	47%	16%	24%	63%

This is a negative statement, so need to identify the people who agree with the statement, to obtain 'bad' current state measure. ***Current state % 'bad' = 47% + 16% = 63%***

Impact – Current State Index = 9.73 * 0.63 = 6.11

Fig. 7 Example calculation of impact/current state index. *Source* Author 'poor' current state position *and* have the most impact on lean transformation. An Impact-Current State Index (ICSI) was calculated which combines a current state measure with the Impact Index discussed above. Again, the objective is to obtain numbers for comparison rather than for an absolute value. The current state score was obtained by reviewing the percentage of responses indicating a 'bad' current state. This was determined by looking at the proportion of respondents who either agreed or strongly agreed with a negative statement, or disagreed or strongly disagreed with a positive statement. So, a higher number means a worse current state. Where there were two survey questions supporting the objective, the average 'bad' proportion of the two numbers was taken.

Figure 7 provides an example ICSI calculation. The higher the number, the more opportunity for improvement, as these represent objectives where the current situation is poor and there is a high impact on successful lean transformation if the issue is resolved.

4.1 Observations—Current Situation

Figures 8, 9, 10 illustrate the proportion of respondents in each Likert category for the current state statements, and brief discussions on the results follow.

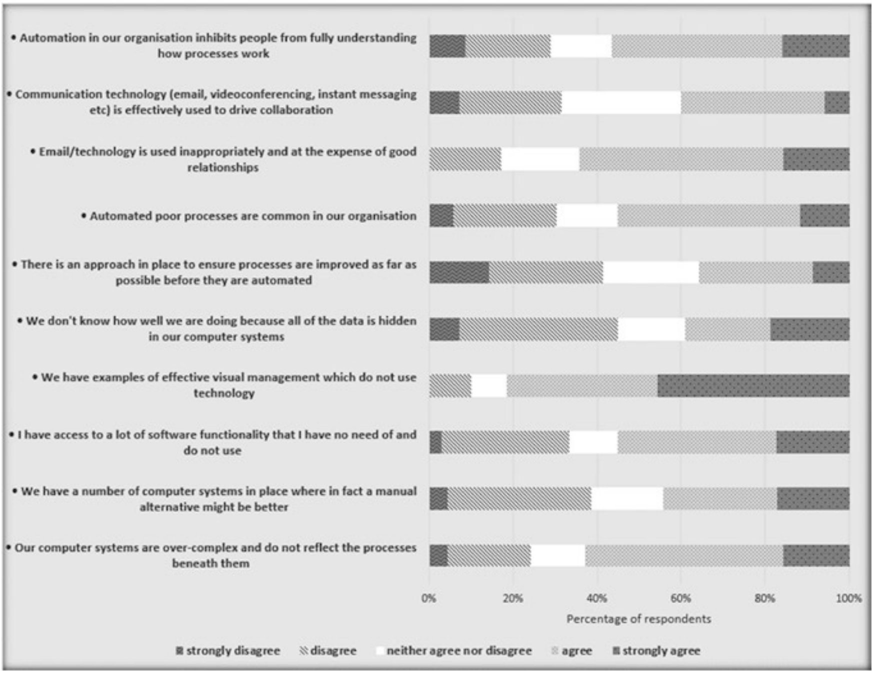

Fig. 8 Current state data: risks introduced by the use of IT. *Source* Survey data

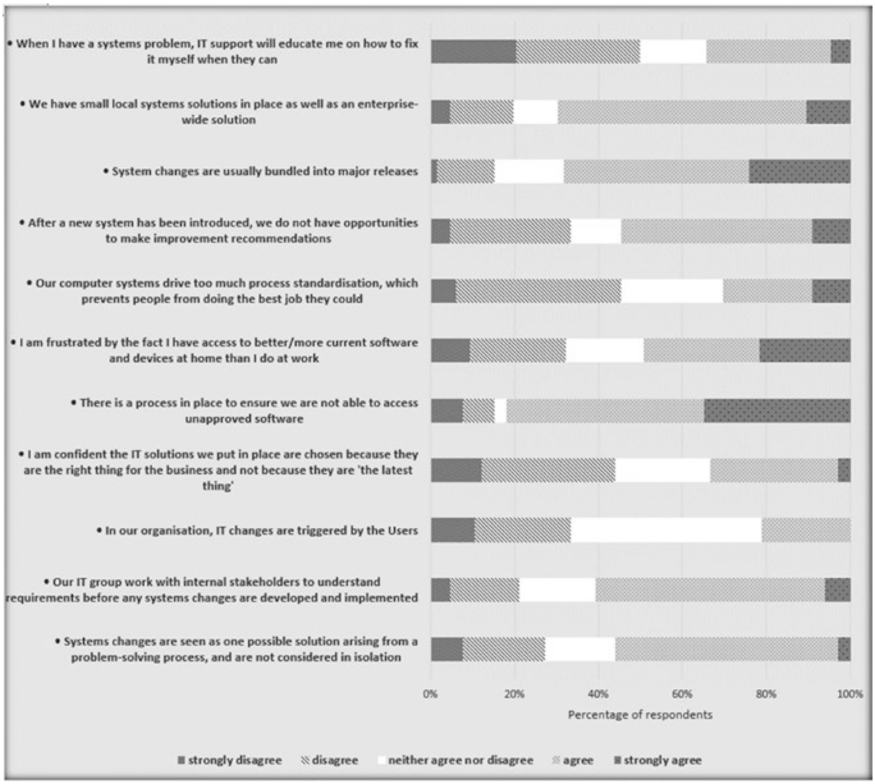

Fig. 9 Current state data: conflicts between lean thinking and traditional IT thinking. *Source* Survey data

Observations are made by summing the agree/strongly agree or disagree/strongly disagree percentages.

The most significant concerning conclusion from Fig. 8 is that more than 60 % of respondents raise a concern about the over-complexity of technology, believing that '*our computer systems are over-complex and do not reflect the processes beneath them*'. Also, just over 55 % believe that *automation inhibits learning*, and nearly 65 % think that *email is used inappropriately and at the expense of relationships*. However there are some positive themes emerging, most notably around visual management. More than 80 % of respondents state they have examples of effective visual management that do not use technology. This is the most conclusive response in the entire survey, although that is possibly due to the question being less opinion-based than others.

The most conclusive response illustrated in Fig. 9 relates to unapproved software, where more than 80 % of respondents agree or strongly agree that there is a process in place to prevent them from accessing it. This suggests that many

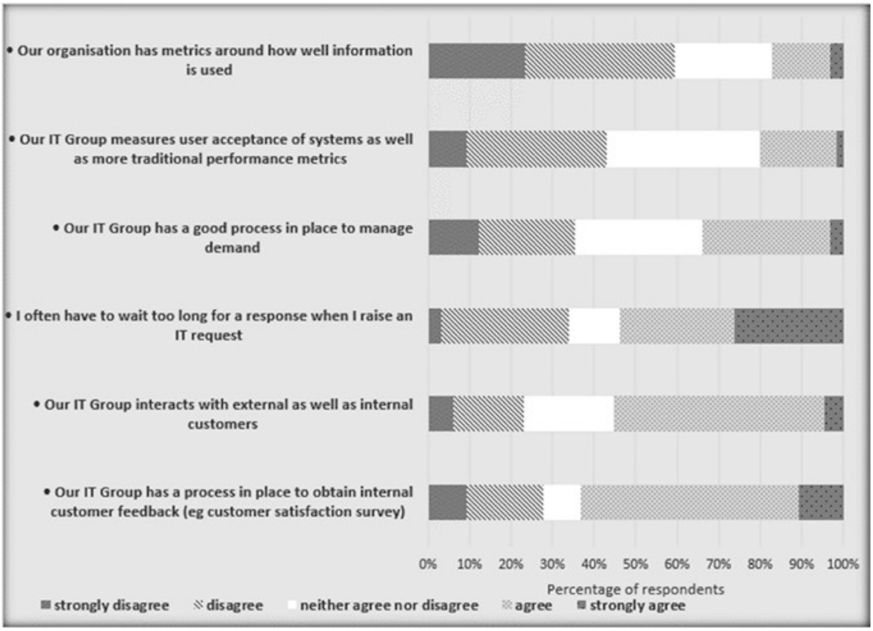

Fig. 10 Current state data: conflicts between lean thinking and IT ways of working. *Source* Survey data

users are not able to experiment with new software and technologies. However this is a complex area worthy of further discussion, as there are many good arguments for organisations restricting access to unapproved software. Nearly 70 % of respondents agree that systems changes are bundled into major releases, and more than 50 % state that they do not have opportunities to make improvement recommendations once a system has been implemented. This suggests that an incremental approach to system development is not yet widespread. Interestingly, a relatively high proportion of respondents (45 %) have no opinion on whether or not systems changes are triggered by users in their organisation. This indicates a concerning lack of user understanding as to how their system change process works.

Figure 10 illustrates that less than 20 % of respondents believe their organisation has metrics around how information is used, and only 20 % think user acceptance of systems is measured. Also, more than 50 % believe they have to wait too long for a response from IT after raising a request, indicating a demand management issue. However, on a more positive note, more than 50 % of respondents believe their IT Group interacts with external customers and seeks feedback from internal customers.

Table 4 Statements with the highest proportion of 'worse' responses

Statement	Proportion of worse' responses (%)
Our computer systems are over-complex and do not reflect the processes beneath them	23
I often have to wait too long for a response when I raise an IT request	22
I am frustrated by the fact I have access to better/more current software and devices at home than I do at work	18
After a new system has been introduced, we do not have opportunities to make improvement recommendations	17
When I have a systems problem, IT support will educate me on how to fix it myself when they can	17

Source Survey data

4.2 Observations—Is the Situation Changing?

The attempt to capture survey feedback on whether or not the situation is changing, as illustrated in Fig. 4 Question 16, was relatively crude. This is recognised as a limitation of the research. However, due to the rapidly changing environments of both Lean and IT, this subject was felt too important to exclude. Table 5 illustrates the proportion of responses in each of the three categories. The clearest observation arising from the data is that, with one exception, the majority think the situation is unchanged from two years ago. This is a concern when considering that this is a field that is believed to be rapidly evolving. The exception is a statement around visual management. The majority (more than 50 %) believe that the situation regarding use of visual management without technology is improving, which is a positive move away from automation where it is not required. It is also interesting to note that a number of respondents believe the situation is getting worse in each case. Table 4 shows the five statements with the highest proportion of 'worse' responses. The most concerning observation is the number of respondents who believe that the over-complexity of computer systems is getting worse rather than better. Respondents who selected the 'Don't Know' category in the Better-Worse questions were excluded from the analysis. Whilst this was a low percentage in the majority of cases, it is interesting to note that a higher proportion of respondents did not know whether the metrics situation was improving.

4.3 Which Conflicts Have the Greatest Impact on Lean Transformation?

Figure 11 illustrates the survey data showing respondents' views on how much impact the differing objectives have on successful lean transformation. An initial review of this chart confirms that all objectives identified have an impact, as

Table 5 Proportions of better/unchanged/worse responses

	Better (%)	No change (%)	Worse (%)
System changes are usually bundled into major releases	8	81	11
I am frustrated by the fact I have access to better/more current software and devices at home than I do at work	8	74	18
Our computer systems drive too much process standardisation, which prevents people from doing the best job they could	10	74	16
I have access to a lot of software functionality that I have no need of and do not use	10	75	15
Our organisation has metrics around how well information is used	14	75	11
Automation in our organisation inhibits people from fully understanding how processes work	14	73	13
When I have a systems problem, IT support will educate me on how to fix it myself when they can	16	67	17
Our IT Group measures user acceptance of systems as well as more traditional performance metrics	16	75	9
Email/technology is used inappropriately and at the expense of good relationships	18	71	11
Automated poor processes are common in our organisation	18	72	9
In our organisation, IT changes are triggered by the users	19	67	14
We have a number of computer systems in place where in fact a manual alternative might be better	20	67	14
There is a process in place to ensure we are not able to access unapproved software	21	67	13
We have small local systems solutions in place as well as an enterprise-wide solution	21	65	15
I often have to wait too long for a response when I raise an IT request	22	57	22
After a new system has been introduced, we do not have opportunities to make improvement recommendations	22	60	17
Our IT Group has a good process in place to manage demand	24	60	16
I am confident the IT solutions we put in place are chosen because they are the right thing for the business and not because they are 'the latest thing'	24	63	13
Our computer systems are over-complex and do not reflect the processes beneath them	24	53	23
Our IT Group work with internal stakeholders to understand requirements before any systems changes are developed and implemented	25	65	10

(continued)

Table 5 (continued)

	Better (%)	No change (%)	Worse (%)
Our IT Group interacts with external as well as internal customers	25	69	5
Systems changes are seen as one possible solution arising from a problem-solving process, and are not considered in isolation	27	65	8
There is an approach in place to ensure processes are improved as far as possible before they are automated	29	58	14
Our IT Group has a process in place to obtain internal customer feedback (for example—customer satisfaction survey)	29	58	14
We don't know how well we are doing because all of the data is hidden in our computer systems	38	52	11
Communication technology (email, videoconferencing, instant messaging etc.) is effectively used to drive collaboration	42	50	8
We have examples of effective visual management which do not use technology	55	41	5

Source Survey data

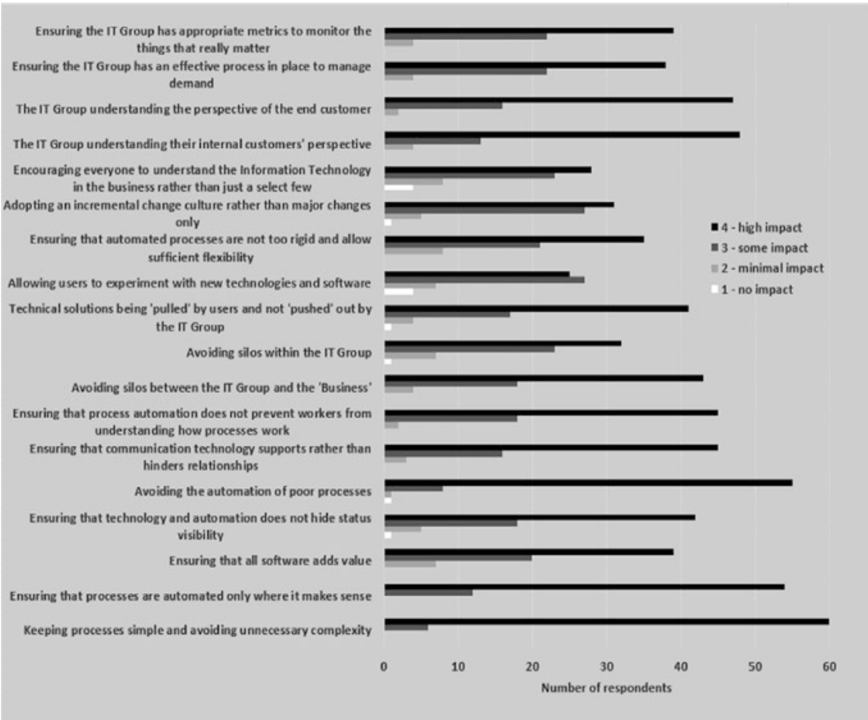

Fig. 11 Impact of conflicts identified. *Source* Survey data

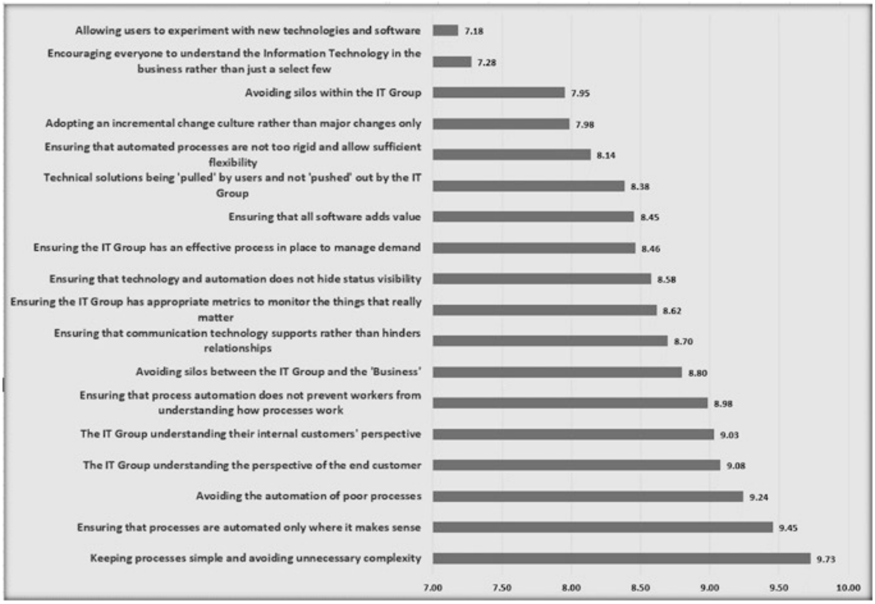

Fig. 12 Impact index of conflicts identified. *Source* Survey data

it shows a high proportion of 'high' and 'some' impact bars, with the size of the 'minimal impact' and 'no impact' bars being small in comparison. This is confirmation that the conflicts identified at the start of this study are valid.

As the responses are similar for each objective, further analysis was carried out with the aim of drawing out the differences. An Impact Index, as explained in Fig. 7, was calculated for each of the objectives and these are shown in Fig. 12. This illustrates that the objectives considered to have the most impact on lean transformation all relate to process design and automation. It reinforces the need to keep processes simple, to ensure processes are optimised first, and to automate only where it makes sense.

4.4 Where Should Improvement Effort Be Focused?

The Impact-Current State Index (ICSI) was developed to identify where to focus effort around IT to make a difference to lean transformation, by understanding which conflicts have the most impact *and* the worst current state. The measure was calculated using the Impact Index combined with a measure of 'bad' current state, as illustrated in Fig. 7. The ICSIs for each conflict are shown in Table 6 with the Top 3 highlighted. This identifies that the first area of focus for improvement should be aiming to keep processes simple and without undue complexity. It is unclear from Table 5 if the situation is improving or deteriorating. Whilst the survey data highlighted this area as receiving the highest number of 'worse' responses (23 %), a similar proportion believe that the situation is improving. The second area of focus is the need to ensure that automation does not inhibit process understanding, whilst the third area reflects the importance of accommodating incremental changes. This is another instance where a slightly higher proportion of respondents believe the situation is getting worse and not better (Table 5).

4.5 Comparison of Data Subsets

Due to the demographic data collected at the start of the survey, it was possible to carry out some limited analysis comparing responses from differing groups of respondents. In particular a review was undertaken of data from respondents who stated their organisation was at a mature stage of lean transformation. Further, the responses from individuals who worked in the IT function were also reviewed. It should be noted that both of these groups are much smaller sample sizes (14 respondents at mature stage of lean transformation, and 7 respondents who work within the IT function). These small samples will have an impact on the validity of any findings and therefore conclusions should be considered provisional only. In addition only limited analysis has been completed and there is much scope for further work.

Figure 13 identifies the breakdown of respondents by stage of their organisation's lean transformation. This section focuses on comparing the 14 responses who stated their organisation was at a mature stage of their lean journey, 'the mature group', with the full sample. The comparison provided several interesting observations. Perhaps unsurprisingly, with regard to whether or not the situation was improving, the proportion of 'better' responses was higher for the mature group in all but three instances. The average proportion of 'better' responses was 34 % for the mature group in comparison to 22 % for the full sample. This suggests that the situation is improving more for those organisations at a mature stage of lean transformation. Also, it is notable that 64 % of mature group respondents either agree or strongly agree with the statement 'our computer systems are overcomplex and do not reflect the processes beneath them'. This is very similar to the result for the full group (63 %), which calls into question whether this problem is reduced as an organisation matures through a lean transformation.

In reviewing responses from IT Practitioners, it was found that seven respondents stated they worked within the IT function of their organisation. Six of the seven stated that they either have or are working towards a certification in Lean, so it is assumed that they have a good understanding of lean principles. However only five IT respondents completed all the questions, making the sample size very low, and therefore drawing any conclusions is risky. Further investigation into this area would be a great subject for future research. Bock and Sergeant (2002) state that one possible conclusion that can be drawn from a small sample is the 'all or none' conclusion, where every participant gives the same response to a question. In this

Table 6 Ranked impact-current state index

Statement	Impact Index (II)	Current State Index (CSI)	Impact – Current State Index (ICSI)	ICSI Rank
Keeping processes simple and avoiding unnecessary complexity	9.73	63%	6.11	1
Ensuring that process automation does not prevent workers from understanding how processes work	8.98	57%	5.08	2
Adopting an incremental change culture rather than major changes only	7.98	61%	4.90	3
Allowing users to experiment with new technologies and software	7.18	66%	4.71	4
Ensuring that all software adds value	8.45	55%	4.66	5
Avoiding the automation of poor processes	9.24	48%	4.46	6
Ensuring the IT Group has appropriate metrics to monitor the things that really matter	8.62	51%	4.41	7
Ensuring that processes are automated only where it makes sense	9.45	44%	4.19	8
Ensuring that communication technology supports rather than hinders relationships	8.70	48%	4.16	9
Ensuring the IT Group has an effective process in place to manage demand	8.46	45%	3.78	10
Technical solutions being 'pulled' by users and not 'pushed' out by the IT Group	8.38	39%	3.24	11
Encouraging everyone to understand the Information Technology in the business rather than just a select few	7.28	35%	2.54	12
The IT Group understanding their internal customers' perspective	9.03	28%	2.50	13
Ensuring that automated processes are not too rigid and allow sufficient flexibility	8.14	30%	2.47	14
Avoiding silos between the IT Group and the 'Business'	8.80	24%	2.13	15
Ensuring that technology and automation do not hide status visibility	8.58	25%	2.11	16
The IT Group understanding the perspective of the end customer	9.08	23%	2.09	17

Source Survey data

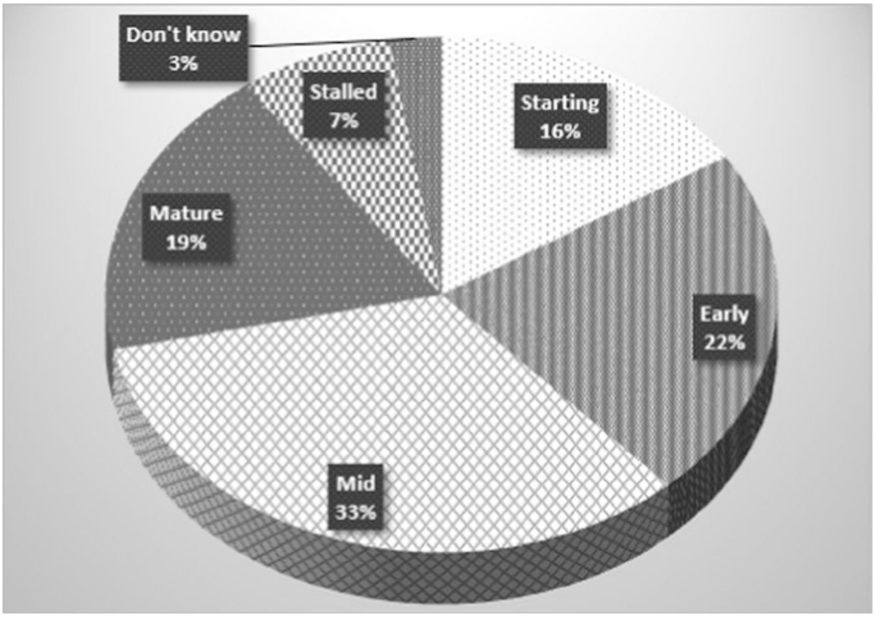

Fig. 13 Stage of lean transformation of respondents' organisations. *Source* Survey data

case, for most questions the responses were spread across all possible answers, making any conclusions challenging. The exceptions to this allow a small number of observations. Four out of five respondents agree that they have access to unnecessary software (the fifth has no opinion). All five respondents are agreed that over the last two years there has been no change to the major release approach to system change. Further, all respondents recognise either 'some' or 'high' impact, of: keeping processes simple, avoiding the automation of poor processes, and ensuring processes are sufficiently flexible. Finally, metrics is one area where the small group of IT respondents is in full agreement. They all agree that their organisations do not have metrics around how information is used.

5 Conclusions

The aim of this research was to carry out an initial exploration of the relationship between Lean and IT in businesses today, specifically to understand the situation regarding the conflicts discussed in the available literature. The literature review identified a number of potential conflicts between Lean and IT, which fall into three different categories. Some conflicts are due to risks that naturally arise when using IT in organisations, others have evolved due to differences between lean thinking and traditional IT thinking, and there are also conflicts between lean thinking and current IT practice.

Having identified a number of potential Lean-IT conflicts, the first objective of this research was to investigate whether the conflicts exist in organisations today. Data from the survey carried out validate the existence of all the conflicts. The results indicate that respondents recognised all conflicts identified, and their potential to impact lean transformation, although to varying degrees. Based on the survey results, there is abundant opportunity in organisations today to improve the situation with regard to these conflicts, thereby enhancing the Lean-IT relationship. If not recognised and addressed, the potential conflicts present risks to achieving successful lean transformation. The survey results indicate that the conflicts which have highest impact on lean transformation all relate to process design and automation. Ensuring that processes are not over-complex, that they are automated only where it makes sense, and that they are optimised prior to automation are the key objectives that will be most effective in supporting successful lean transformation. The survey analysis also identified those conflicts with a combination of both ‘poor’ current state *and* high impact on successful lean transformation. This was with the aim of understanding those areas that require the most improvement focus in order for Lean and IT to become more aligned. The top three objectives from this analysis were: keeping processes simple and avoiding unnecessary complexity, ensuring that process automation does not prevent workers from understanding how processes work, and adopting an incremental change culture rather than major changes only.

The challenge that requires the most fundamental change to the way organisations work is the move to an incremental change culture rather than ‘bundling’ changes. Since the majority of organisations treat IT as a cost centre and need to charge resource costs accordingly, they require a project approval process to be followed to secure IT resources to work on system improvements. This drives the requirement to bundle changes, which is fundamentally different from a lean approach as it hinders the implementation of an incremental change culture for IT solutions. Also, it is possible that the requirement to bundle changes increases solution complexity, as users may aim for perfection at the start due to lack of confidence they will ever see any improvement after the initial implementation.

A second objective of the research was to explore whether the relationship between Lean and IT is changing, a pertinent question due to the fast-moving nature of both fields. It is challenging to answer this question conclusively based on the survey results. Whilst some respondents believe the situation is getting better, others think the opposite, and a clear majority think the situation has not changed over the last two years. The one exception to this was the question on the use of manual visual management. This was the only instance where there was a higher number of ‘better’ than ‘no change’ responses, suggesting that organisations are now more likely to resist the temptation to automate visual management where it is unnecessary.

A logical next step for this research is to understand to what extent the identified conflicts can be overcome. Although not covered in detail as part of this paper, some initial work to explore this was undertaken, using a case study of an example that demonstrated alignment between lean thinking and the use of IT in the workplace. The example in question was a recently implemented automated touch-screen visual management board, which effectively used lean visual management principles but was also a good technological solution. It was recognised within the organisation as a success, and additional implementations had followed the original pilot. This case study, although only one example, is a valid illustration of Lean and IT being aligned within an organisation, demonstrating that it is possible for some of the conflicts identified to be overcome.

Studying the case study in depth identified the relevance of a number of the conflicts identified earlier in this paper. The project was an interesting balance between pull and push, as the IT Group's desire to showcase innovation was achieved whilst at the same time meeting several genuine business requirements. In addition, the team working on the project had made a conscious effort to keep the solution simple, despite some challenges in doing so. Further, the solution designed allowed users to make incremental improvements, avoiding the need to refer everything to IT which necessitates 'bundling' of changes. Although the project team had not consciously been recognising and addressing Lean-IT conflicts, the adherence to the principles of simplicity and accommodating incremental change had clearly been key success drivers, which was validated by interviews with selected key project stakeholders.

A further success driver of the project, identified through the stakeholder interviews, was the fact that it was the 'right time' to implement such a solution. Reasons cited for this included employee acceptance of touch-screen technology, decreasing cost of technology, and general organisational maturity in use and understanding of data. This highlights the significance of the rapid evolution of the fields of Lean and IT, and reinforces that this study represents a snapshot in time only.

Table 7 Guidelines to drive Lean-IT alignment

Number	Guideline
1	Keep processes simple and avoid unnecessary complexity
2	Ensure that processes are automated only where it makes sense
3	Avoid the automation of poor processes
4	Ensure the IT Group understands the perspective of their customers—both the end customer and internal customers
5	Ensure that process automation does not prevent workers from understanding how processes work
6	Avoid silos between the IT Group and the rest of the organisation
7	Ensure that communication technology enhances rather than restricts relationship building
8	Ensure that the IT Group has the right metrics to monitor the things that really matter
9	Ensure that technology and automation does not hide status visibility
10	Ensure that the IT Group has an effective process in place to manage demand

Source Author

Earlier in this paper, the author raised a question over the meaning of Lean IT, a term which has become increasingly used in the business environment in recent years. Having completed this research and started to understand the many challenges to Lean and IT working effectively together, the author proposes guidelines to drive alignment between the two fields rather than suggesting a definition of Lean IT. Ten guidelines are provided as illustrated in Table 7. They are ranked in order of importance, and are based on the ten objectives, derived from the Lean-IT conflicts, that the survey results have identified as having the highest impact on lean transformation.

The top three of the guidelines proposed identify that software development is the area requiring the most focus to ensure IT alignment with lean principles. They all relate to the relationship between business process management and software development. The need for shared ownership between the business and technical experts, regardless of organisation structure, is key to adhering to these principles.

6 Limitations and Future Research Opportunities

Although this research has produced some interesting findings, it is not without limitations, and these should be recognised. The implications of using convenience sampling have already been mentioned. In particular, the survey was circulated to Lean Practitioners only. This approach was chosen to ensure respondents could provide informed views on the impact of the conflicts on lean transformation, however it will definitely influence the current state data. Secondly, sample size is a consideration. Although 66 respondents is a reasonable number, clearly a greater number would provide more reliable results. Finally, the 'better/worse' analysis was somewhat crude and provided only limited conclusions.

Further, there are a number of limitations to any survey approach, which are also relevant in this case. It is possible that people who take the time to respond to the survey will only be those who have an interest or strong opinion, thus biasing the data. Also, as the survey was relatively lengthy, the risk of respondent fatigue is introduced—'a well-documented phenomenon that occurs when survey participants become tired of the survey task and the quality of the data they provide begins to deteriorate' (Lavrakas 2008). Finally, we should not forget the volume of surveys to which we are all exposed in today's world, and the impact this may have on respondents being focused on accurate completion.

With regard to further research opportunities, as this is an initial exploratory investigation only, there is abundant potential. Firstly, there is opportunity to address two of the limitations identified. The first possibility is to carry out the same current state survey with an IT Practitioner community, and understand the different perspectives between practitioners of IT and Lean. This would address the concern that the current results are biased towards a Lean Practitioner view. The second possibility, with the aim of building on the limited 'better/worse' analysis, is to repeat the same survey on a regular basis and compare with previous results to provide greater understanding of if and how the situation is changing. Also, it would be valuable to carry out more case study work, by identifying further examples where lean and IT are successfully aligned, to understand what learnings can be identified.

Aside from additional research with the broader scope, it would also be valuable to drill into one or more of the conflicts in detail to understand why they exist and how they can be overcome. Whilst it is a good first step for organisations to be able to recognise Lean-IT conflicts, guidance and suggestions on how to address them would be a logical and highly valuable follow-up. One possibility is deeper research into process complexity, including understanding the motivations within organisations to introduce complexity, and considering how to differentiate between necessary and unnecessary complexity, and therefore avoid the latter. Similarly, a second option is to seek to understand the difference between necessary and unnecessary process automation in organisations today. As this research provides an initial indication that the situation regarding use of visual management without technology is improving, a further research option would be to validate this more thoroughly, understand how it came about, and consider if there are learnings that can be used to avoid unnecessary automation in other areas.

As a final point, this research has raised many interesting questions about the role of the IT Group in lean transformation. Understanding more about the role the IT Group plays today, what the ideal role should be for an IT Practitioner or Leader in an organisation undergoing lean transformation, and identifying actions to close the gap, would be a fascinating future research subject.

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Lean Thinking and Organisational Learning: How Can They Facilitate Each Other?

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Abstract Academic study of both lean thinking and organisational learning has evolved and is now mature enough to warrant an in-depth review of the practices and issues of each approach. This study explores how lean thinking and organisational learning can facilitate each other's implementation and provides a conceptual model for future research and practice. The model shows the connections between organisational learning and lean thinking which is based on three propositions: (1) single-loop learning which focuses on error detection and correction in the current management system is closer to the tool-based lean approach while double-loop learning which emphasises changing the underlying governing values in the current system is closer to the sustainability-based lean approach; (2) both single-loop and double-loop learning can be operationalised and facilitated through employing a lean culture and a range of lean tools and (3) building organisational memory and institutionalising learning are the two solutions to enhance the sustainability of lean thinking.

Keywords Organisational learning · Lean thinking · Continuous improvement · Single-loop learning · Double-loop learning

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1 Introduction

As organisations increasingly have to compete against global competitors, researchers and practitioners have developed a number of management concepts and techniques. Amongst the most popular is the concept of lean production, or lean thinking (LT), based on the Toyota Production System (TPS) and popularised by the book entitled "*The machine that changed the world*" (Womack et al. 1990). Since the term "lean" entered the business management lexicon (Krafcik 1988) many organisations have applied, or attempted to apply, the principles of LT. Academic study of lean organisations, and research into lean, is now mature enough for reflection on this significant business improvement methodology.

Lean researchers (e.g. Bicheno and Holweg 2009; Hines et al. 2011) propose that developing the knowledge of workers by continual learning contributes to the fifth principle of lean, that of continuous improvement; this is confirmed by Wong et al. (2009) in the context of superior performance in project management and by Barton and Delbridge (2001) in a discussion on contemporary manufacturing in the context of a "learning factory". Although the importance of organisational learning (OL) has been widely discussed, West and Burnes (2000) point out that, given the complexity of business management, employing one management concept or method, such as OL, is insufficient for organisations to achieve success. It is argued that researchers and practitioners still tend to consider OL and lean as two distinct concepts due to the unclear understanding of the connection between these two concepts (Flinchbaugh 2008). Based on a synthesis of the literature this study provides a conceptual model to illustrate this connection. The overall aim of this study is to illustrate the ways these two concepts can facilitate each other's implementation.

The remainder of this chapter is organised as follows: first, the research method adopted in this study is presented. The literature related to LT, including the evolution of the definitions of lean and approaches to becoming lean is then examined. Third, the definitions, typologies and levels of OL is also reviewed. Fourth, the ways to operationalise OL through lean and to enhance continuous improvement through OL are then analysed. A conceptual model is proposed to explain the theoretical linkages between these two concepts. Finally, the implications of the study and the areas of further research are identified.

2 Research Method

A conventional and narrative literature review is conducted in this study. Compared to the systematic literature review which follows a step-by-step guideline (e.g. Tranfield et al. 2003) and usually generates quantitative results through meta-analysis and hypothesis-testing (e.g. Glass 1976; Rosenthal 1995), a narrative review enables researchers to link studies with different topics together and provokes new thoughts or controversy (Baumeister and Leary 1997). In other words, the narrative review is considered as a valuable theory-building and hypothesis-generating technique (Baumeister and Leary 1997). To search and identify the relevant literature in this narrative review, Bates' (1989) "berrypicking" techniques are adopted. Bates (1989) argues that the classic information retrieval model views a literature search as a linear and fixed process. However, in practice, most information or literature searchers start with a broad topic or one reference and then move forward to other related materials (Bates 1989). During the literature search process, the researcher can identify useful information or references (Bates 1989). The initial query can be satisfied by a series of selections of references and bits of information based on the ever-modifying search (Bates 1989). This "a-bit-at-a-time" information retrieval is termed as "berrypicking" (Bates 1989). Bates (1989, 1990) offers a number of techniques to carry out "berrypicking". Two of them are commonly used in the social sciences and humanities, including footnote chasing (i.e. also known as "backward chaining", it focuses on following up the references or footnotes of literature that the researcher is interested in and moving backward to other related literature) and citation searching (i.e. it starts with a citation and then finds out what other literature has cited it) (Bates 1990). In this study, the two most frequent cited (i.e. the times cited are calculated by Web of Science database) papers of lean (i.e. Hines et al. 2004; Shah and Ward 2003) and OL (i.e. Levitt and March 1988; March 1991) are used as the starting point of literature search. Footnote chasing and citation searching techniques are employed to identify more related literature. The key articles and books reviewed in this study can be found in both the review and discussion sections.

As this study aims to explore how LT and OL can facilitate each other's implementation, the reviewed LT and OL literature needs to be synthesised. The qualitative meta-synthesis method is used in this study. Unlike the meta-analysis which attempts to increase the certainty in cause and effect relationships in a specific area, the qualitative meta-synthesis method is more hermeneutic and it can facilitate the researcher to understand and explain findings (particularly qualitative results) of different literature and develop more formalised knowledge for a certain discipline (Sandelowski et al. 1997; Walsh and Downe 2005). Zimmer (2006) agrees that the qualitative meta-synthesis can assist the researcher to develop the theoretical framework in a specific area. Walsh and Downe (2005) suggest three common analytic techniques to conduct the qualitative meta-synthesis. The first is determining how literature is related by a compare and contrast exercise. The second one is reciprocal translation which means translating one study's findings into another by using commonly applicable concepts (Walsh and Downe 2005). The third technique uses the synthesis of translation to develop more refined concepts and core themes (Walsh and Downe 2005). In this study, the commonalities and differences across different literature in LT and OL can be found in the review section and the discussion section shows how the different concepts discussed in LT and OL literature can be connected. Three propositions are developed in the discussion as a result of refining the LT and OL literature and a conceptual model is presented in the conclusion section to visualise these propositions.

3 Review of LT

3.1 Definitions of Lean

A review of the lean literature shows that, although it has been almost a quarter of a century since the term "Lean" was coined by Krafcik (1988) to describe the Japanese automobile production system, there is no standard definition of lean (Shah and Ward 2007). Some researchers posit a tool-based definition and thus, lean means the application of various lean tools or techniques including value stream mapping (VSM), 5S, visual management, for cost reduction (e.g. Achanga et al. 2006; Faisal et al. 2006).

Womack and Jones' (1996) established five lean principles, namely: specifying value (i.e. customer value); identifying the value stream, making product flow smoothly; building a pull system (i.e. information flows from ultimate customer to raw material providers) and perfection. They argue the key to lean is the change from a push to forecast, or stock, system towards a pull, or flow, to actual customer demand system (Chen et al. 2010). Hence, they propose a system-based definition (also see Cooper 1996; Hopp and Spearman 2004; Shah and Ward 2003), which implies that lean, is a demand-driven operating system. In addition to the tool-based, system-based definitions, some researchers demonstrate lean as a management philosophy, and a set of guiding principles, that leads organisations to add value (see Womack and Jones 2005) as well as banish waste (see Bicheno and Holweg 2009; Staats and Upton 2011; Ward 2007) through continuous improvement (e.g. Bhasin and Burcher 2006; Hines et al. 2011; Liker 1996; Shah and Ward 2007). Researchers including Bhamu and Sangwan (2014), Holweg (2007), Moyano-Fuentes and Sacristán-Díaz (2012) and Samuel (2012) argue that lean is polymorphic and evolving, thus forming a precise definition is difficult and would only be applicable to that moment in time before a new understanding emerged. Therefore, whilst a universally accepted single definition of lean is elusive, considering it as a philosophy, or a combination of other meanings, provides more opportunities for researchers to gain comprehensive understandings of the essence of lean.

3.2 Approaches to Implementing Lean

A shop floor based view of lean still emerges as a prominent way of implementation. As argued by Bhamu and Sangwan (2014), Moyano-Fuentes and Sacristán-Díaz (2012) and Shah and Ward (2003), many lean related studies just focus on applying a single or some lean practices to the shop floor. The essence of this shop-floor based view is smoothing and improving operational processes through the application of lean tools. For example, managers employ a variety of mapping tools to identify the value-added and non-value added activities of each process.

From this they can reduce the operating costs by eliminating non-value added activities and re-organising value-added activities. Examples such as the application of 6S, cellular manufacturing and Kanban can be found in the literature (e.g. Gupta et al. 1999; Kobayashi et al. 2008; Kotani 2007; Marria et al. 2012; Tardif and Maaseidvaag 2001; Witt 2006). However, many researchers criticise this perspective arguing that, although the organisation could benefit in the short-term from improved efficiencies by the application of lean tools, these will often disappear in the long term (Lucey 2009; Lucey et al. 2005; Jackson et al. 2008; Hines et al. 2011). Hence, it is usually necessary to consider lean from a holistic systems perspective and to extend the approach across the entire organisation at both strategic and operational levels (Bhasin 2012).

Hines et al. (2004) built a framework for lean which revealed that, at a strategic level LT should be guided by the five lean principles whilst at an operational level, a lean implementation is composed mainly of tool-based activities. This idea is later supported and developed by Rich et al.'s study (2006) where the foundation of the "house of lean" model consists of deploying easy-to-use lean tools such as 5S and visual management. To build the house, the walls should cover quality control, system maintenance and pull systems, which strongly support the organisation's daily operations. The authors point out that the roof should contain policy and key performance indicators (KPIs), which should reflect, and be in accordance with, lean principles (Rich et al. 2006). Although the model extends lean implementation from the shop-floor level to a strategic level, its focus is on improving the company's operations system.

To gain a more strategic and in-depth understanding of lean implementation, Found et al. (2007) provide a sustainability-based lean approach—"the sustainable lean iceberg model" (see Fig. 1). They divide the content of lean implementation into two groups: visible and invisible elements. For the visible elements, it mainly addresses lean tools, technologies and process improvement activities. Whereas the

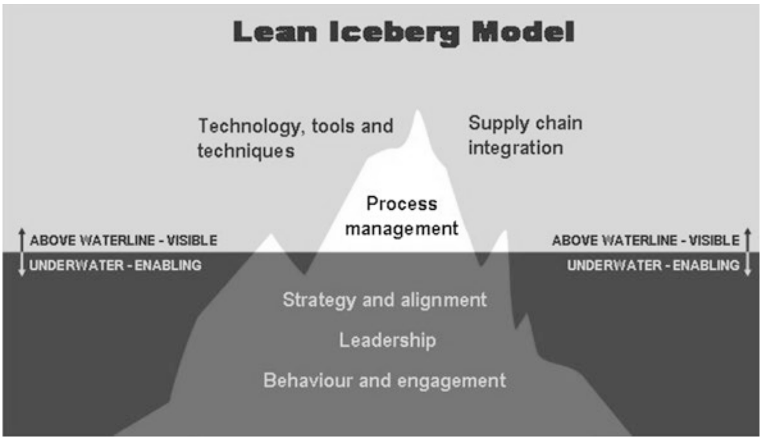

Fig. 1 The lean Iceberg model. *Source* Found et al. (2007)

invisible elements emphasise that lean should be integrated into the organisation's strategy, developing leadership capability, employee engagement and behavioural change (Found et al. 2007; Hines et al. 2011). One of the main contributions made by "the sustainable lean iceberg model" is that it extends lean implementation from efficient lean tools application to effective and sustainable lean based improvement.

3.3 Summary-Issues of Previous LT Literature

Various definitions of LT (i.e. tool-based, system-based and philosophy-based definitions) have been proposed by previous research. While most studies concentrate on how to use lean tools and improve operations efficiency on the shop floor, some researchers argue that lean implementation should be extended to the strategic level. This argument is later developed by some lean thinkers who point out that lean should focus on gaining long-term benefits, rather than only short-term benefits (Bhasin and Burcher 2006; Hines et al. 2011). In addition, lean, and other management concepts in the field of operations management, are criticised for lack of theory (Schmenner and Swink 1998). It may be argued that lean principles fundamentally support lean implementations; however, lean principles are closer to practical guidelines rather than a theory. To build up the foundation of lean, it is necessary to integrate lean with other organisation theories.

4 Review of OL

4.1 Definitions of OL

Researchers define OL from different perspectives; with some viewing OL as a technical process while others prefer to consider it as a social process (Easterby-Smith and Araujo 1999). Despite a variety of definitions (e.g. Argyris 1977; Fiol and Lyles 1985; Nevis et al. 1995; Klimecki and Lassleben 1998; Sadler-Smith et al. 2001; López et al. 2005), there appears to be a consensus that OL is a process of developing knowledge, or insight, by the firm (e.g. Argyris, 1977; Fiol and Lyles 1985; Levitt and March 1988; Nevis et al. 1995). Kolb (1984) helpfully makes the distinction between what people learn (know how) and how they understand and apply that learning (know-why), both relevant to an approach to improvement such as lean.

4.2 Typologies of OL

As there is no standard way to interpret OL, some researchers propose a more structured way to understand this concept. Fiss (2011) suggests typologies are vital to investigate complex relationships and build organisation literature. In the case of OL, the typologies provide clear categories and dimensions, which enable researchers and practitioners to gain an in-depth understanding. They can also be viewed as evaluation dimensions to assess organisation learning maturity (e.g. McGill and Slocum 1993, knowing, understanding, thinking and learning organisation) and/or status (e.g. Argyris 1976, single- and double-loop learning) which contribute to the organisation's further development in terms of identifying the gaps between its current learning state and expected learning state. Argyris' single-loop and double-loop learning can be considered as the most widely accepted typology in the field of OL. Single-loop learning mainly concerns the error detection and correction (Argyris 1977). It aims at identifying and fixing the problems in the current operating system of the organisation. Double loop learning focuses on detecting the problems of underlying values and re-setting the routines, rules and policies in the organisation (Argyris 1977). The most important feature which differentiates single-loop learning from double-loop learning is the ultimate goal of learning. For single-loop learning, the ultimate goal is to ensure that the current system can be smoothly undertaken (Argyris 1999, 2003). Conversely, for double-loop learning, it aims to detect the issues to do with the underlying rules and policies and therefore, the current system can be re-set or at least improved (Argyris 1999, 2003). The idea of single- and double- loop learning is later developed by Fiol and Lyles (1985). They propose that single-loop learning is "lower level learning" which represents adjustments of part of the organization while double-loop learning is "higher level learning" which covers changes of rules, policies norms of the whole organization (Fiol and Lyles 1985). It seems that double-loop learning is more important than single-loop learning but it is worth noting that both of these two types are valuable to organisations and in most cases, double-loop learning is rare (Argyris 1977).

4.3 Levels of OL

OL is an organisational wide process with multiple levels. It is suggested that OL includes at least three levels, namely, individual level, group level and organisational level (Cangelosi and Dill 1965; Crossan et al. 1999). It is argued that individual learning may be the starting point (Kim 1993), but OL is more than a sum of individual learning, as this is limited to individual's preferences, interests and ability (Crossan et al. 1999; Shrivastava 1983; Wang and Ahmed 2003). Found and Kearney (2010) posit that investigating any issue from a single perspective is automatically incorrect as it is impossible for the individual to capture all of the complexities of the issue. Group learning, however, is not equal to OL either (one may argue that an organisation actually could be viewed as a large group). According to Wilson et al. (2007), group learning mainly focuses on the activities of information or knowledge sharing, storage and retrieval. Activities related to institutionalising (Crossan et al. 1999) and organisational memory building (Akgün et al.

2012; Huber 1991; Nevo and Wand 2005) which should occur at the organisational level including setting up organisational rules, routines and policies are not covered by group learning. March (1991) points out that members in the organisation can learn both from each other and from the organisational code.

4.4 Summary-Issues of Previous OL Literature

The review of OL literature shows that OL is not equal to the sum of individual learning. Learning at an organisational level means the learning results should be institutionalised and organisational memory should be built. Argyris (1977) suggests two types of OL, including single- and double-loop learning. While single-loop learning focuses on correcting errors in the organisation's current operations system, double-loop learning stresses the importance of changing the values and rules underpinning the current system. However, it is argued by Argyris (1991) that despite the success of introducing OL to the market place, many people including managers and employees do not know how to learn. Argyris' argument is later supported by Flinchbaugh (2008), who believes OL creates "thinkers" rather than "practitioners" as some managers who adhere to OL are more likely to simply propose new ideas in the name of OL thinkers. The possible result is that top managers may recognise the importance of enhancing learning, but they do not have a clear plan in terms of how to embed the idea of learning in their daily work. As the managers are not able to integrate OL with daily work, it could be more difficult for employees such as supervisors and operators to accept and understand the idea of OL. In addition, another issue of OL is how to ensure the effectiveness of learning. In other words, the issues of how to ensure managers or employees learn "the right thing". For an organisation, it may send and receive plenty of information every day and thereby, it is necessary to develop a guideline to sort out and filter information. Dodgson (1993) recommends that concentrating on customer based information may be a reasonable way to achieve effectiveness.

5 Discussion

5.1 Linking Approaches to Implementing LT with Types of OL

Single-loop learning as discussed previously focuses on error detection and correction in the current management system. This equates closely to the view of lean that suggests it stands for a tool-based approach to organisational improvement. This approach possesses several characteristics. First, it emphasises waste elimination rather than value creation, for example, most literature which addresses lean tool application normally summarises its benefits as cost reduction including inventory reduction, lead time and cycle time reduction (e.g. Tardif and Maaseidvaag 2001; Kotani 2007). It implies that the main purpose of reducing cost through lean implementation is to ensure the organisation's current system could be operated smoothly without any interruption. Second, it frequently occurs at the operational level rather than the strategic level as most studies which relate to lean tool application discuss issues of the organisation's daily operations management rather than strategic management, for example, Hines' et al. (2004) "lean framework" shows that most lean tools belong to operational level improvement. Third, it is more likely to pursue short-term efficiency rather than long-term effectiveness, as the essence of many lean tools is to "do things right" rather than "do the right thing".

Double-loop learning, however, considers and evaluates the underlying rules, routines and policies and thereby, re-set these rules in a more appropriate way. In the case of lean, this idea refers to the sustainability-based lean approach. Compared to the tool-based approach, sustainability-based approach possesses the following characteristics. First, it highlights 'invisible' elements such as strategy, culture and employee engagement. Hines et al. (2011) use the term "enablers" to illustrate the importance of invisible elements of lean implementation and conclude these contribute to sustainable lean implementation in the long term. Lucey (2009), who investigates the relationship between employee engagement and sustainability of lean implementation supports this view and states that a lean implementation is more likely to be sustained when employee engagement is high (Lucey 2009). In addition, Bhasin (2012) demonstrates that there is a significant correlation between a systematic and controlled strategy and successful lean implementation. Second, it normally occurs at the strategic level, which implies it could lead to a strategic change. As a sustainability-based approach is expected to diffuse the idea of lean across the whole organisation including both strategic and operational levels, it provides more opportunities for managers to re-think whether or not the current strategy, policies and rules can satisfy the needs of lean operations. Third, it pursues long-term effectiveness. Unlike a tool-based approach, the sustainability-based approach views lean implementation as a never-ending journey with continuous improvement (Found et al. 2007; Hines et al. 2011).

- Proposition 1: tool-based lean approach is closer to single-loop learning while sustainability-based lean approach is closer to double-loop learning.

5.2 Operationalising OL Through LT

To facilitate OL an organisation should enable all the employees to gain access to information efficiently and effectively. In the case of double-loop learning, employees are encouraged to test out new ideas and the organisation guarantees to embrace both successful and unsuccessful results. However, it is difficult to apply these ideas to real practice. For example, as the organisation connects with both internal and external resources, it could receive a vast amount of information every working day. Hence, to ensure employees obtain the information that they need can often be problematic. In other words, the organisation itself lacks a mechanism to sort out and filter information. In response many organisations have employed various information systems that can at least sort out and categorise information. It is worth noting that the information system itself will not provide the required information unless the organisation sets it up. In addition, the ability to ensure the efficiency and effectiveness of information transformation and communication between managers and employees, employees and customers could be another issue. From a lean perspective, establishing a lean culture could solve this practical issue. Although there is no standard definition for lean culture, the following characteristics can be summarised.

First, lean values customers above any other stakeholder. This means information related to customers such as customer orders, requirements and feedback should be selected as the "must-have" information for all the employees. Additionally, the organisation should build a team, which directly contacts customers and analyses or deciphers customer related information. In this case, it requires the organisation's current management system to be re-built or at least adjusted based on customer requirements (Teehan and Tucker 2014). Womack and Jones (2005) summarise some common principles from a customer's perspective: completely solving problems, solving problems as soon as possible, providing the right thing at the right time and place, and simplifying decision making processes. They suggest that every product or service provider should understand these principles, which implies that the new management system should also reflect these principles.

Second, a lean culture views any waste as the enemy and it encourages all employees to detect waste. To achieve high effectiveness of information transformation and communication, lean thinkers recommend the organisation to discover waste in the communication processes and knowledge work. Ward (2007) identifies three types of knowledge waste and proposes that, to cope with waste, the organisation should encourage employees to discover the root cause of the waste and learn its whole operational mechanism rather than piecemeal learning. Similarly, Staats and Upton (2011) demonstrate that the idea of lean is applicable to knowledge work improvement through finding out the root cause of waste. This implies that their ideas partly reflect Argyris' idea of double-loop learning as they guide the organisation to question or re-build the current rules, routines and policies.

The third characteristic of a lean culture is the emphasis on empowerment and coaching, where Toyota managers act as coaches who enable employees to experiment and learn from their ideas as frequently as possible (Spear 2004). Finally, a lean culture highlights continuous improvement. It means the organisation should, through PDCA (plan-do-check-action), be able to continually improve its current state (Gonzalez-Rivas and Larsson 2011).

In addition to a lean culture, many lean tools could facilitate the application of OL. Although it is discussed in the previous section that solely applying lean tools fails to gain long term benefits, it does not mean lean tools are useless. It is proved by lean thinkers that lean tools contribute to streamlining and smoothing both physical and information flows (Bicheno and Holweg 2009). In the case of OL, single-loop learning follows the logic of detecting and fixing the problems in the current system whilst double-loop learning involves new ways of doing things. Researchers from an OL perspective do not provide a practical tool or mechanism to guide managers or employees to visualise or detect these problems. From a lean perspective, some fundamental lean tools such as visual management and 6S (Bicheno and Holweg 2009) could facilitate single-loop learning. The main advantage of these tools is they are easy-to-use and relatively low cost as the application of them does not necessarily require the organisation to be equipped with advanced machines or highly skilled employees.

For double-loop learning, the ultimate goal is to question and transform the underlying rules or policies of the organisation. However, it is commonly argued that double-loop learning is rarely achieved. From a lean perspective, other lean tools can be employed to support double-loop learning, for example, using the problem solving techniques, such as 5 Whys, to determine the root cause of a problem. VSM can also be considered as a useful enabler for double-loop learning. VSM enables the organisation to concentrate on the value added processes rather than waste (Rother and Shook 1999; Womack and Jones 2005). In addition, there are many higher-order lean tools, such as Quality Function Deployment (QFD), Design for Manufacture (DfM), concurrent engineering etc. (Hines et al. 2006; Bicheno and Holweg 2009) from the quality and new product development schools as well as processes such as Hoshin Kanri (Policy Deployment) and 'catchball' (Cowley and Domb 1997) that facilitate double-loop learning.

It is worth noting that many lean tools can be implemented in an integrative way to enhance both single- and double-loop learning. For example, VSM aligned with 5Whys and visual management. The organisation could identify the non-value adding activities through VSM of the current state, use problem solving techniques to detect the root cause of the problems and visual management to track progress towards the removal of the non-value adding activities and movement towards an improved future state. Furthermore, considering improvement tools within the context of learning could lead to the redesign of these activities.

- Proposition 2: the ideas of OL can be operationalised and facilitated through employing a lean culture and a range of lean tools.

5.3 *Enhancing Continuous Improvement of Lean Through OL*

Although lean has developed from shop-floor improvement to value system building, it is difficult for the organisation to achieve continuous improvement. It may be argued that some lean tools such as Kaizen could enable the organisation to set up an efficient mechanism to support continuous improvement. However, Found and Kearney (2010) demonstrate that the nature of continuous improvement can be described as a “mess” (Ackoff 1974), which means issues related to continuous improvement are complicated and interdependent. In this case, it is insufficient to achieve continuous improvement by focusing on only one or two lean tools.

It is observed that external professionals and consultants assist many lean programs. The use of these external stakeholders raises an important issue: how can the organisation ensure that it can sustain the benefits from the program when the consultants or key members leave? From the OL perspective there are two solutions: organisational memory building and institutionalising.

It is argued that organisations own their memory, which comes from both internal and external resources (Huber 1991). Akgün et al. (2012) indicate that the components of organisational memory include declarative memory (e.g. facts, events), procedural memory (e.g. procedures, routines) and emotional memory (e.g. past emotional events). Huber (1991) suggests two computer-based approaches, an information system for storing “hard” data such as performance data and financial reports, with an expert system for storing professional skills and ideas (Huber 1991). Nevo and Wand (2005) confirms that information technology is central to organisational memory building.

Crossan et al. (1999) propose that institutionalising is also a powerful approach to retain the learned knowledge, which means the organisation should embed useful knowledge in its strategy, rules, routines and principles. As a result, even though consultants and key members leave the organisation, the established strategy and principles could guide its daily operations. For example, Tesco (the UK based global retailer) which has launched lean/continuous improvement program for more than 15 years, establishes its underpinning principles as better, simpler and cheaper and thereby, regardless of the changes within management teams, all the new ideas and initiatives proposed by managers and employees are assessed and selected based on these principles (Hu et al. 2012).

- Proposition 3: building organisational memory and institutionalising learning are the two solutions to enhance continuous improvement.

6 Conclusion

This study provides an in-depth view of the connections between OL and LT through integrating OL typologies, levels, lean definitions and lean approaches. It copes with the criticism of OL by using lean culture and lean tools to operationalise OL. It also copes with the criticism of lean production by employing the concept of OL to enhance its theoretical foundation. From a synthesis of the OL and LT literature we have analysed the definitions, typologies and approaches for both concepts and developed a model, “OL-LT model” which illustrates the connections between them (see Fig. 2).

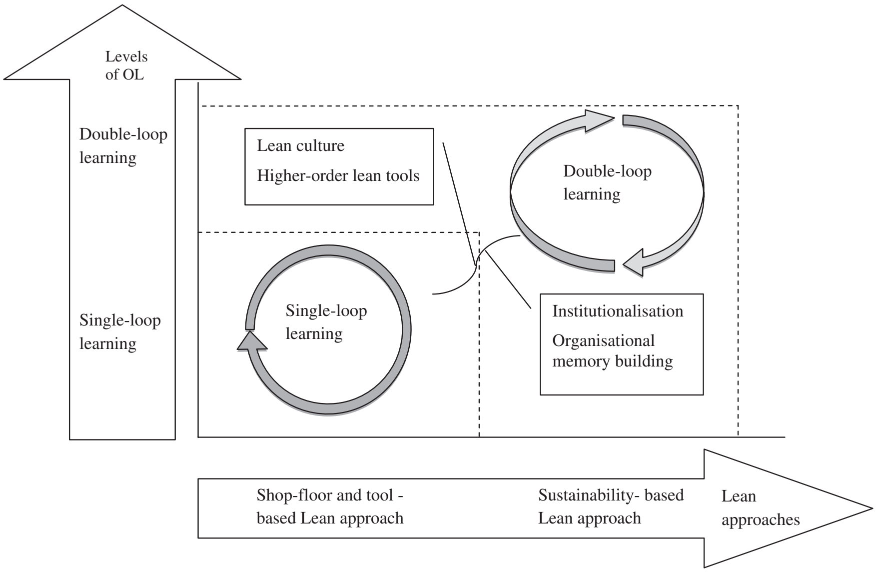

Fig. 2 The OL-LT model

There are several academic contributions of the "OL-LT model". First, it extends Hines et al.'s (2004, 2011) studies to a broader context through integrating OL typologies, learning levels, and lean approaches. Second, it contributes to the literature of these two concepts by clearly showing the theoretical links and interactions. It also operationalises the concept of OL by exploring the meaning of OL typologies and processes in the context of lean. Fourth, this study should also prompt a review of methods employed to assess how organisations learn to be lean or how lean can enhance learning.

This study has several managerial implications. First, this study proposes lean culture can have a positive impact on information transferring and filtering through highlighting customer based information, eliminating knowledge waste, emphasising empowerment and continuously improving the current status. Hence, managers who intend to apply both OL and lean production within their organisations are suggested to re-think and re-organise their current management system and information system based on the characteristics of lean culture.

Second, this study explores the way single- and double-loop learning can be achieved by applying lean tools. It indicates that some basic lean tools can facilitate single-loop learning whilst some higher-order lean tools can contribute to double-loop learning. The development of these two stages of learning is critical to the spread and sustainability of lean improvements. For managers who accept the ideas of OL, but do not have a practical plan of applying OL, lean tools can be considered as a start point and an easy-to-use method to operationalise the idea of OL.

Third, as lean implementation is often criticised for lack of sustainability, the last section addresses how the ideas from OL perspective, including building organisational memory and institutionalising, could enhance continuous improvement in a lean organisation. Managers are also advised to review and revise the organisational rules and policies to ensure that these rules and policies reflect the ideas of lean.

Finally, organisations need to ensure learning cycles are complete and if necessary remove any barriers to learning, such as constraints on job roles, ambiguity around learning, inability to codify learning for future use. In terms of improvement, the use of Plan-Do-Check-Action (PDCA) cycles may enhance the completion of learning and assist in codifying and embedding learning within the wider organisational actions or practice.

As a conceptual study, the proposed "OL-LT model" lacks empirical data to support it. The future research is encouraged to empirically test "the OL-LT model". In particular testing of the model across different industries would be useful. Those, such as the automotive sector, considered more sophisticated with implementing lean compared with those with less experience might provide some interesting insights to how learning is achieved. Similarly, geographic location and size of organisations may also provide some valuable insights into this area of research. There is also a need to observe how learning is captured, transferred and disseminated within the context of lean. For example, PDCA cycles may help to ensure learning cycles are completed and VSM may need to be modified so that knowledge flows are as prominent as material, information and financial flows.

We propose that building organisational memory and institutionalising the learning are essential to enhancing continuous improvement. For many organisations this will require managers to re-think the way they approach improvement and implement lean. Much more consideration should be given to management and information systems that can support and encourage learning. How and when lean tools and techniques are employed needs careful planning in order to foster a culture of learning and improvement.

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Flow Accounting: The Next Challenge for 21st Century Lean Businesses

John Darlington, Pauline Found and Mark Francis

Abstract Traditional management accounting conventions do not support the Lean paradigm and, whilst numerous alternative accounting approaches have been developed over the last 25 years, there is still dissatisfaction amongst academics and practitioners in developing an alternative approach to address this issue. This paper presents a framework for such an approach that the authors call *Flow Accounting*. This has been developed over a number of years of empirical research at several large test sites and is advanced as an improved management accounting approach for more effective performance assessment and operational decision-making within the Lean enterprise. This paper further presents an empirical case study of an application of the technique within the aerospace industry. In particular, it discusses the findings derived using a new holistic mapping technique called Big Picture Financial Mapping that helps target improvement initiatives and quantifies the financial potential.

Keywords Lean · Standard costing · Lean accounting · Throughput accounting · Decision making · Flow accounting

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1 Introduction

Financial accounting, in some form, has been around for thousands of years. As far back as 500 years ago, a Venetian monk, Fra Pacioli, described the basics for double entry book keeping used today. It was done in order to establish ownership of ventures. However, Management Accounting is a relatively new phenomenon and came about and arguably fuelled the development of more complex organisations. Pre 19th century all exchange transactions were by 3rd parties with 3rd parties. An owner of a factory would:

- Buy raw material from suppliers
- Pay "piece" rates to workers
- Sell to customers

At this time here were few if any layers of management. As organisations became more complex there was a commitment to capital for economies of scale. Workers were hired for long term rather than "spot" employment and gains were revealed for organisations that adopted a hierarchical approach. As the conversion process lost market traceability a demand developed for measures of efficiency denied because of internalisation. For example, cost per hour or cost per ton

More complex organisations often began with vertical integration, exploiting scale, whilst improved transportation opened up other markets and distribution methods. The operating ratio, a measure of the relationship of operating expenses to sales was applied and assisted in measuring how different segments of the business contributed to the whole. In each instance quoted in "Relevance Lost" (Johnson and Kaplan 1987) there was little or no effort made to reconcile financial accounting, reporting to the outside world, with management accounting used internally to assist decision making and motivate managers and supervisors. Scientific management principles advocated by Taylor (1903) amongst others defined standard parts, methods and times for tasks developed "the one best way". This fuelled the idea to develop the view of the one best cost later termed the standard cost. According to some it was G Charter Harrison who in 1911 designed and installed the first complete standard costing system known to exist. In 1921 Harrison published the first set of equations for the analysis of variances.

A survey of 300 UK manufacturers in 1993 reported 76 % operated a standard costing system (Badem et al. 2013). Similarly in the USA Cornick et al. (1985) reported 86 % of the responding companies were using standard costing systems. In the late 1950s and through the 1960s a debate developed between two schools of thought in management accounting; those that supported the view that "Fully Absorbed Standard Costing" (FASC) was the appropriate methodology for judging decisions and those that believed that a "Marginal Costing" (MC) approach was superior.

The debate in 1980s was fundamentally the same, although it could said that the arguments had become even more polarized to Activity Based Costing (ABC) and Throughput Accounting (TA). With ABC managers are required to identify the major activities that pertain to the manufacture of specific products and allocate manufacturing overhead costs to activity cost pools (Innes and Mitchell 1991). Then identify the cost drivers that accurately measure each activity's contributions to the finished product and compute the activity-based overhead rate and, finally, assign manufacturing overhead costs for each activity cost pool to products using the activity-based overhead rates (cost per driver) ABC is the foundation behind Lean Accounting (Maskell and Baggaley 2004).

If ABC is seeking a more accurate product cost by a new way of allocating fixed costs through cost drivers Throughput Accounting (TA), hardly acknowledges product costing at all. In TA (Corbett 1998, 2000), Throughput is defined as sales less the variable cost of producing one more or one less unit. In many instances this means only the material cost; although costs such as royalties or freight costs would also feature depending upon circumstance. All other "operating expenses" are considered fixed. So in this sense TA is based around a high level contribution, or super marginal costing approach. It would be fair to say that TA also relies on a greater understanding of capacity because of its links to Theory of Constraints. This manifests itself in Throughput per Constraint Minute to develop a ranking method in the absence of more conventional product costing.

Although TA might be considered "innovative" at least in the sense that it challenges the premise that cost accounting methods like ABC are necessary for decision making it is argued by the authors that it is really an extension of the older debate between fully absorbed and marginal costing in earlier decades. By way of evidence for this consider the following extract:

A report published in 1961 by The Institute of Cost Accounting and Works Accountants (Periasamy 2009) stated

> **22. Marginal Costing** The ascertainment, by differentiating between fixed and variable costs, of marginal cost, and of the effect on profit of changes in volume or type of output

> **26. Limiting Factor** The factors in the activities of an undertaking, which at a particular point in time or over a period will limit volume of output.

1.1 Historical Context and Assumptions

Conventional management accounting systems comprise an *absorption costing* approach that is used to establish the *standard cost* of an individual product unit. *Variance analysis* of the deviation between actual versus forecast (standard) cost is then used as the basis for performance evaluation and cost control within the firm. This conventional approach was developed to support management decision making in the late nineteenth/early twentieth century during the beginning of the era of mass production (Harrison 1921; Johnson and Kaplan 1987; Johnson 1992; Cooper 1995). Compared with today, the cost structure of manufacturing operations in that era were characterised by a relatively high percentage of direct labour and low indirect costs.

1.2 How Does Absorption Costing Work?

First the *direct costs* such as material and labour are *attributed* to the *cost unit* (a product). The direct material cost is established by rolling up the Bill of Material (BOM) file for each product that is produced, and adding up the previously established standard cost for each of its component items in the BOM. Similarly, the direct labour cost is calculated by multiplying the number of standard hours recorded for producing that product and multiplying it by the prevailing labour rate.

Next, the *overheads* (*indirect costs*) are *allocated* to that cost unit in order to convert the *fixed costs* into a pseudo *variable cost*. This is achieved via the following method:

1. Estimate the total *overheads* for the period concerned e.g. £100,000
2. Estimate the total number of *cost units* (units of production) in the period concerned to be used to *recover* this overhead e.g. 10,000
3. Select an appropriate *basis for allocating* the *overheads* to these cost units e.g. direct labour hours
4. Establish the relationship between this *basis for allocating* per *cost unit* e.g. There are 3 direct labour hours per unit … therefore total production = 3 × 10,000 = 30,000 h
5. Calculate the *absorption rate* (the rate at which overhead will be *apportioned* to the *cost unit*). Absorption rate = £100,000/30,000 h = £3.33 of *overhead* will be *absorbed* by each *cost unit* per 1 h of direct labour consumed by it. Therefore expect 3 h × £3.33 = £9.99 per unit

The absorption costing approach therefore forecasts assumes that all costs (*direct* and *indirect*) will be *recovered*. It is for this reason that it is also sometimes known as the *total costing* or *fully absorbed costing* approach. NB: If any of the above underpinning assumptions are incorrect, there will be an *under-recovery* or *over-recovery* of the overhead.

1.3 Inherent Advantages and Disadvantages

Within management accounting textbooks the inherent advantages and disadvantages claimed for the absorption costing approach are:

1.3.1 Advantages

- It is formula based and simple to calculate—which many managers find comforting.
- Provided that overheads are *absorbed* on a relevant basis, a total unit or *product cost* can be established.

- If the forecast level of production/sales is achieved, all *overheads* will be *recovered*.
- It is particularly useful for setting the *standard cost* for control purposes.

1.3.2 Disadvantages

- The need to absorb *fixed costs* into product costs can lead to dubious or unjustifiable cost apportionment—resulting in meaningless unit cost figures.
- The bases for overhead allocation are subjective and therefore open to different interpretations. Clearly, the selection of a different *basis of allocation* will result in a different product cost.
- Product/unit cost also depends on the level of production selected as the basis for the estimate.
- Even a small (forecast error in this production level can result in massive cost implications when magnified over a large number of units.
- *Overhead* is allocated uniformly to products based upon volume of production. Products today are rarely uniform.
- Indiscriminate *overhead recovery* based on single *basis of allocation*, such as direct labour hours or machine hours, can result in misleading product cost/profit performance.
- It is a compartmentalised approach to costing that does not address present (or past) processes/activities that cross departmental boundaries.
- Because it is a ‘tidy’ approach that leaves no awkward remainders, there is a tendency for managers to consider it as ‘accurate’ (and comforting).

2 Implications Regarding Lean/Flow

Two categories of criticism of absorption costing have emerged. The first is general criticism of its relevance in the contemporary (manufacturing) age. Building upon this, the second category contains specific criticisms of the ‘fit’ between the principles and mechanics underlying absorption costing and the Lean/Flow environment.

2.1 General Criticisms: Relevance to Contemporary Manufacturing

The two key critics of the relevance of *conventional cost accounting* systems are Robert S Kaplan and H. Thomas Johnson. In a series of seminal works (see Kaplan 1984, 1988; Johnson and Kaplan 1987) they argue that the accounting ideas and systems developed at the turn of the last century were appropriate for the era of mass production. However, they are not conducive to servicing the needs of contemporary manufacturing operations that are characterised by high variety, small batch sizes, mass customisation, shorter product lifecycles and selling prices that are aggressively forced downwards. This is therefore an issue of *uncorrected obsolescence* rather than original error (Darlington et al. 2008). Johnson and Kaplan go as far as suggesting that the conventional costing approach is not only inadequate for contemporary manufacturing, but actively *undermines* it.

Kaplan (1988) summarises three different functions of any cost accounting system. These are:

- ***Inventory valuation*** for financial and tax statements, allocating periodic production costs between goods sold and goods in stock.
- ***Operational control***, providing feedback to managers on the resources consumed (labour, materials, energy, overhead) during an operating period.
- ***Individual product cost measurement***, establishing the individual product cost and hence informing the product pricing decision.

Using this as a framework for discussion, Johnson and Kaplan (1987) observe that absorption costing was designed primarily to reconcile the need for the same information to be the basis for costing accounting and financial accounting information and that the method of inventory valuation, described above, provided the means for it to be accomplished. They argue that today's cost accounting information is driven by the procedures and cycle of the organisation's *financial reporting system* (often monthly) and is consequently too late, too aggregated and too distorted to be relevant for operational control purposes. The resulting management accounting reports offer little help to operating managers seeking to reduce costs and improve productivity—and can actually decrease productivity because they require such managers to spend time understanding and explaining reported variances driven by issues over which they personally have little or any control.

These authors also criticise the relevance of absorption costing in providing an accurate individual product cost measurement. They suggest that under this approach costs are attributed to products by a simplistic and arbitrary *basis of allocation*, which is usually *direct labour* (that is relatively insignificant in today's production environment) and doesn't represent the demands made by each product on the firm's resources. They point out that such simplistic product costing methods are adequate for financial reporting purposes because they yield values for inventory and cost of goods sold (COGS) that satisfy external reporting and auditing requirements. However, systematically bias and distort costs at an individual product (*cost unit*) level.

2.2 Specific Criticisms: 'Fit' with the Lean/Flow Environment

The previous section summarised the operational control deficiencies of the conventional absorption approach when applied to contemporary manufacturing generally. However, a number of other authors (amongst others Ansari et al. 1997; Drury 1999; Johnson 2007; Monden 1989, 1992; Yoshikawa et al. 1993) have characterised the specific problems that originate from this approach when it is applied to a Lean/Flow environment.

For example, Johnson (2007, p. 1) criticises conventional accounting systems for costing, inventory valuation and performance assessment "… *(for promoting) delay and discontinuity in operations, rather than flow and short lead times.*" He also criticises such conventional accounting practice for *not disclosing the potential financial benefits of adopting lean practices* (i.e. the opportunity cost) because it does not show directly the cost savings and financial opportunities that might arise from disposing of or redeploying resources made redundant by a successful lean initiative.

Citing Ansari et al. (1997), Bicheno (2000) likewise summarises four key areas of contention between the conventional accounting approach and Lean/Flow environments. It:

1. Assumes that costs vary with inputs such as material or are fixed over a set period of time, hence encouraging long production runs.
2. Stresses individual and departmental performance measurement and accountability. By contrast, Lean emphasises team and supply chain based measurement and rewards.
3. Is very concerned with inventory costing and control. Lean stresses simplicity and inventory reduction.
4. Emphasises labour and unit-based measures and costs. Lean places a greater emphasis on (reducing) indirect costs.

Darlington and Moar (1996), Darlington et al. (2008) provide detailed insight into six specific issues. These illustrate that the *conventional costing* approach actively *discourages* Lean/Flow improvements and *misrepresents* the results when they are actually made 'as a leap of faith' regardless of this barrier:

2.2.1 Local Optimisation

Absorption costing is premised upon the reductionist principle that the sum of the local optimums equates to the global optimum (i.e. if we optimise all the parts, the whole system will be optimised). Absorption costing incentivises managers to optimise their department or function. Production is consequently run to achieve the Accounting department's conception of such local optimisation, which at best is only a proxy for 'real' organisation boundary criteria such as actual customer demand or the flow of cash in/out of the bank. Given the mechanics of absorption costing, this translates into incentives to maximise *overhead recovery* and *capacity utilisation* (labour and machinery); which consequently form the two biggest drivers of local performance under such a system.

2.2.2 Economic Order Quantity and Batch Sizes

The size of the fixed production batch is very much influenced by the Accounting department and established via the Economic Order Quantity (EOQ) model that forms part of the *conventional costing* approach. According to this approach a number of ancillary costs are incurred when a machine is setup, cleaned or changed over. These additional costs are to be spread over the number of items in the resulting batch. Clearly, larger batch sizes result in higher average stock levels that consume working capital and increase stockholding costs (usually estimated to be between 25 and 80 % of the value of inventory on an annualised basis). The EOQ model therefore looks to establish the most economic trade-off between these factors.

The resultant batch size is not related to real customer demand and is inevitably larger than necessary. In fact all such unit cost and utilisation based performance measures that are so integral to the conventional approach have the same affect; they drive large batch sizes they are ultimately based on the logic that the bigger the batch size, the lower the unit cost and the better the utilisation figures. The reward for successful reduction in batch size (for example, as a result of a precision changeover or Single Minute Exchange of Die (SMED) project) is increased throughput with simultaneously reduced inventory and operating expense. This is never taken into account in the EOQ model so favoured by conventional accountants.

2.2.3 Value Adding Principle

In addition to being premised upon the principle of local optimisation, perhaps the second most fundamental flaw with absorption costing from the Lean/Flow perspective is its clumsy interpretation of the value adding principle. In absorption costing, fixed costs are capitalised in inventory and value is added (and hence overhead recovered) when we MAKE something, and not when we SELL it. This creates incentives for the operations manager to build inventories (and to manipulate inventory levels to smooth income) regardless of whether that production is actually needed/demanded by the customer or not. Absorption costing therefore encourages the making of too much and/or too soon. This is overproduction; the worst kind of waste in the Lean typology (Womack and Jones 1996).

It is also notable that when in a financial period the final inventories are exploited for sale and there is no equivalent replacement then the resulting variances only have one method of escape—through the Profit and Loss (P&L) account! This means quite literally that a Lean/Flow inventory reduction programme that produces a production system that runs off lower WIP and finished goods will result in improved cash flow, although the P&L account will most likely show poorer performance if not net loss!

2.2.4 Cycle Time Instead of Lead Time

The earlier discussion established that there is no reliable method of calculating an 'accurate' *product/unit cost* because of the subjective nature of *overhead allocation*. Effective *lead time* compression is a fundamental goal within the Lean/Flow paradigm. However, the only aspect of TIME considered within the absorption approach is ***cycle*** *time*; which is typically used for establishing the *basis for allocating overheads* (e.g. the number of *standard hours* of direct labour or machine cycle time required per product/cost unit). Such product costing pays no heed to ***lead*** *time* (the total *elapsed* time taken for a part/product to flow through that process).

As a consequence, such an approach provides no incentive to reduce lead time, but instead focuses attention mainly on counterproductive efforts to reduce product/unit cost. In fact, in a plant where direct labour is used as the *basis for allocating overhead* then the more staff taken off the shop floor as the result of a genuine Lean/Flow (*kaizen*) improvement, the higher the *overhead burden* becomes (per cost unit) … hence the higher the product cost appears to be!

2.2.5 Value of Bottleneck Time

A compounding flaw in the absorption approach is the uniformity of value that it places upon all (cycle) time. For example, if direct labour hours are selected as the *basis for allocation* in a plant, the *absorption costing* approach does not make any distinction regarding the location (workstation/resource) at which that labour time was consumed in its calculation of product cost and hence influence on decision making. However, the Theory of Constraints (Goldratt and Cox 1984) tells us that a minute (of cycle time) lost at a *bottleneck* is a minute lost to the system forever, while a minute saved at a non-bottleneck is a mirage. Clearly, bottleneck time must therefore be more 'valuable' than non-bottleneck time—but this isn't recognised in the conventional approach.

2.2.6 Cost Reductions

The last of the issues identified by Darlington is that accountants are often keen to embrace the waste removal credentials of conventional Lean/Flow initiatives. However, the total savings claimed are usually a mirage as they are rarely reflected in the bottom line. For example, Darlington cites his own experience in the mid 1990s where the sum of the claimed savings made from the Lean waste elimination projects implemented throughout the year were found to exceed the turnover of the firm! Such a situation leads us to conclude that:

(a) Waste removal is not the same as cost reduction—and/or—
(b) A better approach needs to be found to establish the benefits of genuine Lean/Flow improvement initiatives.

3 Research Motivation

The authors were recruited as part of a team looking at the impact of digital manufacturing in the aerospace industry with one large aerospace company acting as host site. The authors were asked to contribute a "lean" perspective to the project.

Initial visits to the site revealed that there were already a number of lean initiatives being actioned and centring on improvements in final assembly. The host were working in conjunction with a large consulting company and the basic premise was that they would create a "model lean assembly line" which could then be rolled out to some other 8 assembly lines within the host and elsewhere in the component and sub assembly areas.

There was a real need to rationalise how the authors could contribute to the project and what form "lean" might take in areas other than final assembly; this provided the motivation to use Flow Accounting to scope out the opportunity for improvement.

4 Research Methodology

In order to satisfy the research motivation for this investigation, a case study approach was selected as the research strategy (Yin 2003). A case study is an empirical inquiry that investigates a contemporary phenomenon within its real life context, especially when the boundaries between phenomenon and context are not clearly evident (Yin 2003). A case study can provide rich knowledge of a specific context (Meredith 1998; Sousa and Voss 2008; Yin 2003) and has a heritage within both Operations Management and Logistics, where it has been employed for research purposes that include exploration, theory building, theory testing and theory extension (Eisenhardt 1989; Ellram 1996; Voss et al. 2002). Action research was the approach taken in this study. Gilmore et al. (1986 p. 161) define action research as:

> Action research aims to contribute both to the practical concerns of people in an immediate problematic situation and to further the goals of social science simultaneously. Thus, there is a dual commitment in action research to study a system and concurrently to collaborate with members of the system in changing it in what is together regarded as a desirable direction. Accomplishing this twin goal requires the active collaboration of researcher and client, and thus it stresses the importance of co-learning as a primary aspect of the research process.

The case study reported upon in this paper was purposively selected (Silverman 2000) and was a longitudinal study conducted over a two-year period. The firm's senior management team championed the project and a project team was formed with a large room dedicated to them for the duration of the study. The team had, at its core, six managers drawn from a cross-functional range of the resource and support areas found within the organization. The research team comprised 3 senior researchers with professional expertise and significant knowledge of lean operations management. A simulation-modeling expert was also seconded to the team.

Under the terms of a confidentiality agreement, a three-year moratorium on publication has been observed for this study. Other measures have also been applied within this paper to assure the anonymity of the firm whilst simultaneously maintaining the integrity of the findings. These measures include the disguise of all terminology that could be used to identify the company. This includes all specifics regarding the firm's product portfolio, the industry sector within which it operates, its geographic location and all reference to its annual turnover and scale of employment. Lastly, all financial and operational data has been disguised by means of a constant modifying factor.

5 Research Findings

5.1 Analysis

Flow Accounting (FA) comprises of a number of elements and is based upon the premise that the bottom line financial results are a function of how you manage Demand Capacity and Inventory in manufacturing and the key performance indicators (KPIs) which influence how people manage these subjects and the return on net operating assets (Fig. 1).

It follows that if you want to generate a different (better) result you have to change how you manage any one these subjects or combination of them.

FA analyses and studies the current means of managing demand capacity and inventory to understand the scope for improvement in terms of money, attempting to try and establish "cause and effect" analysis at a company level. To do this it looks into both financial and non-financial data and the "structure" of the manufacturing business in question. This latter element requires an understanding

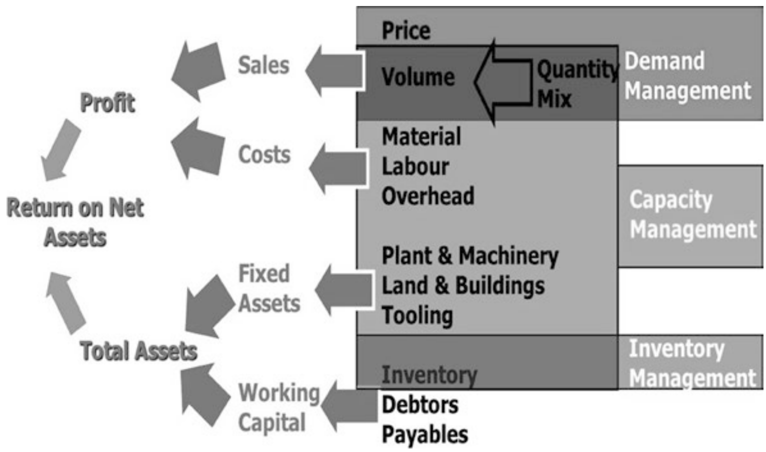

Fig. 1 Return on net operating assets

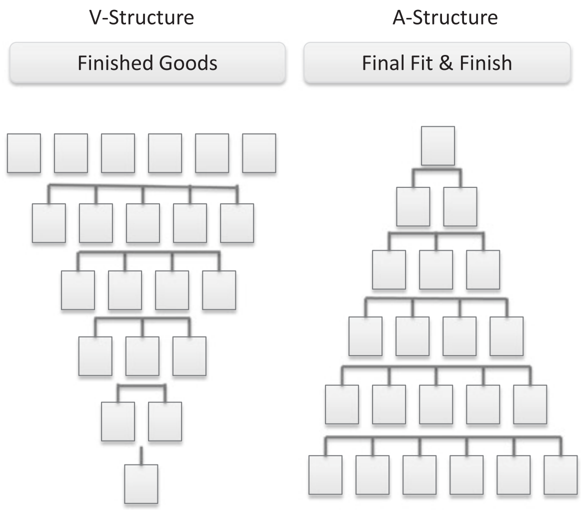

Fig. 2 V, A & T businesses (Adapted from Cox and Spencer 1998, p. 127)

of "VAT Analysis", a constraint management procedure for understanding the dominant structural issues of the manufacturing unit. V, A & T analysis (Fig. 2), so called because these describe the dominant structure of the bill of materials (BOM) categorizes businesses into 3 types that have their own distinctive problems and this understanding can be used to avoid the "cul-de-sac" of "one solution for all" approach. It also contrasts with the current propensity of lean practitioners who describe themselves as value stream based organisations. Appealing though this latter description might be for simplicity sake, VAT analysis is sounder as it is based upon the combination of bill of material and route; i.e. tangible structures.

5.2 Process

FA launches a number of pieces of analysis and study in parallel at the start of an engagement and the vehicle for pulling the whole thing together is often a Big Picture Financial Map (BPFM). The authors would claim this is a focussing mechanism designed to reduce the risk of "scatter gun" improvement activity targeting low level "waste removal" to no overall beneficial effect.

The first decision in creating a BPFM is to decide the level of granularity appropriate to the objects (where the work is done) that are going to be represented on the map. So to date A BPFM has never got down to each individual process. In the large aerospace host, the various centres manufacturing critical components and sub-assemblies, which fed final assembly, became the basic objects for the map and the main routes that products took are added as well (Fig. 3).

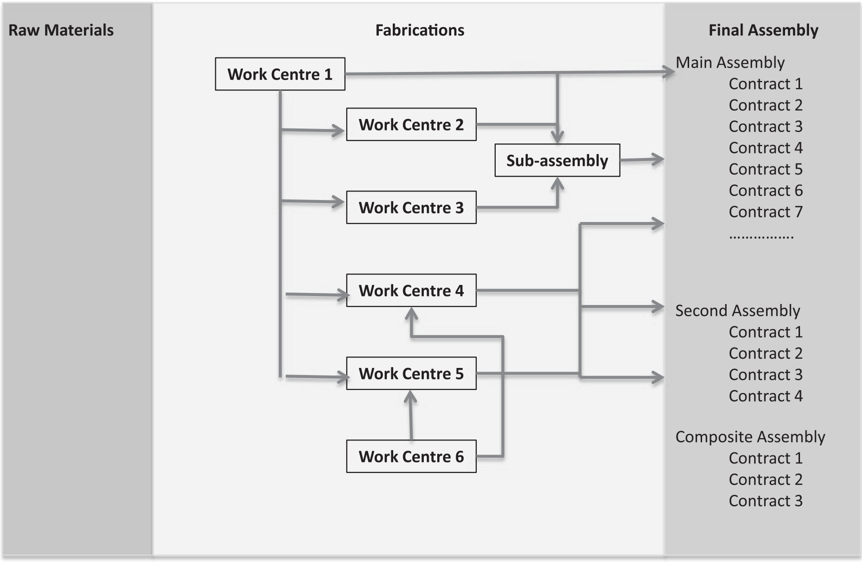

Fig. 3 Main routes of product flows

As the name suggests BPFM uses financial data and starts at the company level. Fortunately Finance departments associated with manufacturing have well established methods of reporting and these are drawn upon to perform calculations which are used to populate the map.

The basic outline is now drawn and the next steps are to populate it with a combination of Money, and KPIs and other insights drawn from the study and for them to become representative of the current performance of the system.

As product costing is considered to have too many negatives implications, such as encouraging "overproduction" by the clumsy interpretation of the value added principle: the formality on the map and other documents is to adopt the Throughput Accounting terminology:

- Throughput
- Inventory
- Operating Expense

It is also fair to say that the only rationale for "allocation" is to develop a product cost and, as this is simply a financial accounting requirement for inventory valuation, it is rejected as having no place in modern management accounting techniques. In fact, it is often misleading, as the majority of the operating expense is quite likely to be away from the shop floor. Figure 4 is the BPFM for this company.

The BPFM is often supplemented by other charts and observations backed up by data but this is the summary level BPFM in the aerospace business.

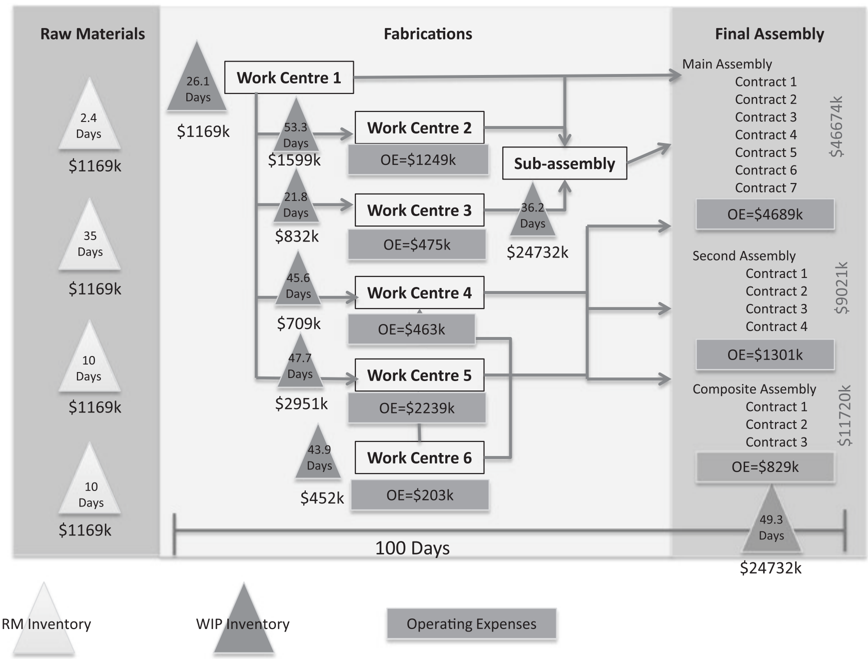

Fig. 4 Big picture financial map

The Throughput numbers $46674k, $9021k and $11720k represent sales over the course of a quarter and this timeframe was felt locally to be a better representation of their mix of sales.

The inventory numbers are shown both as absolute in $k and as relative numbers in "days cover"; the relationship of Inventory Value to Cost of Sales.

It should be noted that the OE or Operating Expense does not include any overhead at all. Overhead would have to be "allocated" and FA policy is not to allocate as this neither reduces the overhead total expense nor can the production centres control "the spend". So the OE represents the real cost of running these centres per month at the current levels of activity.

The cash implications of this sort of performance are illustrated as follows in Fig. 5.

Of course the strictly financial accounting view would challenge that each of these "day calculations" should be based upon different valuation criteria but FA is content with impact and getting people interested in lead time compression as a means to greater competitiveness.

FA would argue that although the debtors and creditors can influence the "Finance Days" that this requires "negotiation" with the outside world in terms of 3rd party organisations whereas the Work in Progress is really completely in the

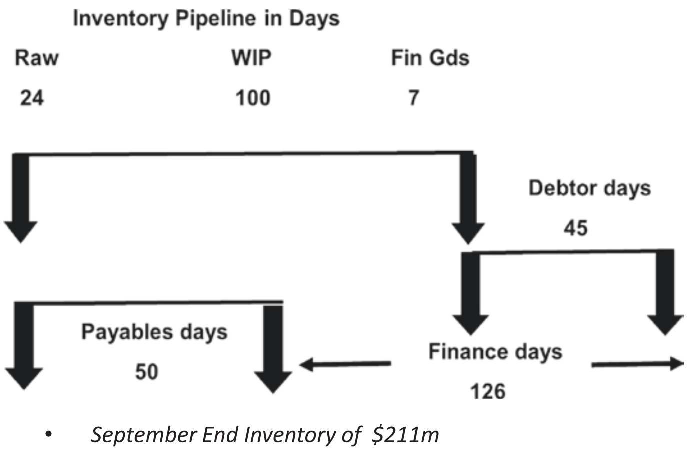

Fig. 5 Cash implications of inventory management payment terms

hands of the company itself. A typical challenging question arising from this chart would be "how big a queue do you need?".

5.3 Inventory Significance

One of the features of FA in manufacturing is the attention that is paid to Inventory and particularly to the work in progress and finished goods. Only capacity has can create work in progress and finished goods and so the level of both is a comment on how well the company is executing its capacity and how quickly or slowly the company reacts to changes to demands.

In the example is it clear that it takes approximately 100 days to build an aircraft body. Some of the production centres are working in parallel so the addition of each centre will not add to 100 days as a total.

The figure of 100 days is not so surprising in an "A" plant environment; these are characterised by deep bills of material with many components and sub-assemblies finally resulting in unique aero bodies. It can be seen from the supplementary charts that 100 days is reasonably representative.

Figures 6 and 7 complemented the BPFM and seek to draw attention to root cause analysis.

It is not unusual with long lead times that there are significant amounts of Obsolete Stock. If a new component is designed in an "A" plant, the business must ask itself whether it is going to rush through the engineering change and risk obsolescence of the materials already in production or wait 100 days for the new improvement to find its way into the product. This was the case in the aero business with a total provision of $12 million and quarterly movements of up to $0.9.

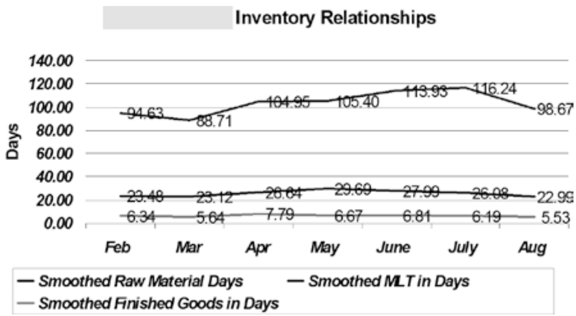

Fig. 6 Inventory relationships

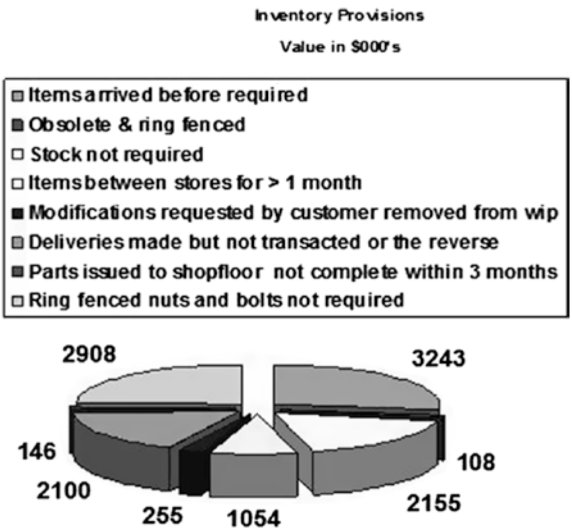

Fig. 7 Inventory provisions

6 Challenges

No production centre on the BPFM directly produces "Throughput"; they contribute either directly or indirectly to the components and sub-assemblies required for final assembly, which are the parts of the organisation that sell to the outside world. Only at the boundary walls where real money changes hands is "Throughput" created.

So the question became how do we judge which of these production centres offers the biggest opportunity?

A ranking system was devised as follows (Fig. 8).

The BPFM featured again for a "sanity check" looking to see whether anything else could distinguish the prioritisation of working in WC 5 versus WC 2 those centres that came out at the forefront of the ranking (Fig. 9).

Centre	Rank on Value of Inventory	Rank of Lead Time in Days	Rank of Op Ex per Month	Total
WC 5	1st	2nd	1st	4
WC 2	2nd	1st	3rd	6
WC 1	3rd	5th	2nd	10
WC 4	5th	3rd	5th	13
WC 3	4th	6th	4th	14
WC 6	6th	4th	6th	16

Fig. 8 Ranking of production work centres

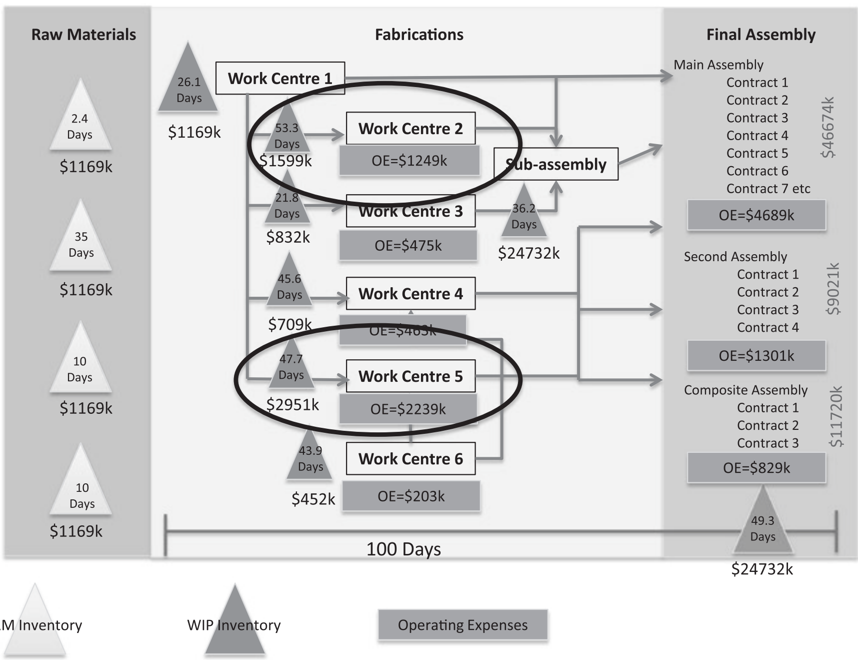

Fig. 9 BPFM with production work centres 2 and 5 *circled*

The fact that WC 2 feeds final assembly areas with significantly higher "Throughput" than WC 5 begged some further comparisons at a new level of detail.

Looking at the delivery performance of the two production centres to their respective assembly lines proved revealing and conclusive:

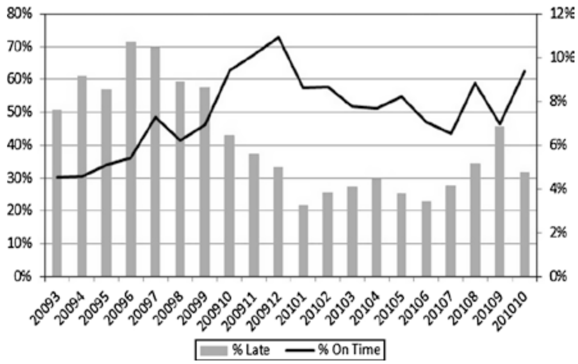

Fig. 10 Due date performance production centre 2

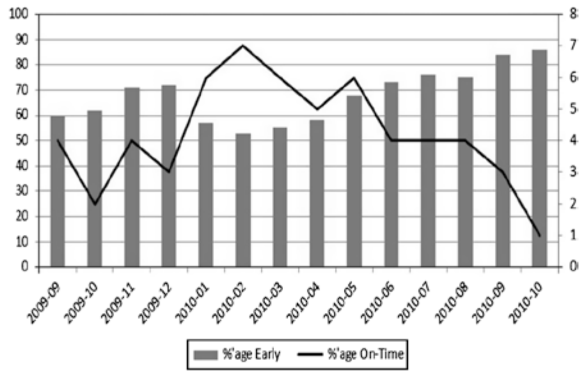

Fig. 11 Due date performance production centre 5

Production Centre 2 was late delivering much more that Production Centre 5 and in fact the latter was early and getting earlier. One might ask why Centre 5 is "pulling ahead" so far but the impact on final assembly of Centre 2 delivering late was judged much more significant. Figures 10 and 11 illustrate the due date performance of these two work centres.

7 Conclusions

Production Work Centre 2 was then studied in depth and eventually became the subject of a new initiative to introduce "pull" and gain responsiveness to their internal assembly customers. This initiative was concluded successfully with lead times halved releasing cash through inventory reduction and reducing the incidence of "shortages" in final assembly which moved from an average of "6 stops per week" to between "0 and 1 stop per week".

We recognise that no manufacturing company is going to take lightly the complete overhaul of its traditional accounting system, not least because it's part of the business environment which they can't change independently considering the financial accounting legal requirements arising from current product costing methodologies. However this case provides evidence that by using accounting and ancillary information at a "global level" and presenting it in a simple and innovative way it is possible to better guide decision makers to points of prioritisation that do impact the bottom line. Time and money are the two lowest common denominators in every organisation. In manufacturing companies the "time" element requires the organisation to describe its capacity and the "money" element requires a description of revenue and costs. In this short article the authors questions how well these important aspects are represented in the 21st Century.

ERP represents the current state of the evolutionary development of computing power via integrated, shared data systems for organisations. Their growth and adoption statistics are impressive. Often built on a centralized database and normally utilizing a common computing platform, ERP systems encompass all business operations into a uniform and enterprise-wide system environment. Unfortunately the authors would argue that they have effectively "institutionalised" redundancy of thinking at the installation phase by the repetition of a costing methodology more suited to the early 1900s than the 21st century.

Whilst it is popular today to discuss "culture change", the initiatives sprung from such talk are typically aimed at the shop floor and rarely embrace the question of the role of the FD. The authors would argue it is high time senior finance stopped playing the role of "administrator" of the costing module of their ERP system and reclaim management accounting information for decision making. ERP systems contain the data to allow decisions to appeal to common sense, be more logical and allow accessibility amongst many more levels than are inclined to engage today. The challenge is to get information systems to work like a human being rather than a dumb computer.

This case revolves effectively around supply chain prioritisation; the next phase of application of "pull" in the aerospace WC 2 also revealed the need for a different approach during the critical "transit period" between current and future states. This hinges around the need to show progress before the aspirations of the future state manifest themselves. Flow Accounting is pitched to be an assessment methodology completed periodically and giving a new voice to finance staff as providers of information which complement CI above and beyond the redundancy of "cost savings".

In conclusion, despite the emerging challenges, Flow Accounting and Big Picture Financial Mapping offer a way to reconcile some of the issues between Lean and Traditional management accounting. It is not suggested that one can replace the other at this stage, but Flow Accounting and Big Picture Financial Mapping offers Lean businesses a methodology to focus the improvements and to align their Lean implementation with bottom line results to drive the right behaviours.

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Changing an Organisation's Culture with Systems Thinking

A Case Study from the Financial Services Industry

Paul Bettle

Abstract This research has studied three aspects of a multi-method Systems Thinking intervention in a large Service Organisation. Firstly, an experiment studied its effectiveness in terms of changing the leaders in the organisation thinking. The second and third aspects looked at issues relating to success and sustainability of the programme, specifically, the major system conditions and the level in the organisation at which there must be an understanding and acceptance of Systems Thinking. Analysis of the experimental results showed that the intervention had started to cause a change in thinking, from command and control to systems thinking, in the experiment group relative to the control group. However, the change could not be shown to be statistically different between the beginning and end of the experiment. Observations made throughout the intervention identified two major systems conditions threatening the success and sustainability of the programme. The first system condition relates to multiple parties competing for the role of the customer across the organisation, e.g. the service user vs. shareholders, who are owned by different parts of the organisation. This results in different parts of the business having different, competing purposes. The second system condition relates to the link between business and individual measures in the current world, which are anchoring the organisation in the command and control way of thinking.

Keywords Systems thinking · Financial services · Culture change · Performance management · Multi-methodology · Multiple and conflicting purposes · Service industry

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1 Introduction

Over the past 15 years a large financial services organisation, in common with many other service based companies, has launched numerous improvement programmes using approaches such as Six Sigma and Lean through a central in-house improvement team. The earlier programmes did achieve some initial success, but did not sustain. Often unravelling as soon as the central team members moved on to their next assignment.

In the view of the researcher, these programmes fell into the trap of becoming all about implementing Lean tools, rather than seeing Lean as a Systems approach, and the delivery of value to the customer through embedding Lean principles and capability in the operations across the whole *end-to-end* value stream. As such, the programmes inevitably focussed on cost saving through driving transactional efficiencies in the customer facing operations.

The organisation has realised that it needs to move away from the tools based approaches of the past to take a more systemic view of organisational improvement. As such, a new programme was launched in September 2013, with Systems Thinking principles at its core.

The purpose of this research project is to establish if taking a whole system approach, rather than tools based, can help the programme to achieve its objectives, and to establish if there are any other factors (system conditions) outside of the programme design that directly impact its potential success and sustainability.

The programme design has two complimentary elements that combine multiple systems approaches. This is something of an experiment in itself, as these two particular practitioner based approaches have not been combined in this way. However, the researcher believes there is a strong theoretical basis for doing so. The first element involves the redesign the end-to-end core customer journeys from the top down. Whilst at the same time, the second element will focus on changing the thinking of frontline leaders and building the capability of the organisation from the bottom up.

The core systems approach to be used across both elements in the intervention will be the Vanguard Method. According to Seddon (2005), it is the current thinking or logic in an organisation that drives the design of that system. The design of the system in turn will determine how well that system performs. Therefore, unless you can change the thinking of those responsible, in order to design a better system, the performance will not improve (see Fig. 1).

Seddon (2005) calls the current way of thinking in western management 'Command and Control Thinking'. Command and Control does not mean being bossy, it means separating decision making from the work (Seddon 2013). Command and Control Thinking is contrasted with Vanguard's Systems Thinking in Fig. 2.

Quite often in a System, certain less powerful groups are often ignored and do not necessarily have their voices heard. Giving these groups a voice is known as emancipation. This is one of the objectives of the second element of the

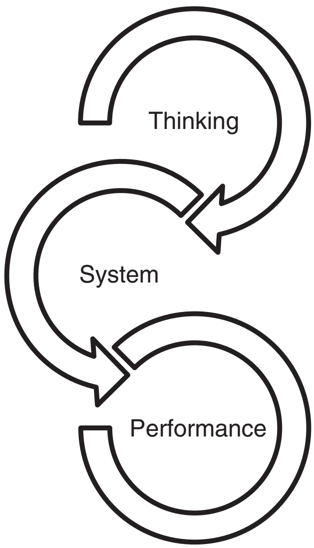


Fig. 1 Vanguard's thinking-system-performance framework. Adapted from Seddon (2005)

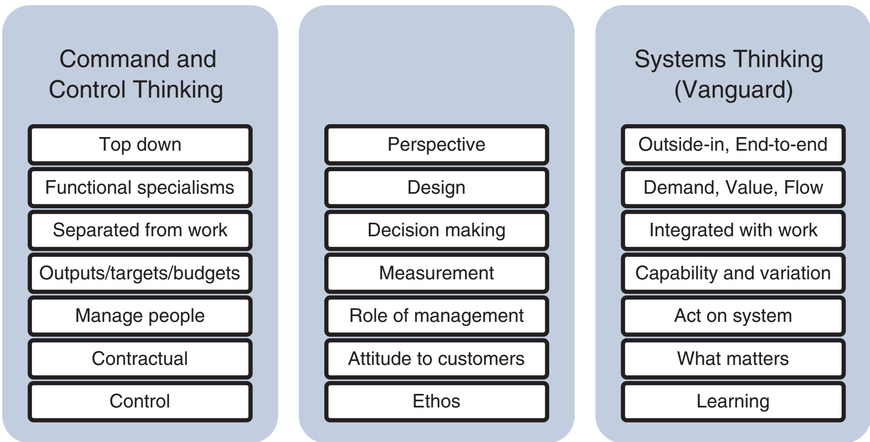


Fig. 2 Command and control versus systems thinking. Adapted from Seddon (2005: 11)

programme, as it will give a voice to the frontline leaders in the organisation. Typically, in the past, their roles and responsibilities, measures and work design are handed down to them to execute with no input from themselves. During the second element of the programme, the frontline leaders will study the work in their areas and reflect on what their roles should be and how they could better measure the work their teams are doing.

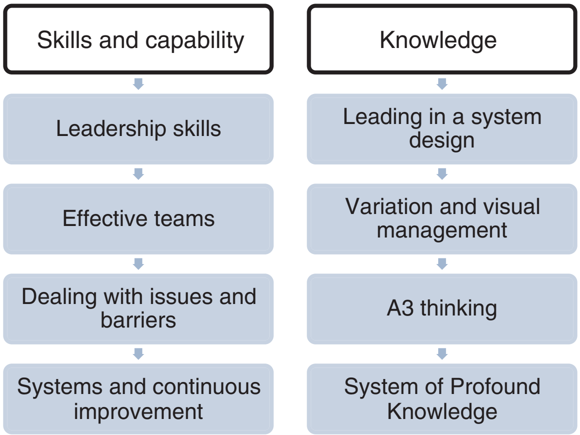


Fig. 3 Components of the skills, capability and knowledge uplift for frontline managers

As they will not get the skills to do this from the Vanguard Method alone, another complementary Systems Approach, based on action learning, will be run in parallel which will focus on building the skills, capabilities and knowledge of these frontline leaders (see Fig. 3).

2 Research Project

A controlled experiment was conducted within the intervention to establish if a direct link could be made between the intervention and any measurable change in thinking that may occur during the intervention.

More specifically, this research project set out to answer the following research questions, described in Sect. 2.1, and to achieve the objectives described in Sect. 2.2.

2.1 Research Questions

- To what extent will a whole organisation, multi-method approach to the implementation of a systems thinking intervention, from the top down and the bottom up, change the way managers and frontline leaders think about their business; specifically in terms of the role of a leader, measures and targets and capabilities?
- At what level in the organisation must there be an understanding and acceptance of the counter-intuitive dimensions of Systems Thinking in order increase its likelihood of success?
- To what extent do current system conditions and thinking inhibit the successful deployment of Systems Thinking?

2.2 *Research Objectives*

- To establish the critical success factors of a Systems Thinking intervention.
- To identify opportunities to improve the current methodology for future interventions across the wider organisation.
- To understand the barriers to a successful Systems Thinking implementation.
- To understand how measures can be used to change management thinking.

3 Literature Review

3.1 *What Is a System?*

According to Deming (1994: p. 50), one of the original *Systems Thinkers,* a system is *a network of interdependent components that work together to try to accomplish the aim of the system.* Figure 4 shows Deming's famous diagram of an organisation represented as a system. The system must have an aim, or a purpose. All the components of the system will contribute to achieving the purpose of the system, but none of the parts on their own can achieve that purpose. A popular analogy is that of a car as a system, whose purpose is to transport people from one location to another. None of the individual components of the car, such as the engine or chassis, can achieve this purpose on their own; they must work together as a system to do so (Scholtes 1998). The properties the system exhibits are that of the whole rather than those of the individual components (Checkland 1981).

Jackson (2003) identifies six different types of system:

- Physical
- Biological
- Designed
- Abstract (Checkland 1981 describes this as designed abstract)
- Social
- Human activity

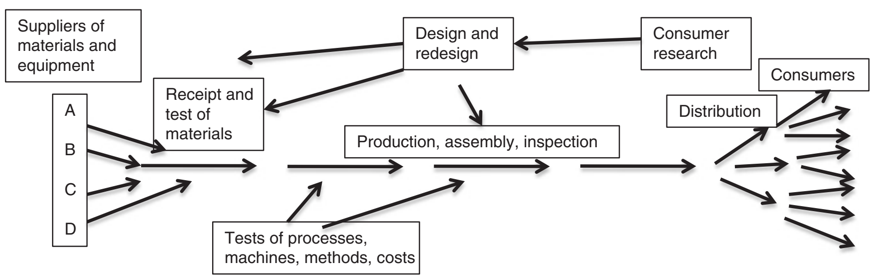


Fig. 4 Production viewed as a system. Adapted from Deming (1982: 4)

3.2 Systems Thinking Approaches

Checkland (1981) describes Systems Thinking not as a discipline in its own right, but rather a way of thinking about a problem. This way of thinking is centred on two themes:

- Emergence and Hierarchy—in a system exists *organised complexity*. A system contains a hierarchy of complexity, described as levels, the highest level being the most complex and each level being more complex than the next level down. Emergence refers to the properties seen at each level in the hierarchy. Properties emerge at each level that cannot be seen in the level below.
- Communication and Control—a complex hierarchy of levels within an open system must have a process of *communication and control* in order to detect and react to changes in its external in internal environments.

A major split in Systems Thinking approaches started to emerge during the 1970s to deal with the complexities inherent in organisational systems and the multiple purposes held by the human social systems that exist within them.

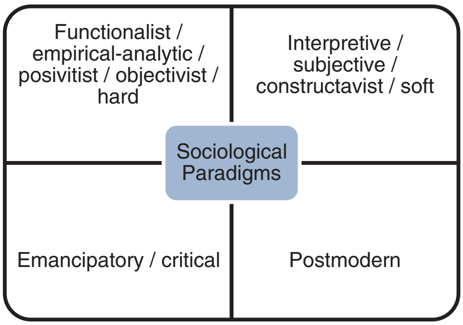
Interestingly, Systems Thinkers seemed to split along the lines of either dealing with complexity or dealing with multiple purposes, not both, whilst at the same time academics continued to develop Hard Systems ideas in various Universities (Jackson 2003). Systems Thinkers also tended to anchor themselves to, and develop their approach within, a particular sociological paradigm, described in Fig. 5 (Jackson 2003; Mingers and Broklesby 1997; Checkland 1981).

Jackson also illustrates this split in terms of problem contexts as shown in Fig. 6. The approaches that emerged during this time tend to fit into one of these boxes, that is, those developing the approach make an assumption that the box can describe an organisation.

These approaches have continued to be developed along these lines to present day. They do not cross over, either vertically or horizontally, into other contexts, or other paradigms. Indeed, most approaches have their own academic journal aligned to it. The effect has been to take them further and further apart.

The main approaches developed in the academic world are shown in Fig. 7.

Fig. 5 Sociological paradigms



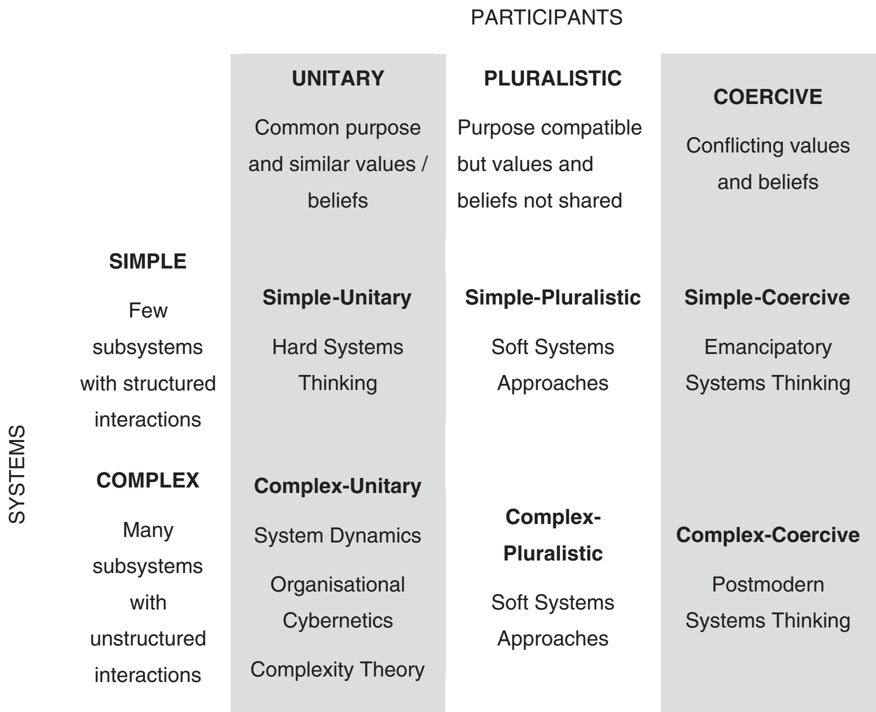


Fig. 6 Jackson and Keys grid of problem contexts. Adapted from Jackson (2003: 18, 24)

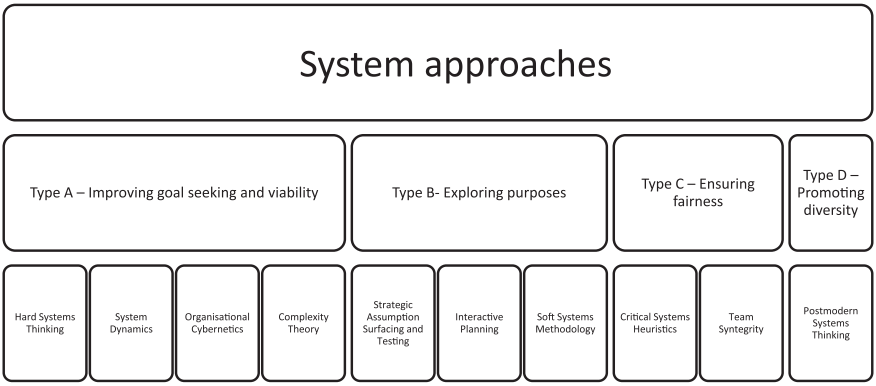


Fig. 7 The main systems thinking approaches organised by type. Adapted from Jackson (2003: xxiii)

3.2.1 The Vanguard Method

Deming (1982) believes that it is necessary to study the whole system in order to be able to make it better for customers, a view strongly shared by Seddon.

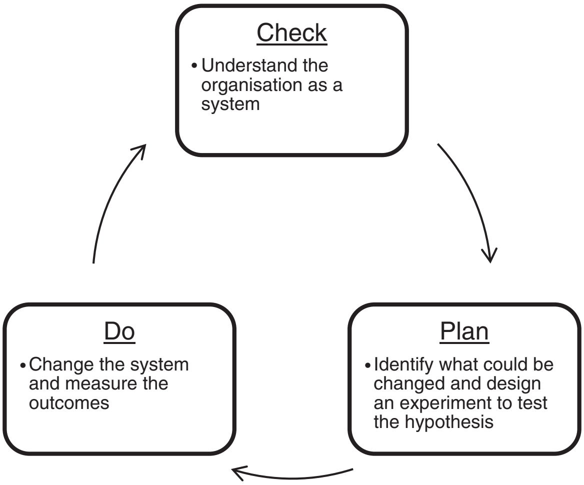


Fig. 8 The Vanguard approach to service improvement. Adapted from Seddon (2005: 110)

Figure 8 illustrates the Vanguard Consulting approach to service improvement, developed by Seddon. This review will just focus to the check stage (see Fig. 9) in more detail, as this is the main area of focus for this research. The 'check' approach is summarised in Table 1.

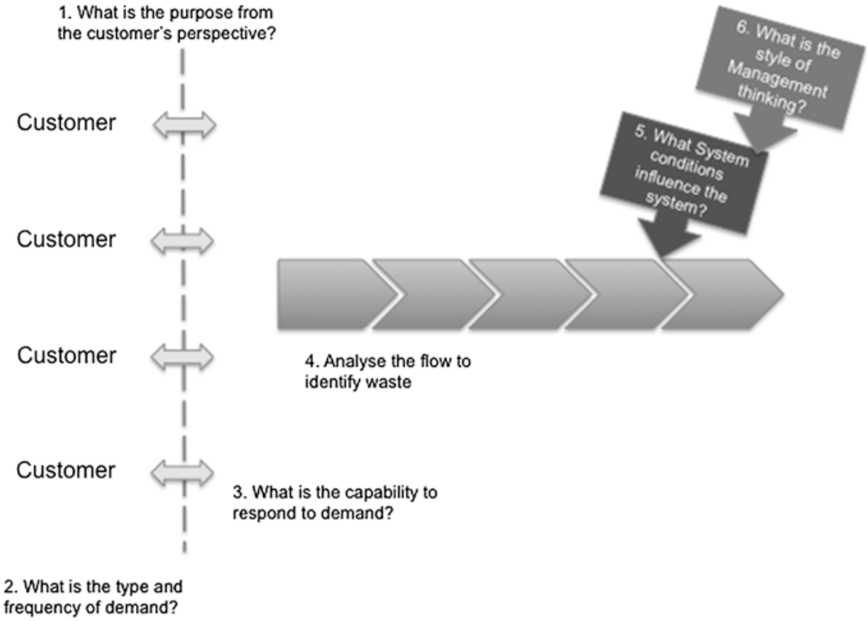


Fig. 9 The Vanguard 'check' method. Adapted from Seddon (2005: 112)

Table 1 The Vanguard model for check

Step	Overview
Step one—understand purpose from the customer's perspective	Seddon (2005) argues that you must first understand the customer's purpose before you can determine how best to deliver a service to them. As a consequence of not understanding the purpose organisations will likely have measures that are aligned to business objectives and not around delivering customer purpose. The achievement the measures (targets) becomes the purpose of the organisation (Seddon 2005). Stepping back and looking at purpose helps to keep the view of the whole system and helps to avoid the sub-optimisation of its parts (Bicheno 2008)
Step two—understand the type and frequency of demand	The customer purpose is used to determine which demands are value and which are failure. Value demand is demand that meets the customer's purpose; it is demand that they want to initiate. Seddon (2005) defines failure demand as '*a failure to do something or do something right for the customer*'. The level of failure demand that an organisation is experiencing is an indication of the amount of unnecessary work in the organisation
Step three—understand the capability of the organisation	Deming (1982) talks at length about management's failure to understand the variation of the system. To understand if the organisation can respond to demand in a predictable way, a measure must be identified that is aligned to the customer's purpose
Step four—understand the flow	Flow is particularly important to customers in a service. They will experience any interruption to flow that results in a delay first hand, giving them a negative perception that is hard to recover from and will likely result in failure demand
Step five—understand system conditions	System conditions are the underlying causes of waste. They have a profound effect on the way an organisation behaves. System conditions come from an organisations: • Policies, processes and procedures • Measures, targets and performance management • IT systems • Organisational structure
	Seddon considers measures the most important system condition. Spitzer (2007) describes measurement as the lens through which the performance of the organisation is viewed, thus making it *the most fundamental management system upon which other management systems are based.* Therefore if the measurement lens is focussed on the wrong things, bad decisions will be triggered in all of the other management systems. But this is not the only issue with measuring the wrong things; according to Kohn (1993) measures will impact the way in which people do things. This is because they supersede any other motivations that a person might have, consequently they change the *attitude* a person takes towards the work that they are doing
	A reward will often increase the likelihood of us doing something, but more often than not, it changes the way in which we do it, usually for the worse, and is only effective in the short term (Kohn 1993). Seddon (2005) observes that imposed targets will almost certainly result in employees using their ingenuity to 'game' the system in pursuit of achieving the target. This is something that the researcher has witnessed occurring right up to the senior levels in the operation during the research. The senior managers are aware that it is happening, but feel they have little choice given the pressure they are under to achieve the targets. This starts to explain why it is given so much attention when an SLA is breeched

(continued)

Table 1 (continued)

Step	Overview
	Deming (1982) defined seven deadly diseases that are prevalent in western organisations. The third deadly disease relates to the *evaluation of performance*, *merit rating or annual reviews*. Any performance management system that is centred on management by objectives and numbers will lead to the following issues: • A focus on short term delivery at the expense of long term planning • A demotivated workforce
Step six—understand management thinking	An organisations culture is a reflection of the beliefs of management (Bicheno 2008). Is the management focus on fulfilling a purpose relating to the business or is it on meeting the customer purpose?

Jackson (2009) acknowledges that whilst the Vanguard Method has not been widely reviewed by academics, it is having considerable success in practice, particularly in the UK Public Sector. Jackson et al. (2008) argues that the Vanguard Method may encounter problems when trying to define the purpose of the system when presented with multiple parties, completing for the role of customer. The Vanguard Method does not take account of these competing world views and variety of purposes that this may result in. Jackson et al. (2008) further argues that there is a risk that the Vanguard Method allows the optimisation of a sub-system without understanding if this might sub-optimise the wider system. Jackson et al. (2008) concludes that the Vanguard Method is essentially a hard systems approach, when assessed on the System of System Methodology framework (see Fig. 10), but has the ability to deal with complexity and some pluralist concerns, leading him to suggest that methodology expansion could be a viable alternative to Multi-methodology.

3.3 Combining Different Systems Approaches, in Theory and in Practice

3.3.1 Combining Systems Approaches in Theory

This section will review the literature to try and identify if there is a theoretical basis to support the combining Systems Approaches, and if so, how it should be undertaken. Mingers and Broklesby (1997: p. 491) describes the possible ways in which Systems Approaches can be combined (see Table 2).

Systems Approaches developed in the academic world tend to be aligned to a particular paradigm and the set of assumptions that underpins the thinking within that paradigm. There has been much debate amongst academics relating to the constraints of *paradigm incommensurability* preventing the ability to combine

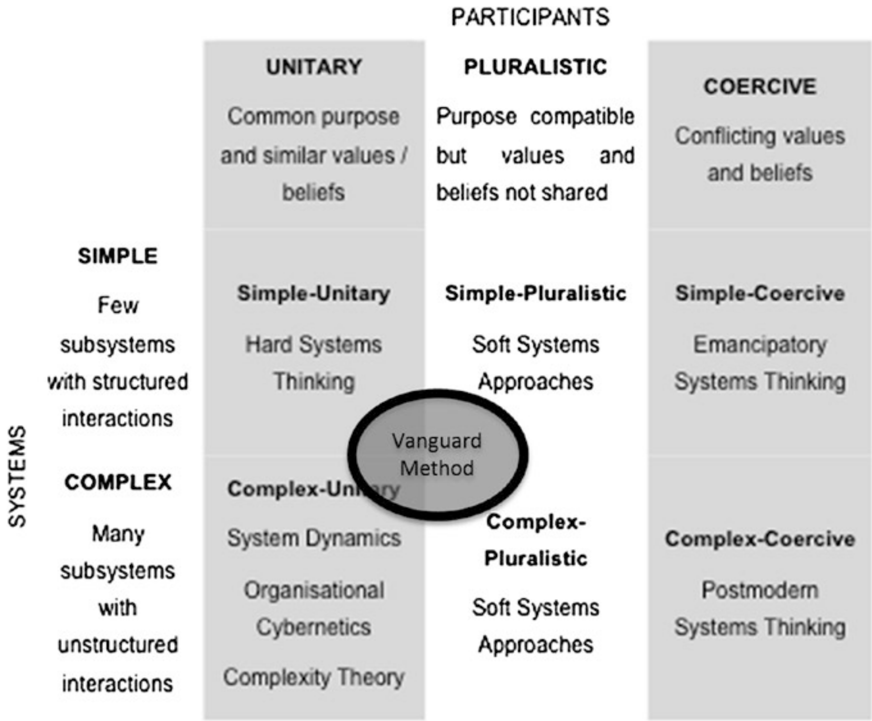


Fig. 10 The Vanguard method assessed on the SOSM. Adapted from Jackson et al. (2008: 196)

Systems Approaches (Mingers and Broklesby 1997; Kotiadis and Mingers 2006). The argument being that the theoretical logic and assumptions inherent within the paradigm, upon which the different approaches are built, are in incompatible because of their different world views and cannot be reconciled (Mingers and Broklesby 1997; Jackson 2003). Shepherd and Challenger (2013) found the use of paradigms and the concept of paradigm incommensurability to still be widespread in management research.

A second challenge to combining Systems Approaches relates to cultural feasibility. That is the experiences of the practitioner using the approaches and their assumptions about the world (Mingers and Broklesby 1997; Kotiadis and Mingers 2006). If a practitioner's experience and training is predominately rooted in a particular paradigm, they may find it difficult if they have to then operate in another when using a different approach.

Another challenge is the cognitive feasibility. Practitioners will have different personality types that will naturally have a preference for a particular approach and operating within a particular paradigm.

Table 2 Options for combing systems approaches

Name	Description	Multiparadigm?	Example
Methodological isolationism	Using only one methodology from only one paradigm	Single	Soft systems methodology only or operational research only
Methodology enhancement	Enhancing a methodology with techniques from another	Single	Cognitive mapping used in Soft systems methodology
		Multiple	Jackson systems development used in soft systems methodology
Methodology selection	Selecting whole methodologies as appropriate to particular situation	Multiple	Using a Hard approach in one situation and Soft systems methodology in another
Methodology combination	Combining whole methodologies in an intervention	Multiple	Using interactive planning and the viable systems model
Multi-methodology	Partitioning methodologies and combining parts	Single	Using cognitive mapping, root definitions, commitment packages
		Multiple	Using cognitive mapping and systems dynamics

Adapted from Mingers and Broklesby (1997: p. 491)

A System of Systems Methodologies

Jackson and Keys (1984) started to explore the idea of combining Systems Approaches as long ago as early 1980s. They discovered that particular approaches, rather than competing to be used for general problem solving and trying to claim they can solve any problem, they should limit their use to the context for which they are best suited. From this analysis, they derived what they term a System of Systems Methodologies.

Jackson (1990) describes how the System of Systems Methodologies might be used in the real world to select an appropriate methodology. Jackson recognises the limitations of this approach in the paper, questioning how many real world problems will neatly fall into one of the resulting contexts and to what extent coercion will affect the decision made. Jackson argues that the System of Systems Methodologies can be used to highlight the relative strengths and weakness of the various Systems Approaches. Jackson argues that this also allows problems to be considered using different perspectives and as such problem contexts, this would also mean opening the way for using different Systems Approaches to tackle the same problem, although he does not go as far as to say approaches could be combined.

Jackson's Critical Systems Thinking (Creative Holism) and Total System Intervention

Critical Systems Thinking aims to achieve three goals (Beckford 2002):

1. Complementarism—different problems may require different approaches to solve them. Critical Systems Thinking requires the *most appropriate* approach be used to solve a problem, but with the awareness of the theory and assumptions associated with that approach.
2. Sociological awareness—recognition that the culture of organisations is different and will change over time. This must be considered when selecting an appropriate approach for an intervention.
3. Emancipation—supports an inclusive approach and frees people from existing constraints.

Jackson (2003; p. 283) cites Habermas as arguing that humans have two conditions underpinning their lives:

1. Work—humans achieve satisfaction through working. They have an inherent 'technical interest' in *predicting and controlling* the systems in which they operate.
2. Interaction—humans seek to gain the *mutual understanding* of those operating in the system, said to be a 'practical interest'.

Equally important, according to Habermas, is the understanding of the use of power within a system, which can prevent gaining a proper understand of work and interaction due to inadequate engagement of those involved. Humans operating in a system will naturally seek to be engaged and to break out of the constraints of power, this is described as having an 'emancipatory interest'.

This led Flood and Jackson to argue, in their 1991 book (cited in reference list although not available to these researcher), that the different systems approaches can in fact be aligned to each of the three human interests identified by Habermas (see Fig. 11), and that the human interest level sits above that of paradigms thus overcoming the challenges imposed by paradigm commensurability.

Total Systems Intervention is the meta-methodology by which Critical Systems Thinking is put into practice. It encourages looking at problems from a number of

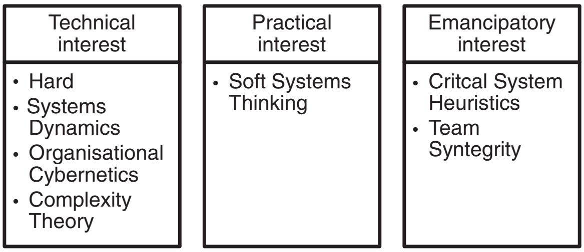


Fig. 11 Aligning systems approaches to Habermas human interests. Adapted from Jackson (2003)

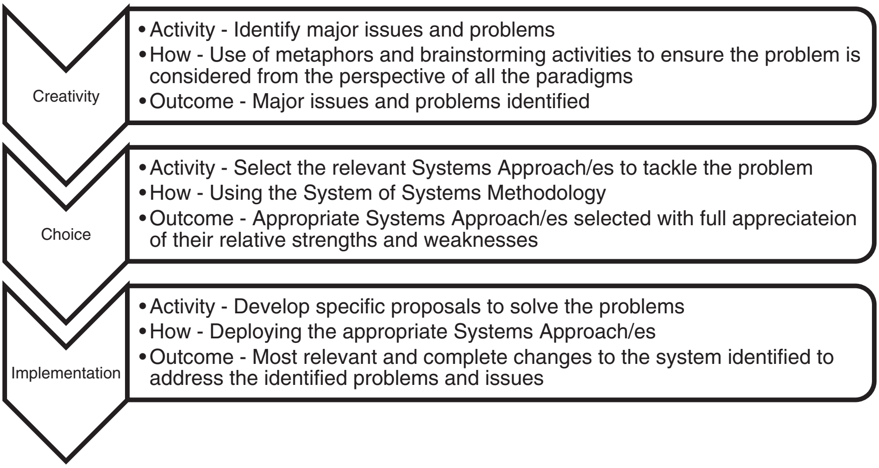


Fig. 12 Total system intervention methodology. Adapted from Jackson (2003, 2006)

different perspectives, using metaphors as a guide, in order to aid the selection of the appropriate Systems Approach or set of Approaches that are most suited to that particular problem. Total Systems Intervention has three phases called Creativity, Choice and Implementation. The three phases are outlined in Fig. 12.

Ulrich's Critical Systems Thinking—Critically Systemic Discourse

Ulrich (2003) believes that Jackson's interpretation of Critical Systems Thinking and the Total Systems Intervention methodology does not deal adequately enough with the emancipatory issues. Firstly, the methodology forces a choice as to whether or not to include an emancipatory approach in the analysis of a problem. Secondly, the System of Systems Methodology isolates the emancipatory approaches to purely coercive problem situations. Ulrich argues that most real world situations will in fact be coercive.

Ulrich prefers not to think of situations in terms of either being coercive or non-coercive, but rather as a range of discourse situations in which there will be a varying distortion/asymmetry of power.

Ulrich also believes there is a general misunderstanding relating to Habermas concept of emancipatory interest. If interpreted from an ideological stance, it would suggest that the role of a practitioner is to favour, and stand up for, groups that they determine to be somehow disadvantaged. Ulrich argues that this is not how Habermas uses the term. He in fact uses the term from a methodological perspective in terms of securing a discourse in which the participants involved have an equal opportunity to be heard.

Ulrich instead suggests that emancipatory interest should be elevated to the critical level thus making it integral to any intervention.

Table 3 The five principles of critically systemic Discourse

Principle	Overview
Discourse	Promotes a discourse-theoretic framework
The role of civil society	All participants in a system are provided with numerous opportunities to raise concerns to avoid bias on choice of methodology
Emancipatory orientation	Moves emancipatory interest from ideology to methodology and away from being a choice to being a core principle
Systemic boundary critique	Challenge the validity of solutions through critical review of system boundary judgements
Deep complementarism	Emancipatory interest and system boundary critique are raised to the critical level and not subordinated to a methodological choice

Adapted from Ulrich (2003)

Ulrich proposes that Critical Systems Thinking needs to make the conceptual step to Critically Systemic Discourse. He sets out five principles of Critically Systemic Discourse, which are described in Table 3.

Mingers' Multi-methodology

Mingers and Brocklesby (1997), Mingers (2001) present four arguments as to why combining different Systems Approaches is not just desirable, but also necessary. In his first argument, he describes working in only one paradigm as like looking through a particular instrument, such as telescope or an MRI scanner. Each will reveal something completely different that the other cannot. Unfortunately, in the real world it not like this, it is in fact multi-dimensional. When you apply a single approach from a particular paradigm to a real world problem situation, it would mean you would only understand the problem from one perspective. Mingers and Brocklesby (1997) have developed a framework, based on the work of Habermas and also that of Searle, to show three dimensions that will all exist in a real world problem; this framework is illustrated in Fig. 13.

The second argument put forward by Mingers and Brocklesby looks at intervention as a process. The basis of this argument is that any intervention will go through multiple stages (see Fig. 14). Each stage will have different activities as part of it. Mingers and Brocklesby argue that it is not likely a single approach will

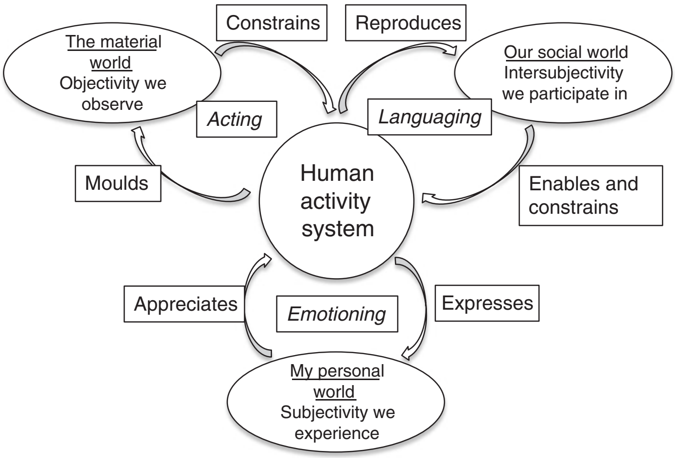


Fig. 13 Three dimensions of problem situations. Adapted from Mingers and Brocklesby (1997: 493)

Fig. 14 Stages of an intervention. Adapted from Mingers and Brocklesby (1997)

adequately cover all of these stages and their associated activities, some will be better at on particular stage and set of activities and vice versa. As such, combining different approaches would result in a much more complete intervention.

The third argument put forward by Mingers and Brocklesby is that practice is already well ahead of the theory relating to the combining of Systems Approaches. There are now numerous examples of a combination of different Systems Approaches having been successfully applied in solving real world problems.

The final argument Mingers and Brocklesby use in support of combining Systems Approaches is the relationship to postmodernism, which fundamentally challenges established ways of thinking. Postmodern thinking would support the idea that combining approaches should not be constrained by current theoretical barriers.

Rather than accept paradigm incommensurability as a given Mingers and Brocklesby cite research that suggests there is no obligation to adhere to it. For example, the work of Weaver and Gioia (1994), Giddens (1984) questions the validity of the claims relating to paradigm incommensurability based on the objective and subjective paradigms being mutually exclusive. Shepherd and Challenger (2013) have found grounds to reject the concept of paradigm incommensurability and find strong arguments to support *paradigm pluralism.*

	Appreciation of	Analysis of	Assessment of	Action to
Social	Social practices, power relations	Distortions, conflicts, interests	Ways of altering existing structures	Generate empowerment and enlightenment
Personal	Individual beliefs, meanings, emotions	Differing perceptions and personal rationality	Alternative conceptualisations and constructions	Generate accommodation and consensus
Material	Physical circumstances	Underlying causal structure	Alternative physical and structural arrangements	Select and implement best alternatives

Fig. 15 Mingers framework for mapping systems approaches (Mingers and Brocklesby 1997: 501)

Mingers and Brocklesby (1997) have developed a matrix with the three dimensions of problem situations on one axis and the stages of the intervention on the other (see Fig. 15). In each box on the matrix there are questions relating to that particular stage and dimension that must be addressed. This matrix can then be used to assess the relative merits and weaknesses of each Systems Approach in addressing the various questions posed.

Mingers and Brocklesby state that this should not be a one off exercise, but should be done in consideration of the problem situation being addressed.

3.3.2 Combining Systems Approaches in Practice

One of the main drivers for the development of the theory to support the combining of different Systems Approaches was that it was already being done in practice, leaving the theory behind to some extent (Munro and Mingers 2002).

Munro and Mingers (2002) conducted research to try to establish the extent to which Systems Approaches are being combined in practice. The authors concluded, from the examples in the research, that combining systems approaches in practice has been relatively successful. They also found:

- Few examples where Hard and Soft approaches had been brought together.
- Combinations of approaches chosen tended to reflect the background of the practitioner in terms of experience and education.
- Relatively little data as to why and/or how the various combinations of approaches were arrived at.

3.3.3 New Thinking

Zhu (2010) believes the link between systems approaches and paradigms is no longer useful, and may even be holding the field back from making significant advances. Zhu cites significant evidence to support this stance. Particularly given that there are now multiple examples of practitioners ignoring so called paradigm incommensurability in the real world. Zhu further argues that is now necessary to move beyond creating multi/meta method frameworks that attempt to solve the paradigm constraints. Instead, Zhu (2010) suggests a pragmatist approach needs to be adopted.

4 Methodology

This research project has adopted the pragmatist philosophy. This philosophy encourages the use of whatever methodological choice best helps to answer the research questions (Saunders et al. 2012). In the case of this research project, both quantitative and qualitative research was required in order to answer the research questions satisfactorily.

The Vanguard Method, one of the systems intervention approaches being used in this research project, is arguably a form of ***action research*** in its own right. However, because this research project is trying to establish a link between sets of variables, independent of trying to actually make improvements in the business (which is the main aim of the intervention) in which the research project is operating, a ***classical experiment*** was run within the intervention.

The experiment (see Fig. 16) included the group involved in the intervention (the experiment group) and a control group who performed a similar function in the organisation, but were not involved in the intervention. The experiment group was further broken down into a core-team who were involved in the check phase and capability building element of the intervention, and the non-core team who were just part of the capability building element of the intervention. The experiment collected quantitative data, from both an experiment group and the control group, in order to attempt to establish the answer to the first research question and establish if there is a link between the intervention and a change in thinking. A questionnaire was designed to investigate opinion variables relating to how thought about a subject, in this case if the participants thinking was more aligned to Command and Control or Vanguards Systems Thinking (see Fig. 2).

The experiment also collected qualitative data, through direct observation and informal interviews in order to answer the remaining questions. Because of

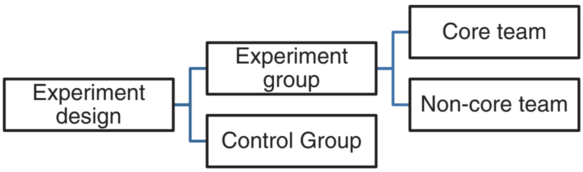


Fig. 16 The experiment design

the author's role of practitioner in the intervention, the author felt it might also be useful to provide additional context and insight through presenting these in a ***Narrative*** strategy.

5 Analysis and Discussion

5.1 Results

Prior to commencing the intervention, it was important to establish the current thinking within each of the three groups and to identify if there was any measurable difference between them. As such, the members of each group were asked to complete the experiment questionnaire in the week before the intervention started. This data, illustrated in Fig. 17, will then form a baseline against which any changes of thinking can be measured at the end of the 'check' phase of the intervention.

Figure 17 shows that, visually at least, each of the different groups has answered the questions in much the same way. Three two sample t-tests (see Fig. 18), assuming equal variances, have been completed for each question, to test if there is a difference in means between each of the groups. The results for the t-test show, that for all questions, there is statistically no difference between the group's answers.

Although the t-tests demonstrate that there is no statistical difference between the groups, there are still some interesting observations that can be drawn from the data. Table 4 shows the mean answer for each of the experiment groups and the control group.

The results clearly indicate that there is a strong preference towards command and control thinking across all of the groups. There is a particularly strong preference for command and control thinking relating to measures.

5.1.1 End of 'Check' Phase (Week 6)—Has the Thinking Changed?

At the end of the 'check' phase of the project, which fell at around six weeks from the start of the intervention, each of the groups was given the same questionnaire to complete. The overall results are summarised in Fig. 19 and Table 5, which show the average answer for each question for each of the experiment groups.

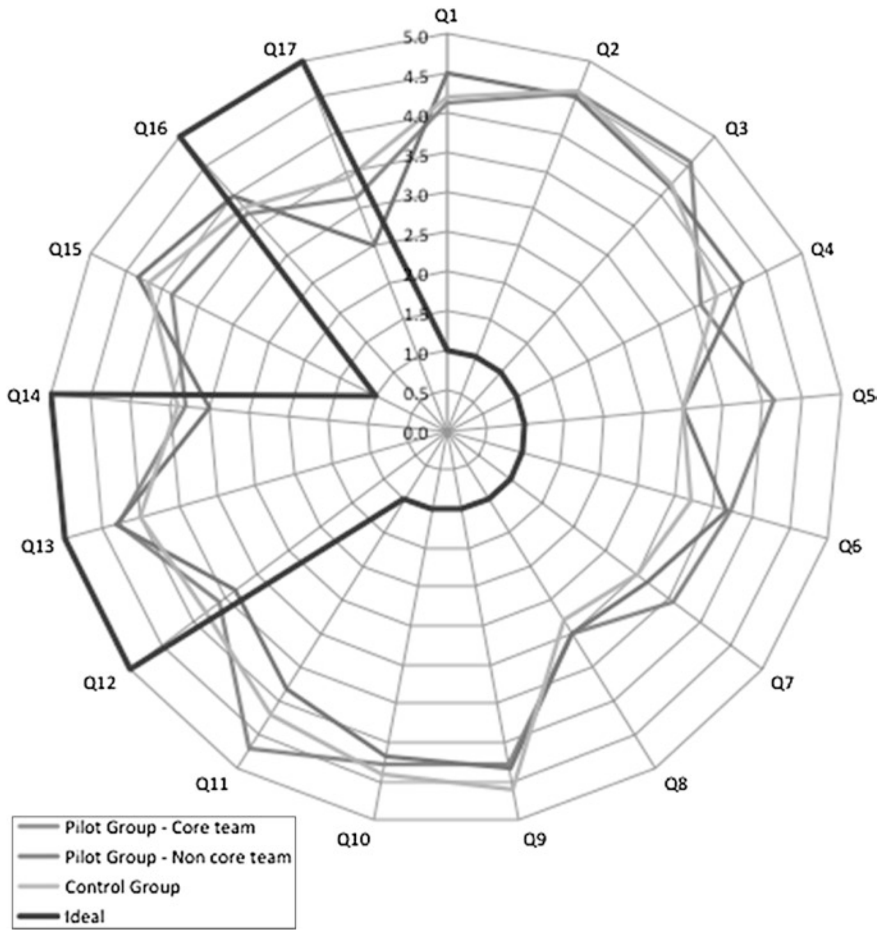


Fig. 17 Diagram showing the average answer for each group and an ideal 'systems thinking' response pre-intervention

Fig. 18 Two sample t-test combinations completed

Table 4 Table showing the average answer for each of the experiment groups pre-intervention

Group	Question																
	Questions relating to measures								Questions relating to the role of a leader					Questions relating to management of change and capability			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Pilot group—core team	4.1	4.6	4.6	3.6	4.1	3.7	3.6	3.0	4.3	4.3	4.7	3.6	4.3	3.3	3.9	3.7	3.1
Pilot group—non core team	4.5	4.5	4.2	4.2	3.0	3.7	3.2	3.0	4.3	4.2	3.8	3.3	4.3	3.0	4.3	4.0	2.5
Control group	4.2	4.6	4.2	3.8	3.0	3.2	3.0	2.8	4.6	4.4	4.2	3.8	4.0	3.4	4.2	3.8	3.4
Grand total	4.3	4.6	4.3	3.8	3.4	3.6	3.3	2.9	4.4	4.3	4.3	3.6	4.2	3.2	4.1	3.8	3.0

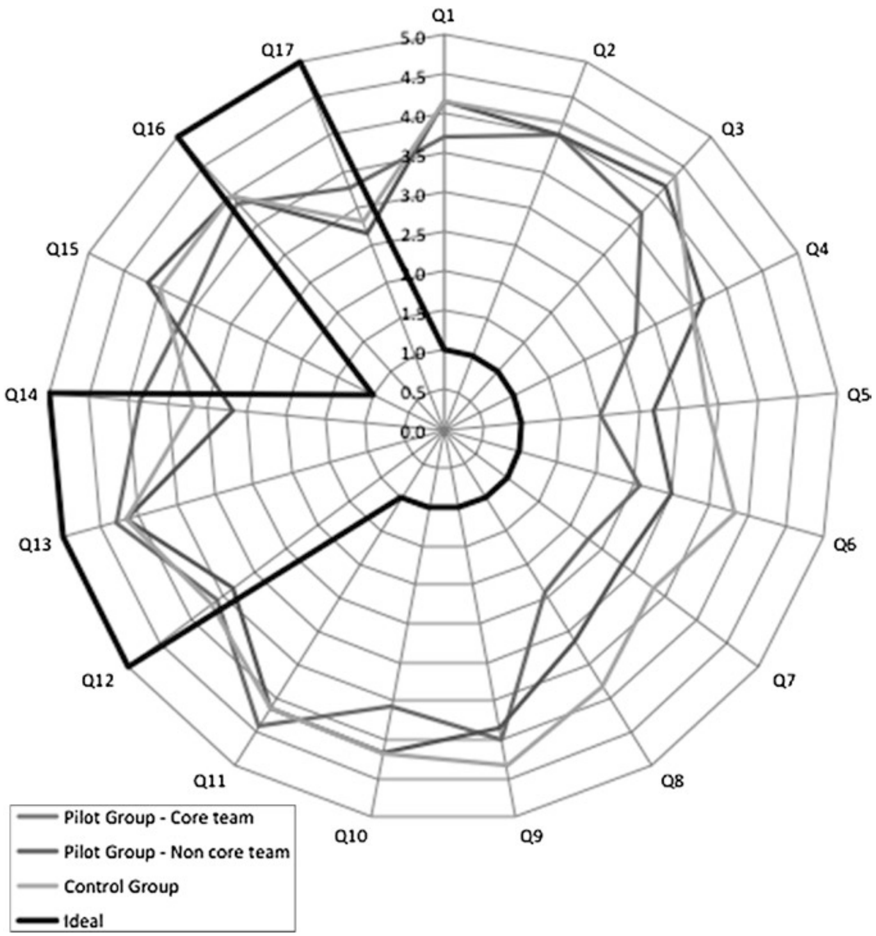


Fig. 19 Diagram showing the average answer for each group and an ideal 'systems thinking' response at the end of the 'check' phase (week 6)

5.2 *Summary*

This experiment set out to answer the first research question from Sect. 2.1.

The hypothesis being tested was:

- The multi-system approach will cause a measurable change in thinking from command and control thinking to systems thinking specifically relating to:
  - Measures
  - The role of a leader, and
  - Skills and capability

Table 5 Table showing the average answer for each of the experiment groups at the end of the 'check' phase (week 6)

Group	Question																
	Questions relating to measures								Questions relating to the role of a leader					Questions relating to management of change and capability			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Pilot group—core team	3.7	4.0	3.7	2.7	2.0	2.6	2.3	2.4	4.0	3.6	4.4	3.6	4.3	3.9	3.6	3.9	3.3
Pilot group—non core team	4.2	4.0	4.2	3.7	2.7	3.0	2.8	3.2	3.8	4.2	4.2	3.3	4.2	2.7	4.2	4.0	2.7
Control group	4.2	4.2	4.3	3.5	3.3	3.8	3.3	3.8	4.3	4.2	4.2	3.7	4.2	3.2	4.0	4.0	2.8
Grand total	4.0	4.1	4.1	3.3	2.6	3.1	2.8	3.1	4.1	3.9	4.3	3.5	4.2	3.3	3.9	3.9	2.9

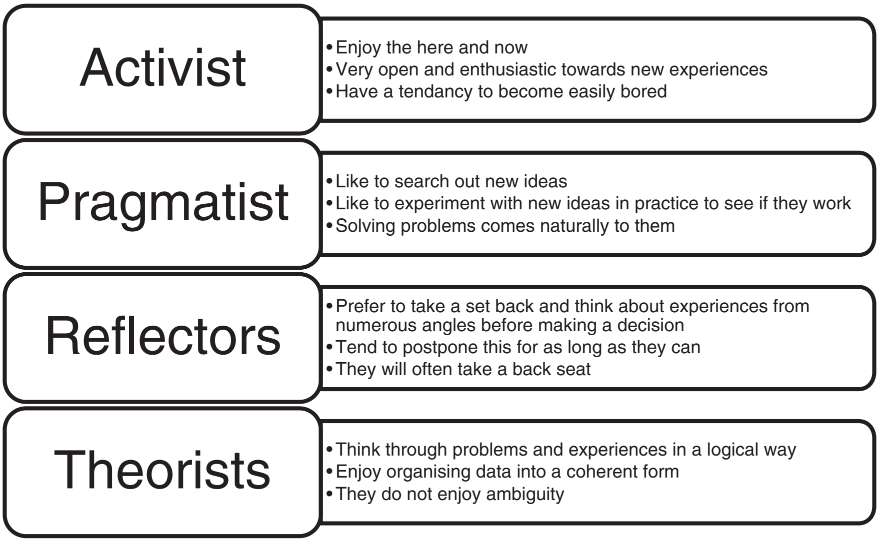


Fig. 20 Honey and Mumford's learning styles. Adapted from Honey and Mumford (2000)

Despite the core team showing signs of their current thinking changing, or at least being challenged, this research has found that the hypothesis has not been statistically proven for any of the aspects above.

A big factor in this is the variation in answers given by the group. This suggests that the intervention is having a bigger impact on some members of the group than others in terms of challenging their thinking, and as such their thinking has changed more quickly.

The fact that the changes in thinking are potentially happening more quickly in some members of the core team could be a reflection on their individual learning style. During the intervention, the core team's learning styles were assessed using Peter Honey and Alan Mumford's model. This model identifies four styles, for which any individual will have a natural preference. The four styles are described in Fig. 20.

The core team is made up predominantly of Activists and Reflectors. Perhaps unsurprisingly, it is the activists who have made the quickest and also the biggest shift from command and control thinking to systems thinking. There has been some movement amongst the reflectors, but nothing like a pronounced as the activists.

This observation would also suggest that, given time, the reflectors do still have the potential to move their thinking from command and control thinking to systems thinking. It is likely therefore, that the six weeks over which the experiment was measured, was not sufficient enough a time for the reflectors in the group to have made the shift.

This suggests that the changes in thinking happen over a much longer time period than could have been detected in the short duration of this experiment. This could be an issue in an organisation that demands immediate results.

5.3 System Conditions and Levels of Engagement

In retrospect, research question 2 is perhaps the wrong question to ask, as the answer is not as straightforward as just looking up the hierarchy, although the senior level engagement and understanding has certainly had a significant bearing on the intervention in which the researcher has been involved. The answer to this question must also be understood in the context of the system conditions impacting on the business and programme, which are described in Sect. 5.3.1. As such, it makes sense to answer question 3 first before attempting to answer question 2.

5.3.1 What Are the Main Current System Conditions and Thinking Preventing Systems Thinking?

The researcher has identified the first key system condition, that could prevent the programme being successful, to be:

Key system condition #1: ***Multiple purposes exist across the organisation, which are currently conflicting with each other.***

In the part of the organisation where this research took place there are different groups representing different parties competing for the role of the customer. These are the user of the service and shareholders, who have different purposes.

If these different *world-views* are not addressed and reconciled, it may well derail the programme. To date, it has been extremely difficult to even get the right stakeholders in the room to even begin working through these issues. This is especially important given that the power over the design and measurement of the work sits in a separate part of the organisation, with a completely different management hierarchy, to the operation in which this intervention is taking place, as was the case in this research.

Conversations with senior operations managers and observations throughout the intervention, have led the researcher to identify the second key system condition to be:

Key system condition #2: ***The current measures and performance management system are anchoring the organisation in Command and Control thinking.***

The measures for the part of the organisation in which the research took place are defined and monitored by a different part of the business, separate from the operation. The measures typically take the form of weekly and monthly service level agreements (SLAs). If the SLAs are breached, an immediate notification is sent to the top of the hierarchy in Operations. This absorbs a huge amount of time, as much as a whole week at a time on the intervention has been lost to this type of activity, and it happens continually.

Critically, performance against the business measures is linked through into the performance measures in each individual's balanced scorecard, from the director down to the frontline staff. This makes a direct link between achieving targets relating the performance of the business and remuneration. If an individual achieves anything lower than a '*good performer*', they will not be eligible for an end of year bonus.

5.3.2 At What Level Does Systems Thinking Need to be Understood?

In the part of the business in which this research took place, there has been a distinct lack of engagement by the Director of the operation in both elements of the Service Excellence programme. This has caused significant problems for the intervention, some of which are related to and have exacerbated the issues caused by the system conditions described in Sect. 5.3.1. It is not exactly clear to the researcher as to why there has been such a lack of engagement, but the consequences have been quite apparent.

According to the design of the intervention, the Director is supposed to be heavily involved in the top-down end-to-end redesign. This has not happened, meaning that the redesign has lost momentum and is now out of sync, with the bottom up element of the programme.

The lack of engagement cannot be explained by a lack of support in the hierarchy above the Director either, as the overall Director of Operations is sponsoring the programme and is a strong advocate. Having said that, the organisation does believe they are getting mixed messages from this person, particularly relating to the existing measures and achieving the current targets. On the one hand they are told that the existing measures/targets are not fit for purpose, but are still called into regular crises meetings when they are not achieved, which apparently comes from the overall Director of Operations.

As discussed in Sect. 5.3.1, relating to the second system condition regarding measures, if the performance against the dashboard is in the senior managers individual measures, then it stands to reason that it would also be in the Directors scorecard also, putting them under significant pressure to achieve the targets as well, especially given that it is linked to monetary reward. This begs the question as to whether it is right to expect a strong commitment a programme if it will potentially impact individuals financially?

Also highlighted in Sect. 5.3.1 is the fact that the operation is not in control over how they are measured. The measures are set and monitored by a separate part of the business, out of control even of the overall Director of Operations. Therefore, regardless of the level at which the support exists within the Operations hierarchy, support will be needed in this other part of the business, arguably at the same level as the overall Director of Operations, if the programme is to be successful in the operation in which this research took place.

6 Conclusions

When using a Systems approach, the issue of where the boundary of the system being studied will need to be established. Inevitably, with an approach that is putting the customer (service user) at its centre, the system boundaries in a large and complex organisation will cross over existing organisational silos and impact on the numerous support and control functions. As was found in the area in which this research took place, it cannot be assumed that each of these silos and support/control functions has a shared and aligned purpose.

Referring back to Fig. 7 in the literature review, the approach, by combining the Vanguard Method with the frontline capability development, has arguably created a combined approach that is both Type A, *Improving goal seeking and viability,* and Type C, *Ensuring fairness*. However, because of the limitations of the Vanguard Method identified by Jackson et al. (2008), the researcher believes the approach may have a gap relating to Type B, *Exploring purposes*, as the Organisation certainly has multiple parties who are competing for the role of customer, for instance the Service User and Shareholders. What is in the interests of one of these parties may not be in the interests of the other.

An unintended consequence of the programme has been the difficulty presented to the senior leaders in terms of finding a balance between maintaining the current levels of service against existing measures, and the time they are able to commit to the programme. It is the view of the researcher that the current business measures and performance management framework is anchoring the organisation in the command and control thinking. Those involved must be ensured that their involvement in the programme will not be detrimental to them in any way, and should be given the backing and support to challenge the current system, including the way in which they are currently measured.

An interim solution, for any individuals involved in the programme, would be to immediately disconnect their individual scorecards from the performance of the business. However, the researcher believes that longer-term solution is required relating to how the organisation measures its people will be required, as the current performance management framework focussed on the individual, does not support a Systems Thinking environment.

The researcher also strongly believes that further research is required into the impact of performance management of individuals in organisations, especially given that several high profile companies, including Microsoft, have ditched their performance management frameworks. Of particular interest is building on the observations in this research around how the wrong measures can anchor an organisation in its old way of thinking, making it incredibly difficult to make any changes, let alone make any long term change in the culture. It would be fascinating to see if culture change happened more quickly if better measures can replace the old command and control measures at the outset.

Based on the data collected, the critical success factors relating to a Systems Thinking intervention can be summarised as follows:

- Ensure the organisation is ready, particularly in terms of senior engagement. Timing is critical; so do not start if the organisation is not ready.
- Ensure there is an understanding of the organisations work and its structures by the interventionist prior to starting.
- Allow the design of the programme to remain flexible to be able to adapt to the situations and contexts encountered in such a complex organisation. This may mean reconciling multiple purposes.
- Interventionists must be aware of how to adapt the approach, and appreciate that one size does not fit all.
- Protect those involved in the intervention from any negative consequences and work with them to free up their time to stay involved.

Given the drag that existing measures place on an organisation, it is likely that a big change in thinking could be made if the organisation could be freed from their constraints early in the intervention. To do this would require significant support from the top, in order to engage and involve the various interested parties, to come to an agreement prior to the intervention starting.

The researcher further believes that these findings, particularly relating to the measurement systems would be applicable in most organisations and industries, but are likely to vary depending on the context in which they have been implemented in that organisation. As such, these systems must be considered and studied as part of any transformation programme. Not doing so risks the sustainability of the programme, especially if the measurement systems are not changed to align with the new ways of work, and more importantly *thinking*.

Finally, a word about *paradigm incommensurability* that, according to the literature, is considered to be the major constraint to combining systems approaches. Both in terms of the approaches themselves and for the practitioner attempting to operate in multiple paradigms. In practice, the researcher did not come across any issues relating to this during this research project, suggesting that perhaps these concerns are overstated. If anything, having an approach to the intervention that covered both functionalist and emancipatory concerns greatly enhanced the intervention.

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Understanding Effective Problem Solving

Pauline Found and Lyndon Hughes

Abstract Over the last 25 years of Lean effective problem solving is seen as the key to a continuous improvement culture. Yet, what constitutes effective problem solving and the skills to develop it, is an often taken for granted concept in management studies. In the authors' experience, organizations faltering in their lean transformation often cite a failure to capitalize on the benefits of problem solving as one of the primary reasons. It is our contention that there are three key elements to effective problem solving: critical thinking, motivation and knowledge; this paper reports the findings of an exploratory study that tests this assumption and focuses on the role of critical thinking in effective problem solving.

Keywords Lean · Problem solving · Motivation · Critical thinking · Knowledge · Toyota production system

1 Introduction

Ken Kreafle, former head of Toyota North America, defines 'true lean' as team-based systematic problem solving aimed at improving the work they do, to deliver the company's targets and goals. Lean is a process-based improvement philosophy popularized by *The Machine that Changed the World* (Womack et al. 1990) that is based on a study of the Toyota Production System. According to Womack and Jones (1996) there are five underpinning principles: understanding value from the customer's perspective, defining the value stream, ensuring that the product or

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service flows without interruption, detour or deviation, at the rate of actual customer demand (pull) and continually improving the way the organization does business in the strive for perfection. Organizations following these principles understand that to achieve perfection they need to have a culture of seeking and resolving problems actively so they do not re-occur. Toyota Motor Company is possibly the most well known for applying this philosophy, however in their book, The Toyota Way Field Book, Liker and Meier (2006) explain that "*calling the process 'problem solving' may be a misnomer, since the process goes well beyond the basics of solving problems*". They explain how the method encompasses critical and logical thinking processes. Francis (1990) in his publication "Effective Problem Solving" discusses the traits of an effective problem solver, his book was published in the decade when critical thinking became a 'hot' topic within the educational system and, as a result, there are similarities of thought throughout his four distinct areas. The areas are strong motivation, positive disposition, powerful self-image and developed skills. He reduces these categories even further to 40 attributes of an effective problem solver, many of which are comparable to those of a critical thinker. However, the authors of this paper contend that there is more to effective problem solving than simply the ability to think critically. We argue that in order to solve problems the individual has firstly to be motivated to solve the problem and, secondly, they need to have some knowledge of the task to be improved. Therefore, in addition to examining critical thinking, motivation and the influence of the job-specific knowledge is explored.

2 Literature and Propositions

2.1 Problem Solving and Critical Thinking

Critical thinking (Table 1) is not a new phenomenon, according to Paul (2009), Socrates began to develop the principles of critical thinking 2500 years ago when he established the importance of "seeking evidence, closely examining reasoning and assumptions, analyzing basic concepts, and tracing out implications not only of what is said but of what is done as well". This method of questioning is now known as 'Socratic Questioning' and is the best-known critical thinking strategy. In this mode of questioning, Socrates highlighted the need for clarity and logical consistency in thinking. Critical thinking helps foster a healthy democracy; it is part of what it means to be a developing person and, according to Brookfield (1987), without it work places would remain organized as they were 20 years ago. The need to develop critical thinking skills within education has long been agreed, but it has also long been debated, and consensus has not yet been achieved on how to define or assess a student's ability, which in some instances has led to inaction. This inaction results in the development of students who are ill equipped for today's complex, fast paced, information-laden environment. Bailin et al. (1999) discusses the boundaries of critical thinking and what tasks should be

Table 1 Definitions of critical thinking

Definition	Cited by
Active, persistent, and careful consideration of a belief or supposed form of knowledge in the light of the grounds which support it and the further conclusions to which it tends	Fisher (2001) but attributed to John Dewey, the American Philosopher, Psychologist and Educator
That mode of thinking—about any subject, content, or problem—in which the thinker improves the quality of his or her thinking by skilfully taking charge of the structures inherent in thinking and imposing intellectual standards upon them	Scriven and Paul (2008)
Reasonably and reflectively deciding what to believe or do	Ennis (1993)
The ability to think clearly and rationally, it includes the ability to engage in reflective and independent thinking	Lau (2004)
Critical thinking is the use of those cognitive skills or strategies that increase the probability of a desirable outcome. It is used to describe thinking that is purposeful, reasoned, and goal directed—the kind of thinking involved in solving problems, formulating inferences, calculating likelihoods, and making decisions when the thinker is using skills that are thoughtful and effective for the particular context and type of thinking task	Halpern (2003)

encompassed in its field. They discuss how *"critical thinking is sometimes contrasted with problem solving, decision making, issue analysis and inquiry*". They suggest that these tasks are areas where critical thinking should take place and not as a contrast to the subject. They support this with a suggestion that a person can solve a problem "*in a critical or uncritical manner*". Philley (2005) in his applications to accident investigation supports this view with his illustration of 'investigation data quality spectrum'.

The benefits to industry as a result of critical thinking are evident. However, despite the fact that the skills and attributes required to become a critical thinking person are well documented; there is a definite gap in the development of these skills within industry. In industry's desire to apply improvement tools and techniques rather than philosophies, it appears that critical thinking has been replaced by the term "problem solving". As a result industry teaches 'toolbox' skills rather than nurturing critical thinking by coaching and mentoring. This lack of mentoring has often resulted in organizations applying tools sporadically, which results in problems being solved in an uncritical manner.

Proposition 1 *The ability to solve problems effectively is related to the individual's capability of high order critical thinking.*

2.2 Problem Solving and Motivation

Motivation to solve problems is made up of three components, direction, effort and persistence (Arnold et al. 1998) and an individual's theory of action (Argyris and Schön 1978), which drives the motivation.

Theories of motivation can be broken down into 3 board categories: Content theories, process theories and common-sense theories. Content theories, e.g. Maslow (1948), Herzburg (1987) and McClelland (1978) focus on what motivates human behaviour at work. Process theories, e.g. expectancy based models such as those presented by Vroom (1982) and Porter and Lawler (1968) as well as Adams' Equity Theory (1963) focus on how the content of motivation influences behaviour. Common sense approaches include extrinsic and extrinsic motivation (McGregor 1960; Pink 2009) and the influence of social interactions (Schein 1985). Mullins (2005) combines all three of the above common sense approaches into a threefold theory for modeling people's needs and expectations. These are: economic rewards, intrinsic satisfaction and social relationships.

An individual's theory of action (Argyris and Schön 1978) is based on self-image, values and beliefs as well as the social system environment that the individual is operating in. Nohria et al. (2008) present a more recent theory based on four levers to create motivation. These levers are the: Reward System, Culture, Job Design and Performance Management and Resource Allocation processes. By creating a system, which utilizes all four of these levers, a substantially more motivated workforce will be created than if only one of the levers is used.

Proposition 2 *The ability to solve problems effectively is dependent on the individual's motivation to solve the problem.*

2.3 Problem Solving and Knowledge

Whilst acknowledging that in some instances effective problem solving may occur if there is no formal task-specific knowledge. Within a manufacturing environment, some level of knowledge is essential in order to apply critical thinking. Knowledge comprises the cognitive and analytical knowledge, systems and design knowledge, behavioral knowledge and job-specific knowledge. This group of knowledge, when placed in a social environment with self-image, value, beliefs and traits defines an individual's theory of action.

Proposition 3 *The ability to solve problems effectively is dependent on the individual's job-specific knowledge to solve the problem.*

Focusing only on job-specific knowledge limits the organization to single-loop learning (Argyris and Schön 1978). In order to create continuous improvement, organizational, or double-loop, learning is required where the root cause of the problem is detected and prevented from reappearing (Argyris and Schön ibid). For this knowledge to be of benefit, organizations must foster an environment that supports critical thinking and provides the right motivational drivers for a person to learn and apply the skills of critical thinking.

Based on a review of the literature, it can be argued that there are three key elements to effective problem solving, one of which is critical thinking the other two are motivation and knowledge. The process of this is controlled by an individual's theory of action. Therefore it can be hypothesized that the model, in Fig. 1, can be used to understand an individual's ability to effectively problem solve by empirically testing each of the individual components of the hypothesis within a manufacturing environment.

Proposition 4 *The ability to solve problems effectively requires that the individual is capable of high order critical thinking, is motivated to solve problems and has the knowledge to solve the problem.*

3 Methods

The purpose of this exploratory study was to test empirically first line manufacturing supervision within a medical device manufacturer based in the United Kingdom to challenge the propositions that effective problem solving is a combination of sound critical thinking, knowledge and the presence of positive motivational traits (Fig. 1). This was tested by measuring the problem solving abilities and comparing them to the abilities to apply critical thinking and their dispositions towards the appropriate business attitudes along with their motivational drivers and their tacit and explicit subject-specific knowledge. The need to challenge the multiple facets of the propositions required a mixed methods approach where qualitative and quantitative data were collated and analysed.

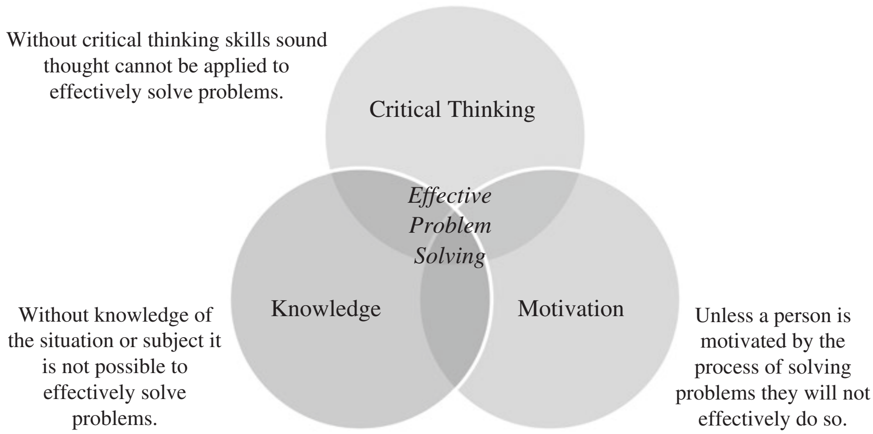

Fig. 1 Model of effective problem solving

3.1 Participants

The research study represents an embedded case study, focusing on the abilities of manufacturing based supervisors within the whole organization and therefore the sample selection is 100 % of the population of supervisors. There are 12 supervisors, eight of whom are responsible for manufacturing activities and the other four for engineering. The supervisors work predominantly a 5 day, two-shift working week rotating between shifts starting at 6am or 2 pm each week, there are two exceptions, two night shift supervisors, who work a permanent 37 h night shift. Each shift supervisor is responsible for 21 lines, with 7 senior line leaders responsible for 3 lines each. Depending on the line and product range there will be 2–5 operators per line. Therefore, each shift supervisor has a direct reporting spam of control of 7 senior line leaders, 21 line leaders and up to 105 operators Table 2.

3.2 Participant Demographics

The research strategy has focused on 12 individuals, all of whom hold a supervisory position within the case study organization. Of the 12 participants the male to female ratio is 3:1. The participants were aged from 29 to 56, the grouping of which is shown in Table 2.

The average service for the participants is 12.9 years and the average number of years in current role is 4.0 years.

3.3 Procedure and Survey Instruments

According to Sampson et al. (2007) individuals cannot be assessed if they do not understand what they are being assessed in. This argues against a single survey approach as a means of assessing critical thinking and, as a result, a mixed method

Table 2 Participant demographics

Age range (Years)	Combined gender	Male	Female
26–30	1		1
31–35	2	2	
36–40	1		1
41–45	3	2	1
46–50	1	1	
51–55	3	3	
56–60	1	1	
Minimum	29	32	29
Mean	43.3	45.8	36
Maximum	56	56	42

approach was preferred. The twelve respondents took part in a series of 8 surveys and tests, each conducted over a six-week period and each conducted under identical conditions.

Initially all twelve supervisors were tested for their problem solving ability. In two timed trials the supervisors were asked to follow instructions and assemble two structures that had been designed to test for logical thinking and reasoning skills. In order to test their problem solving ability against the other variables of critical thinking, motivation and knowledge, three occupational psychology questionnaires and tests were selected for the study. Whilst the validity of occupational questionnaires and tests is questioned recent research has suggested that they are a valuable means of comparison (Ones and Viswesvaran 1996). To counter these concerns, recognized institutes with individual statements of validity provided the questionnaires and tests used. All respondents were purposively selected because they held a supervisory position in the company. To ensure the study was conducted in an ethical manner, a strict ethics procedure was followed throughout the research.

Figure 2 illustrates the assessment instruments used to test the hypothesis.

3.3.1 Problem Solving Assessment

The first of the problem solving activities, known as Gridlock, is usually used in a team context in which the team is observed in their application of thought, knowledge, collaboration and leadership whilst they create the image presented on the

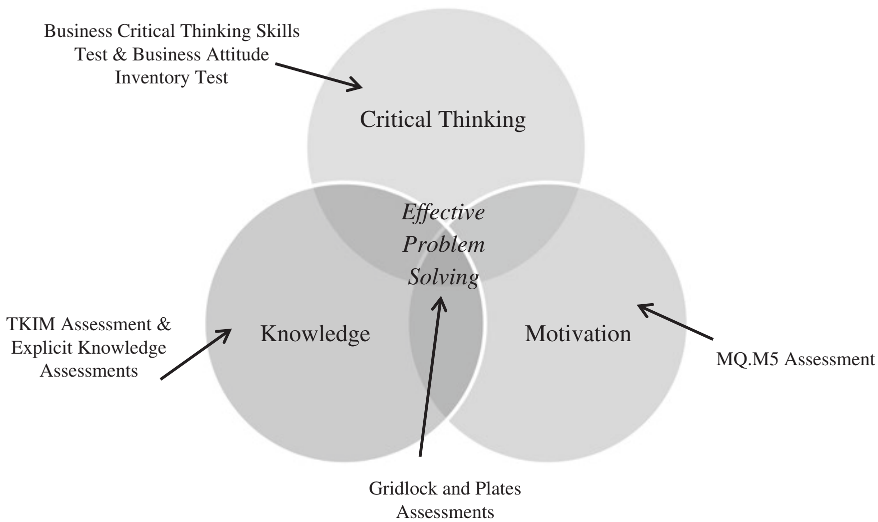

Fig. 2 Assessment instruments used to test the hypothesis

instruction sheet. The activity has been adapted for the purpose of this research in that it is an individual activity and, through timing and observation, the researcher can assess how well the individuals apply themselves to the issue. A time limit of 40 min was imposed.

A second exercise, known as the Plates activity, assesses how individuals interpret instruction and conduct themselves to complete a task within a given timescale. All twelve participants attempted both assessments.

3.3.2 Critical Thinking Assessment

There are two dimensions of critical thinking, the skill that the individual brings and the attitude and disposition of the individual towards thinking critically. To measure these differing forms of within the sample group, two critical thinking assessments were administered, Business Critical thinking Skills Test (BCTST) and Business Atitude Inventory (BAI), both developed by Insight Assesment (IA). IA are part of the California Academic Press group and the test instrument was borne from the Delphi report, (Facione 1990). The BCTST is a case-based reasoning skills assessment tool, which is specifically designed to evaluate the critical thinking skills of working professionals. The BCTST provides an objective measure of critical thinking skills applied to business and workplace, professional and workplace reasoning contexts. It uses mini-cases and vignettes drawn from common business and workplace contexts. The online timed (50 min) assessment comprises of 35 multiple choice test items, which range in difficulty and complexity. Questions are presented in business contexts with all specialized information needed to respond correctly provided within the question.

The results from the test are presented in two ways; there is an overall critical thinking score, and individual rankings against the critical thinking skills of analysis, evaluation, inference and deductive reasoning (Facione et al. 2008; Facione 2009). All twelve of the research participants completed the assessment.

The Business Attitude Inventory (BAI) focuses on the attitudes and dispositions toward using thinking. This tool focuses on an array of attitudes and values that influence a person's capacity to learn and to effectively apply critical thinking skills. Critical thinking disposition and skills go hand in hand: the "*willing and able*" (Facione 2009) of human reasoning. As with the BCTST, BAI is an online assessment, however the questions are not timed nor are they multiple-choice. The responses for this assessment are scored against the desired response for the question posed. The responses are associated to nine individual scale measures; dependability, desire to work, sociability, commitment, willingness to learn, flexibility, honesty and tolerance. The scale score is from 10 to 40 and is sectioned into three distinct areas, individuals scoring 30–40 indicate a positive and desirable attitude towards that specific characteristic. Individuals scoring between 21 and 29 indicate inconsistency in expression towards the characteristic and those scoring between 10 and 20 demonstrate a weak or hostile disposition towards the desired attribute (Facione et al. 2008).

3.3.3 Motivation Assessment

The Motivation Questionnaire (MQ) used in this study to measure the dimensions of employee motivation, was created and supplied by the SHL Group. The MQ. M5 version of this questionnaire is a normative questionnaire that is designed for use with managerial, professional, supervisory or similar level individuals. The questionnaire consists of 144 short, job-related questions in a Likert-scale format. Raw scores are transformed to Standard Ten (sten) scores using a norm group from the general British public. The MQ.M5 questionnaire is broken down into eighteen individual dimensions each of which is assigned to one of four broad areas of energy and dynamism, synergy, intrinsic and extrinsic. These dimensions are based on factor analyses with Cronbach alpha coefficients of between 0.47 and 0.83 (Baron et al. 2002).

The energy and dynamism factor (E1–E7) provide an indication on the main source of energy and drive for an individual; this includes an indication of the level of activity under pressure and their need for achievement and power. The synergy factor (S1–S5) provides an insight into how the individuals react to working in harmony with their working environment and relates to the extent to which they are motivated by praise and recognition; whilst extrinsic in nature they become intrinsic to the organizational culture, such as upholding ethical standards. The intrinsic factor (I1–I3) is a measure of how the features of the job and tasks may effect an individual's satisfaction. The final factor, extrinsic (X1–X3), provides insight into how material benefits divorced from the task itself may impact on an individual's motivation; this may come as a reward from demonstrating good performance.

3.3.4 Knowledge Assessment

There are two forms of knowledge that are focused upon in the field of knowledge management, tacit and explicit (Sanchez 2004). To measure these differing forms of knowledge within the sample group, two knowledge assessments were administered.

The Tacit Knowledge for Managers (TKIM) assessment used in this study has been adapted from the original version created by Sternberg and Wagner at Yale University (Segalla 2010). The TKIM Project enables participants to be compared to an expert panel of over 70 European C-level executives selected by Boyden, a leading executive search consultancy, and over 2000 managers and business students from around the world.

According to Hunt (2003), observing knowledge is not possible and there is a need for a form of test in order to assess a person's explicit knowledge. As a result, the sample group was asked to complete a knowledge self-assessment questionnaire. The questionnaire was developed from discussions with the sample groups, their line leaders as well as department heads. Hunt (2003) also explains that measurement is difficult as people are often unaware of what they should know and, therefore, cannot state their true knowledge. In an attempt to overcome this bias each participant's line manager were also asked to complete the questionnaire to enable a comparison between perceptions of knowledge levels.

4 Results

4.1 Research Results and Analysis of Problem Solving Activities

All sample members attempted both activities, Gridlock and Plates. Only two completed the Gridlock activity fully within the time allocation of 40 min. Of those who completed the activity the average completion time was 19 min. The performance of each of the individuals is shown in Table 3. The results were adjusted by adding a bonus to compensate for those who had completed the majority of the task but had only failed at the final step.

Of the 12 participants to attempt the Plates activity three failed to complete it. Of those who completed the activity the average completion time was 14 min.

To understand the overall ability of the participants to effectively solve problems the two scores have been combined. Figure 3 below provides a summary of each participant's problem solving ability. From this it can be seen that S4, S10 and S7 are the strongest overall participants whilst S2 and S6 performed poorly in both activities. The overall correlation of performance between the two activities is 0.43 and this is not conclusive that ability in one of the activities guarantees success in the other, although it is an indicator of overall problem solving ability.

4.2 Research Results and Analysis of Critical Thinking

4.2.1 Business Thinking Critical Skills Test (BTCST)

These BTCST results are given for each category: inductive reasoning, deductive reasoning, analysis, inference and evaluation, as well as for total critical thinking and these are summarized in Fig. 4a–f.

The total score is the best measure of critical thinking skills and is ideal to compare individuals and identify those that think at a higher level. The summary in Fig. 4f shows a mean score of 15.17 with minimum and maximum scores of 8 and 23 respectively and a standard deviation of 5.31. Using the national scale norm as a comparison, the results show that the supervisors fall between the 1st to the 75th percentile. Table 4 shows the percentage scores for each of the participants with the overall percentage based on a potential score of 110.

According to Facione et al. (2008), total critical thinking scores can be predictors of success within the workplace. From this, it can be assumed that in the

Table 3 Problem solving performance scores and timings by participant

Participant no.	Gridlock					Plates				Total	Rank
	Time taken (mins)	Completed task	Score (max = 35)	Bonus/ Penalty	Final adjusted score	Time taken (mins)	Completed task	Bonus for completion (1 point per min under)	Final adjusted score		
S1	40 (36)	−1	25	5	30	20	DNF		24	54	5
S2	40	N	9		9	18	N		15	24	10
S3	40	−1	27	5	32	17	Y	3	22	54	5
S4	16	Y	23	29	62	10	Y	10	38	100	1
1S5	40	N	14		14	18	Y	2	23	37	8
S6	40	N	16		16	16	DNF		10	26	9
S7	40	N	24		24	9	Y	11	46	70	3
S8	28 (14)	DNF (−1)	22	2	24	11	Y	9	40	64	4
S9	40	N	21		21	15	Y	5	31	52	7
S10	22	Y	26	23	49	18	Y	5	30	79	2
S11	40 (18)	−1	23	5	28	14	Y	2	24	52	7
S12	40 (18)	−1	22	5	27	14	Y	6	26	53	6
Minimum	16				9	9		2	10		
Mean	36.2				27.2	14.1		5.9	27.4		
Maximum	40				62	18		11	46		

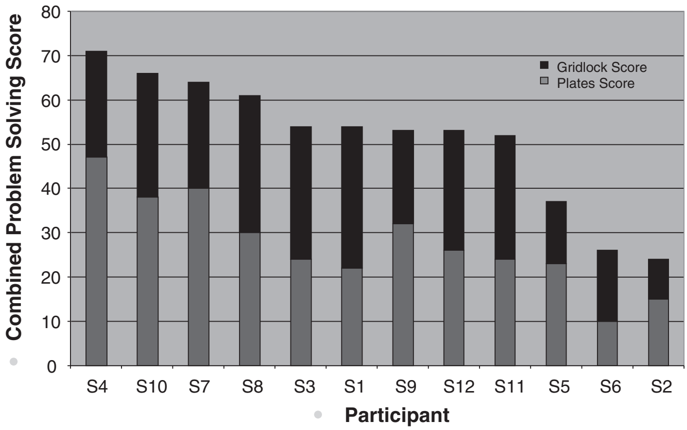

Fig. 3 Combined problem solving score by participant

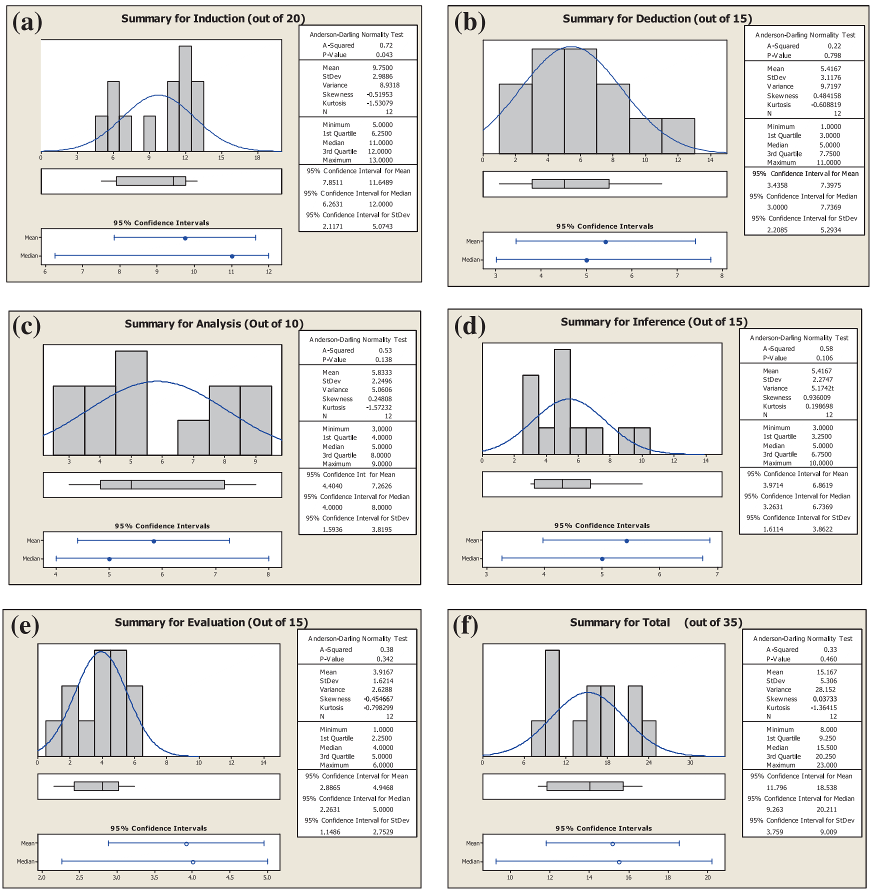

Fig. 4 **a** Inductive reasoning, **b** deductive reasoning, **c** analytical ability, **d** inference ability, **e** evalution ability, **f** total BCTST scores

Table 4 Business critical thinking skills test (BCTST) total scores

Participant no.	Induction (%)	Deduction (%)	Analysis (%)	Inference (%)	Evaluation (%)	Total (%)	Rank
S1	60	27	50	33	40	46	6
S2	30	20	40	20	13	26	10
S3	55	47	70	40	33	51	4
S4	60	67	80	50	33	63	2
S5	65	13	50	27	40	43	7
S6	25	33	40	20	20	29	9
S7	30	20	30	33	7	26	10
S8	45	33	50	33	27	40	8
S9	35	7	30	20	13	20	11
S10	65	53	90	47	33	60	3
S11	60	73	90	57	27	66	1
S12	55	40	80	33	27	49	5
Mean	49	36	58	36	26	43	

assessment of whether the sample group have the ability to effectively problem solve, supervisors S11, S4 and S10 should have a distinct advantage over the other candidates assuming the research hypothesis is valid.

4.2.2 Business Attitude Inventory Assessment (BAI)

The BAI assessment produces a score for an individual's critical thinking style plus eight other attributes required for key employees. These additional eight are dependability, commitment, honesty, desire to work, willingness to learn, flexibility, sociability and tolerance. According to Facione et al. (2008) there are three types of trait for each of the BAI attitudes. Positive traits demonstrate that individuals have a desirable tendency towards the particular attitude. Negative traits mean hostility is shown towards the attitude and ambivalence suggests an inconsistency in their expression towards the attitude. Table 5 shows the scores for each participant against the individual attributes and also the average of the total scores. Scores between 30 and 40 are deemed as positive, between 21 and 29 are ambivalent and between 10 and 20 are hostile towards the attribute.

Of the 12 participants, none exhibited negativity towards any of the business attitudes or the critical thinking style however ambivalence was the overriding trait with only the 'willingness to learn' category demonstrating a strong positive attitude from the group, scoring 92 %. Whilst this data is of concern there is an opportunity that must be capitalised upon, as they are all open to learning.

Table 5 Business attitude inventory (BAI) results

ID	Dependency (%)	Commitment (%)	Honesty (%)	Desire to work (%)	Willingness to learn (%)	Critical thinking style (%)	Flexibility (%)	Sociability (%)	Tolerance (%)	Mean (%)	Ranking
S1	30.91	29.09	30.91	23.64	34.00	27.50	34.55	30.00	31.67	30.25	4
S2	30.00	28.18	27.17	25.45	36.00	25.83	30.00	26.36	30.00	28.78	7
S3	29.09	30.00	31.82	24.55	32.00	29.17	27.27	30.91	30.83	29.52	5
S4	30.00	25.45	26.36	31.82	32.00	27.50	30.91	24.55	25.00	28.18	9
S5	29.09	24.55	27.27	26.36	29.00	24.17	30.00	26.36	26.67	27.05	11
S6	28.18	32.73	24.55	28.18	33.00	26.67	30.00	28.18	28.33	28.87	6
S7	28.18	32.73	26.36	29.09	34.00	29.17	31.82	33.64	30.83	30.65	2
S8	36.36	30.00	30.91	30.00	35.00	31.67	33.64	30.91	28.33	31.87	1
S9	30.91	28.18	25.45	32.73	32.00	24.17	28.18	23.64	25.00	27.81	10
S10	29.09	28.18	19.09	26.36	33.00	29.17	30.00	30.00	32.50	31.04	3
S11	30.91	30.91	30.91	26.36	35.00	30.00	33.54	29.09	32.50	31.04	3
S12	29.09	26.36	26.36	25.45	34.00	27.50	28.18	31.82	30.00	28.75	8
Mean (%)	30.15	28.86	27.26	27.50	33.25	27.71	30.68	28.79	29.31		

4.3 Research Results and Analysis for Motivation Assessment (MQ.M5)

MQ.M5 measures motivation against four groupings, these are; energy and dynamism, synergy, intrinsic and extrinsic. Table 6 provides summaries of the Standard Ten (Sten) scores for each of these groups and their respective sub categories by participant.

To understand the motivational drivers of the sample group as a whole the average Sten scores were compared to that of the norm group (Table 7).

It was deemed appropriate by the authors that, for each of the Sten scores, a score as high as possible would be suitable when identifying an effective problem solver.

4.4 Research Results and Analysis for Knowledge Assessment

4.4.1 Tacit Knowledge Assessment Results

The TKIM Project enables respondents to be compared to an expert panel of over 70 European C-level executives selected by Boyden, a leading executive search consultancy, and over 2000 managers and business students from around the world. The results from the TKIM assessment are shown in Table 8.

For this particular measure the total TKIM score is the indicator of a person's tacit knowledge.

The results for the TKIM assessment show a wide-ranging level of tacit knowledge; this has resulted in a standard deviation (SD) for the total score of 36.1. Participants S3, S5 and S1 show the strongest performance whilst candidates S7 and S11 showed very little tacit knowledge ability.

4.4.2 Explicit Knowledge Assessment Results

Table 9 summarises the overall individual and line manager's responses for each category. In every instance the individual's perceived personal knowledge was greater than their line manager's perception of that person's knowledge.

Despite the difference in scores there is a high level of correlation (0.7) between those of the individual and those of the line manager. Therefore, for the purpose of this research and to compare explicit job-specific knowledge levels of each individual, it can be assumed that the mean of the two scores can be used as the explicit knowledge value. Table 12 presents these scores for each participant. It is important to note that participant S3 is relatively new to the role and therefore perceived knowledge and the knowledge score given by the line manager is maybe

Table 6 Motivation results by participant

		S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	Mean	SD
Energy and dynamism	E1 level of activity	8	6	3	6	5	6	7	10	5	6	10	6	6.5	2.0
	E2 achievement	7	7	5	7	4	4	4	10	5	7	8	7	6.3	1.8
	E3 competition	5	6	5	7	5	8	6	10	5	6	9	7	6.8	1.5
	E4 fear of failure	7	5	2	4	8	7	7	8	8	5	10	9	6.7	2.3
	E5 power	8	6	7	4	3	5	7	10	6	6	9	6	6.4	2.0
	E6 immersion	4	10	3	5	7	8	9	2	7	10	7	7	6.6	2.6
	E7 commercial outlook	5	7	6	8	4	4	6	7	7	7	9	6	6.3	1.5
Synergy	S1 affiliation	6	7	7	4	5	5	5	9	5	7	6	5	5.9	1.4
	S2 recognition	4	10	10	7	6	5	5	6	3	10	6	4	6.3	2.5
	S3 personal principles	6	4	6	9	4	6	3	6	3	4	4	6	5.1	1.7
	S4 ease and security	4	4	10	5	3	4	3	8	6	4	6	2	4.9	2.3
	S5 personal growth	9	7	5	8	4	6	5	9	6	7	9	7	6.8	1.7
Intrinsic	I1 interest	8	4	5	9	4	4	5	6	4	4	6	9	5.7	2.0
	I2 flexibility	4	3	2	4	4	3	6	2	8	3	7	8	4.5	2.2
	I3 autonomy	5	5	10	5	4	1	3	7	7	5	3	8	5.3	2.5
Extrinsic	X1 material reward	4	4	8	8	3	3	2	8	5	4	6	6	5.1	2.1
	X2 progression	5	3	4	10	3	4	4	10	5	3	10	5	5.5	2.8
	X3 status	4	6	8	7	2	5	3	9	5	6	5	5	5.4	2.0
	Total	103	104	106	117	78	88	90	137	100	104	130	113		
	Rank	7	6	5	3	11	10	9	1	8	6	2	4		

Table 7 Motivation scores compared to standard ten (Sten) scores

	Motivation sub category	Mean of sample	Mean of norm group	Difference	SD
Energy and dynamism	E1 level of activity	6.6	6.0	0.6	1.98
	E2 achievement	6.3	5.0	1.3	1.83
	E3 competition	6.8	6.0	0.8	1.54
	E4 fear of failure	6.7	6.0	0.7	2.27
	E5 power	6.4	6.0	0.4	1.98
	E6 immersion	6.6	5.0	1.6	2.61
	E7 commercial outlook	6.3	6.0	0.3	1.50
Synergy	S1 affiliation	5.9	6.0	−0.1	1.38
	S2 recognition	6.3	5.0	1.3	2.46
	S3 personal principles	5.1	6.0	−0.9	1.73
	S4 ease and security	4.9	5.0	−0.1	2.27
	S5 personal growth	6.8	6.0	0.8	1.7
Intrinsic	I1 interest	5.7	5.0	0.7	1.97
	I2 flexibility	4.5	6.0	−1.5	2.20
	I3 autonomy	5.3	5.0	0.3	2.45
Extrinsic	X1 material reward	5.1	5.0	0.1	2.11
	X2 progression	5.5	5.0	0.5	2.81
	X3 status	5.4	6.0	−0.6	1.98

Table 8 Summary of TKIM scores

Participant no.	Managing yoursef	Managing others	Managing tasks	Total TKIM	Rank
S1	27	40	31	98	10
S2	45	52	60	157	4
S3	28	35	26	89	11
S4	33	52	29	114	9
S5	34	31	29	84	12
S6	46	47	48	141	5
S7	55	57	72	184	2
S8	39	66	67	172	3
S9	48	51	40	139	6
S10	39	39	47	125	8
S11	62	68	71	201	1
S12	50	41	38	129	7
Minimum	27.00	31.00	26.00	89.00	
Mean	42.2	48.3	46.5	136.9	
Median	42.0	49.0	43.5	134.0	
Maximum	62.00	58.00	72.00	201.00	
SD	10.8	11.7	17.2	36.1	
n	12.0	12.0	12.0	12.0	

Table 9 Summary of explicit (job-specific) knowledge scores

Categories	Individual scores			Line managers scores		
	Min	Average	Max	Min	Average	Max
Role specific knowledge	6.2	8.3	10.0	5.0	6.6	9.0
Site EHS	7.3	8.9	10.0	4.8	7.4	10.0
Product knowledge	6.0	8.0	9.3	4.3	6.8	9.0
Quality/Regulatory	6.9	8.2	10.0	4.5	6.1	7.1
Finance	1.0	4.3	9.0	1.0	4.3	7.0
Project management	6.3	7.9	10.0	3.7	6.7	10.0
Use of date	4.3	7.6	10.0	3.3	6.6	10.0
Information technology	4.0	8.1	10.0	3.7	6.6	8.3
Customer service	6.7	8.3	10.0	5.5	6.4	7.7
Leadership and management	7.6	8.5	10.0	4.1	5.9	7.0
Overall score	1.0	7.8	10.0	1.0	6.4	10.0

Table 10 Final adjusted explicit knowledge scores

Participant No.	Individual score	Line managers score	Final adjusted score	Rank
S1	88.2	72.3	80.3	2
S2	67.6	56.6	62.1	11
S3	66.3	51.3	58.8	12
S4	72.9	71.0	72.0	6
S5	74.3	58.8	66.6	8
S6	74.5	66.1	69.8	7
S7	80.9	70.6	75.8	4
S8	90.9	74.6	82.8	1
S9	77.9	70.6	74.3	5
S10	88.8	65.5	77.2	3
S11	75.9	57.0	66.5	9
S12	76.9	50.2	63.6	10

lower than expected due to the position on the learning curve of S3. The mean explicit knowledge score is 70.78 and the standard deviation of the sample group is 7.5. To establish the overall knowledge ranking of each participant the two scores were combined and shown in Table 10 with the results from the other tests.

5 Discussion

The results from the problem solving assessment exercises are compared with the motivational assessment, knowledge assessment and critical thinking assessment to establish a correlation. To enable the comparison, the participant's scores for

Table 11 Rankings for each assessment compared with problem solving

Participant	Problem solving	Critical thinking	Business attitude	Motivation	Implicit knowledge	Explicit knowledge	Overall score[a]
S4	1	2	9	3	9	6	3
S10	2	3	3	6	8	3	4
S7	3	10	2	9	2	4	8
S8	4	8	1	1	3	1	2
S1	5	6	4	7	10	2	5
S3	5	4	5	5	11	12	7
S12	6	5	8	4	7	10	6
S9	7	11	10	8	6	5	9
S11	7	1	3	2	1	9	1
S5	8	7	11	11	12	8	12
S6	9	9	6	10	5	7	11
S2	10	10	7	6	4	11	10

[a]Overall Score is Critical Thinking, Motivation and Explicit (Job-Specific) Knowledge

each individual assessment have been ranked in order of their position compared to the rest of the sample (Table 11). The overall assessment and problem solving rankings are represented graphically in Fig. 5.

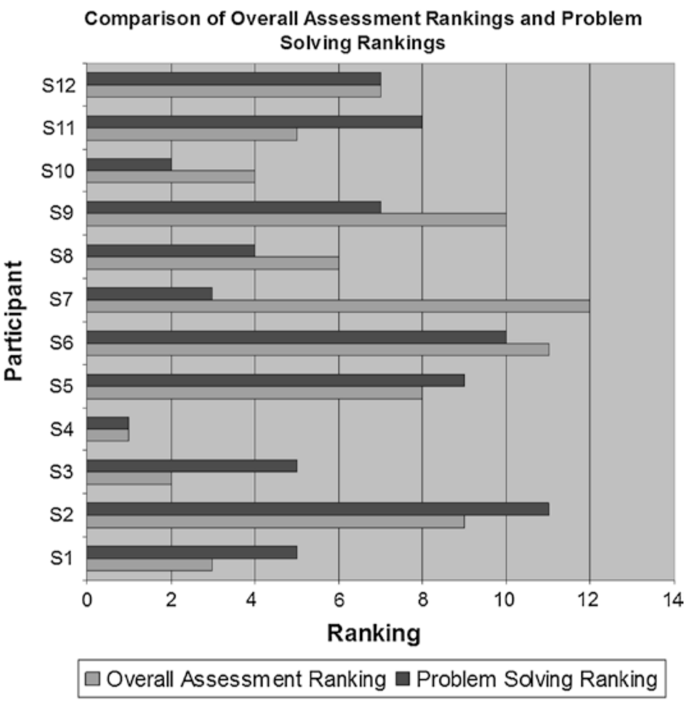

Fig. 5 Comparison of participant assessment rankings

These rankings provide a platform to describe the correlation between the overall performance in the assessments and that of the problem solving tasks. Pearson's one-tailed test was selected to compare the knowledge, motivation and critical thinking assessments to that of the problem solving raw-score assessments (Table 12). Pearson's product-moment correlation coefficient is a measure of the correlation between two variables. The critical value of r for a sample of 10° of freedom (N-2 where N = 12 samples) is 0.497 at a confidence level of 0.05 (95 %).

Focusing purely on correlation and significance with problem solving, and using the same criteria as above, the correlation between critical thinking and problem solving is the only one of the individual tasks that returns an r value (0.542) greater than that of the critical value. This supports proposition1.

Proposition 1 *The ability to solve problems effectively is related to the individual's capability of high order critical thinking.*

However propositions 2, problem solving and motivation where r = 0.380 and 3, problem solving and job-specific knowledge r = 0.442, are not supported.

Proposition 2 *The ability to solve problems effectively is dependent on the individual's motivation to solve the problem.*

Proposition 3 *The ability to solve problems effectively is dependent on the individual's job-specific knowledge to solve the problem.*

However, correlation of the overall assessment (a combined critical thinking, motivation and job-specific knowledge score) with problem solving returned a value of r = 0.61 which can be deemed as significant at a confidence level of >99 %. It can therefore be concluded that the combination of motivation, knowledge and critical thinking has a direct significance on the ability of an individual to effectively solve problems. This supports proposition 4.

Table 12 Correlation matrix (r = 0.497 at 95 % significance)

	Motivation	Implicit knowledge	Explicit knowledge	Business attitude	Critical thinking	Overall assessment
Motivation	1					
Implicit knowledge	0.442	1				
Explicit knowledge	0.174	0.191	1			
Business attitude	0.575*	0.545*	0.483*	1		
Critical thinking	0.519*	−0.115	−0.043	0.262	1	
Problem solving	0.380	−0.020	0.442	0.291	0.542*	0.610**

* Correlation is significant at 0.05 level
** Correlation is significant at 0.01 level

Proposition 4 *The ability to solve problems effectively requires that the individual is capable of high order critical thinking, is motivated to solve problems and has the knowledge to solve the problem.*

The individual correlations demonstrate that the strongest contributor to this correlation is that of critical thinking, followed by job-specific knowledge and motivation although opening the comparisons wider and including motivation and business attitude with critical thinking returns a significant correlation coefficient of $r = 0.526$, which suggests that there is a relationship between these. This would support the generalizability of critical thinking and suggests that these skills can be, and should be, developed.

Further research is required to develop the propositions posed in this paper and to test them in other industries. In addition, an understanding of the weightings of the three attributes to problem solving need to be addressed, along with the possibility of attributes not identified in this research being included. However, given the importance of problem solving as the core constituent of Lean and Continuous Improvement in so many contemporary businesses it is imperative to understand the elements of effective problem solving in order to develop the skills necessary to compete in the future business environment.

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Completely Taktless! What Is Pull in the Context of the Process Industries?

Stewart Stevenson and Pauline Found

Abstract The widespread implementation of lean in discrete manufacturing has changed the face of those businesses with mechanisms such as setup reduction, bounded WIP, takt time, level scheduling and other elements of pull production aimed at reducing variation to create flow with minimal inventory, improving lead time, cost and service. While in the process industries, much is written regarding traditional approaches to planning and production control (PPC), the lean paradigm and pull production remain largely unadopted. This paper explores the nature of process industries and inadequacy of existing taxonomies to understand the underlying complexity, which significantly impacts planning and production control. Definitions and principles of pull are considered alongside existing process sector PPC and the fundamentals of demand, capacity and variation, to demonstrate that a contingent approach, which considers the environment is required. A manufacturing case study is used to confirm the underlying complexity and explain how the inherent variation and resulting trade-offs impact the applicability of discrete pull mechanisms with potential process manufacturing pull definition and mechanisms concluded. Furthermore, a pull system implementation in the case company operation is examined and simulated concluding the fundamental importance of sequence to flow and pull in process manufacturing and its impact on capacity, utilisation, waste and service.

Keywords Lean · Pull · Process industries · Production planning

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1 Introduction

There is evidence that the competitive environment of process industries is becoming more challenging as firms in a sector which is already cost focused are forced to control their costs while pursuing new markets, or improve their flexibility and responsiveness to defend existing markets (Yoho and Rappold 2011). The impact of this includes increasing product variety, reduced order size and reduced lead time, leading to increased manufacturing complexity, which when the fixed and inflexible nature of process manufacturing capacity is considered, results in significant challenges in the areas of planning and production control (PPC).

Since the 1980s, discrete manufacturers have benefitted from lean manufacturing techniques and pull production, to better align demand and capacity (Lyons et al. 2013) and create flow, delivering improvements in lead-time and cost. The process industries however have been slow to follow the discrete sector in the use of alternate PPC approaches to improve competitiveness (Dennis and Meredith 2000b). It has been suggested (Abdulmalek et al. 2006; Pool et al. 2011) that this is due to the unsuitability of process industry product/process characteristics, which may hinder the use of such mechanisms.

The authors of this paper would argue that the unsuitability lies with the mechanisms themselves, which are discrete industry founded, and so may not necessarily apply to the process environment, or help process firms compete in the same way they have discrete manufacturers (Crama et al. 2001). Fundamentally, there would appear to be a lack of evidence to support the application of pull in such environments (Belvedere and Grando 2005) and this paper is intended to address that deficiency.

2 Literature Review

2.1 The Process Industries

It is argued that the competitive environment of process manufacturing firms is becoming more difficult (Yoho and Rappold 2011), forcing changes in fulfilment strategy, which brings challenges for PPC and issues of 'fit' between fulfilment and manufacturing (Karmarkar and Rajaram 2012, p. 680). Numerous frameworks have been developed (Lyons et al. 2013) that classify products against processes to understand different operations and their manufacturing strategies (Stavrulaki and Davis 2010).

2.1.1 Published Industry Taxonomies

Hayes and Wheelwright (1979) built on the work of Skinner (1969) and Abernathy and Townsend (1975) cited in Lummus et al. (2006) introducing the product-process framework for aligning products and their life cycles with their corresponding production process life cycle. Traditionally the process industries have been clustered in the bottom right hand zone of the matrix. Crama et al. (2001) and McDermott et al. (1997) claim that firms should rarely exist off this diagonal due to the impact on cost/profit.

However, with changing markets, hybrids which compromise traditionally accepted manufacturing strategies are becoming increasingly common (Crama et al. 2001). Safizadeh et al. (1996) observe that most of these off-diagonal companies belong to the process industries where Kemppainen et al. (2008) suggest a "misfit" between capital-intensive equipment and expensive product changes.

Numerous authors have discussed the validity of this product-process approach (Kemppainen et al. 2008; McDermott et al. 1997; Stavrulaki and Davis 2010) proposing additional dimensions including batch consistency, material and product variety. Dennis and Meredith (2000a) argue that as Hayes and Wheelwright's (1979) model was originally developed for the discrete industries, the assumption is that process firms will face the same challenges and can use the same solutions as a discrete firm based on their position on the diagonal. They (ibid) propose that in contrast, manufacturing systems are actually organised by how products are made rather than by the actual end product itself. Abdulmalek et al. (2006) propose the additional dimension of discretisation, which, consistent with the process sector's 'off-diagonal' movement, can facilitate fulfilment flexibility (Pool et al. 2011). Due to fundamental differences (Crama et al. 2001) however process industries may not be comparable with discrete industries.

To distinguish between process and discrete manufacturing (Taylor et al. 1981) as two mutually exclusive strategies is inconsistent with manufacturing reality (Abdulmalek et al. 2006). Most process plants are actually hybrids because their non-discrete products become discrete at some point (Billesbach 1994). Pool et al. (2011) summarise production characteristics on either side of this point, which they claim can support different PPC approaches. Puttman (1991) and Abdulmalek et al. (2006) suggest however that in some systems, characteristics might actually be shared. The literature discusses characteristics typical of the process industries as shown in Table 1.

In more recent years differences within the process industries have received more attention. Fransoo and Rutten (1994) distinguish between process/flow and more flexible batch/mix industries but their model is arguably a constituent of those presented a decade earlier, implying that firms within each group have similar processing patterns (Dennis and Meredith 2000a). While Fransoo and Rutten (1994) lacked an "empirical approach" (Van Donk and Fransoo 2006, p. 211), Dennis and Meredith (2000a) addressed this with their study of the differences within process industry firms proposing that there is considerably more complexity in the process industries than previous research suggests.

In conclusion there remains relatively little research on the nature of the process industries (Crama et al. 2001; Dennis and Meredith 2000a). There has been much analysis and validation of models but the fundamentals of many such models remain founded in discrete manufacture and so there is limited consensus as to their applicability in the process industries. This suggests that due to the diverse nature (Lyons et al. 2013) and increasingly 'off-diagonal' behaviour of process

Table 1 Nature and impact of process industry characteristics

Materials	Variability	Natural sourcing and variability (Rice and Norback 1987)
	Inventory	Due to lead time, shelf life, seasonality and managing supply risk e.g. "months of tobacco" v "days of milk" (Rutten and Bertrand 1998, p. 630; van Dam et al. 1993, p. 581)
	Complexity	Claimed simplicity unfounded (Dennis and Meredith 2000a). Combinations of both low/high volume/variety (Abdulmalek et al. 2006)
	VAT	Typically V-plants (Cox and Spencer 1998; Fransoo and Rutten 1994)
	Push	Due to geographically diverse suppliers so purchases made in MRP 'buckets' (Karkarmar 1991, p. 361)
	Value	Cost represents both a major part of production cost and sales value (Crama et al. 2001)
	Capacity	Varies with material characteristics (Bolander and Taylor 1993; Crama et al. 2001)
BOM	Variability	Varies with material price, availability and quality (Fransoo and Rutten 1994)
	Divergent	Unlike discrete BOMs convergent parent recipe can diverge into differently packaged SKUs bringing decoupling point into play (Crama et al. 2001)
	Complex Products	Chemical BOM processing reactions can result in complex products even from simple BOMs (Crama et al. 2001)
Quality/Yield	Variability	Due to variable materials, BOMs and processing (Abdulmalek et al. 2006; Crama et al. 2001; Fransoo and Rutten 1994)
	Unknown	Often until processing started (Fransoo and Rutten 1994, p. 49)
	Load	Waste of making defective parts (King 2009) Waste can impact load (Bicheno 2011) Similarities with Seddon's (2003) 'failure demand' in service
	Capacity	Must account for scrap rate (King 2009, p. 62)
	Setups	Impact quality/yield due to "warm up"/"time to equilibrium" (King 2009, p. 127; Yoho and Rappold 2011, p. 59) driving tendency towards long runs (Pool et al. 2011)
Processing Equipment	Variability	Large scale, cooking/chemical reaction difficult to control giving rise to complexity and waste (Fransoo and Rutten 1994)
	Capacity	Generally constrained by equipment (Ivanescu et al. 2006) as opposed to discrete industry where capacity is people (Funk 1995)
	Capital Intensive	Capacity expansion can be prohibitively expensive (Abdulmalek et al. 2006)
	Setups	Focus on setup cost and utilisation (Schuster et al. 2000)
	Non Dedication	In contradiction to early literature assumptions (Dennis and Meredith 2000a, p. 1088) bringing sequencing issues (Dennis and Meredith 2000a; Schuster et al. 2000)

firms (Crama et al. 2001) the current literature frameworks are inadequate and may lead to selecting the wrong PPC approach.

2.2 *Planning and Production Control (PPC)*

Taylor and Bolander (1994) state that a firm's planning and scheduling must be tailored to its manufacturing environment and competitive strategy, which in turn has implications for off-diagonal process manufacture. In order to discuss the applicability of production control systems, Kingman's equation is used to explain the impact of variation and the interplay between variation and utilisation. There are three factors within Kingman: arrival variation; process variation and utilisation, all of which influence waiting times or cycle time. Expanding on Kingman we can determine that variation is buffered by Inventory, Capacity or Time (Bicheno 2011) and that the mechanisms available stem from these three fundamentals (Fig. 1).

De Treville and Antonakis (2006) agree, suggesting that the lean paradigm can be defined as a system which maximises capacity utilisation and minimises buffer inventories through minimising variability. In some environments capacity can be increased or utilisation reduced by adding labour whereas in others the only option is capacity in the form of plant/equipment. As this normally comes at significant cost, manufacturers normally focus on reducing variation using the mechanisms discussed above. The use of an appropriate pull system can also serve to reduce variability (Schonberger 1983) and stabilise flow.

2.2.1 Production Control Systems

Pull versus push is the control of WIP versus the control of throughput, typically controlled in relation to capacity which must be estimated and is subject to variation (Hopp and Spearman 2004). Pull systems are more responsive than push systems

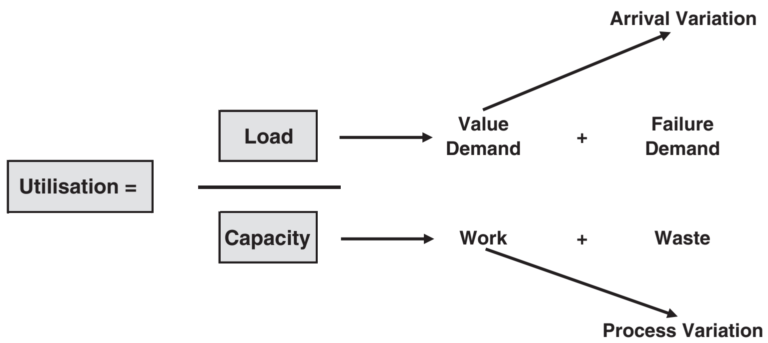

Fig. 1 Expanding on Kingman's equation (Bicheno 2011, reprinted with permission)

(Cheng and Podolsky 1993 cited in Hopp and Spearman 2004). By accounting for system status, pull improves manufacturing cycle times to achieve a lead time shorter than the expected delivery time. Spearman et al. (1990, p. 880) explain however that push and pull are not mutually exclusive concepts and that most systems are hybrids of the two "containing make to order (MTO) and make to stock (MTS) elements".

Whilst kanban was the first production control system to be termed pull (Hopp and Spearman 2004) its limited applicability (Bicheno and Holweg 2009; Hall 1983; Liker 2004) has motivated the generation of alternatives (Gaury et al. 2000) such as CONWIP (Spearman et al. 1990) and DBR (Goldratt and Fox 1986) in addition to various hybrids. However, whilst discrete manufacturers have benefitted from such pull production control systems (Lyons et al. 2013), the literature is "devoid of examples" which address process manufacturing (Yoho and Rappold 2011, p. 61).

Dennis and Meredith (2000a) explain how process industries have had mixed success with ERP systems with Van Donk and Fransoo (2006) suggesting that one of the main issues has been the inadequacy of MRP to plan process industry capacity. MRP logic tends to assume infinite capacity, fixed lead times, (Yoho and Rappold 2011) fixed batch sizes (Darlington and Schmidt 2013) regardless of plant loading and product mix (Karkarmar 1991) and when used for shop-floor scheduling ERP is effectively a push system (Powell and Strandhagen 2011). Schedule feasibility/adherence issues are exacerbated in process industries where materials, BOMs, yield and changeovers are all sources of variation and where there is the need to sequence production based on shared capacity and constraints (Schuster et al. 2000). Consequently other methods to guide and execute the schedule must be found (Schuster et al. 2000).

Based on the practices of process firms, Taylor and Bolander (1994) propose PFS a general approach to scheduling. In contrast to MRP (which uses product structure), PFS uses process structure to find a feasible schedule where capacity, due date, lot sizing and sequence dependency can be accounted for. However infrequent schedule violations are an assumption of PFS (Schragenheim et al. 1994) and as such it may not be suitable in higher product variety, contingent capacity process environments. Hubbard et al. (1992) incorporate the group technology (GT) philosophy into process scheduling. GT improves efficiencies by exploiting similarities and has been successful in cell manufacture where it normally involves equipment dedication (Shahin and Janatyan 2010). However, the philosophy can also be employed in constructing shared capacity schedules (Jamshidi 2009) by grouping products into families (Shahin and Janatyan 2010; Soman et al. 2004).

2.2.2 Planning and Production Control in the Process Industries

Process industries "lag" behind discrete manufacturers in the effective use of PPC (Dennis and Meredith 2000b, p. 68) despite more complex decisions regarding product replenishment (Yoho and Rappold 2011). An increasingly competitive environment for process industries has ushered a shift from MTS to hybrid MTO/MTS, (Crama et al. 2001; Fransoo 1992) bringing with it additional PPC complexity. Combined MTO/MTS is "neglected in the literature" and much of what does exist has limited applicability in process industries assuming for example no setups and batch sizes of one (Soman et al. 2004). The relationships between setups, process yield and differences in run productivity cause issues with estimating process industry capacity and plan feasibility. Bottlenecks can move (King 2009) and schedules initially found to be reasonable can become invalid (Fransoo 1992) because the impact of product mix and sequence are not considered (Dennis and Meredith 2000b), rendering the critical piece of processing equipment a constraint by the number of setups (Schragenheim et al. 1994).

This relationship between demand, capacity and inventory in the process industries creates real cost trade-offs (Fransoo 1993 cited in Crama et al. 2001), which must be managed. Combined MTO/MTS creates issues for shared capacity production control. Stock production is sometimes manufactured in the queue ahead of real demand, creating trade-offs between due-date performance, inventory, flexibility and capacity. The key issue in planning this capacity therefore is to determine what level of inventory is appropriate, how to make that decision and which products to produce at which time, to meet demand in the most cost effective manner (Cooke and Rohleder 2006). This creates further trade-offs between setups which result in waste/lost capacity and larger lot sizes which reduce waste/increase capacity but impact on service (ten Kate 1994). Toelle (1996) cited in Schuster et al. (2000) suggests that the lot sizing trade-off should be viewed as one between set-up costs and capacity constraints. In the context of the process industries waste, contamination and quality costs should be added (Cooke and Rohleder 2006).

In process manufacture, production sequence which is often determined by setups (Van Dam et al. 1993) is of particular importance. In light of the competitive developments in process industry markets, in addition to capacity and waste/cost, trade-offs arguably include service levels all of which can be mitigated by production sequence (Clark et al. 2010; Cooke and Rohleder 2006; Soman et al. 2004) which the authors conclude to be of fundamental importance to PPC in the process industries. This is well supported in the operational literature.

2.3 Flow and Pull

Bonney et al. (1999) suggest that in practice most systems comprise elements of both push and pull. Pull however cannot be viewed in isolation and whilst it is outside the scope of this paper, the authors recognise that pull is effectively a constituent part of "the larger lean construct" (Hopp and Spearman 2004, p. 144).

Lean manufacturing (Krafcik 1988) emerged in post-war Japan (Womack et al. 1990) where observations of the work of Ford creating flow in a mass production environment and learning from other leading intellectuals were assimilated by Japanese industrialists. They combined them with their own ideas to create a hybrid, (Bicheno and Holweg 2009) holistic and sustainable system of management focused on reducing waste (Womack et al. 1990). This system compressed lead time (Schonberger 2015) leading ultimately to the creation of flow in a low volume, high variety environment with pull as a core concept (Liker 2004).

Pull and the achievement of flow are fundamental elements of the five lean principles (Womack and Jones 1996). For Ohno and Toyota the mantra was "flow where you can, pull where you must" (Rother and Shook cited in Liker 2004, p. 108) suggesting that even for Toyota, achieving flow was not straightforward.

There is considerable ambiguity (Bonney et al. 1999) regarding the definition of pull in the literature with JIT, kanban and pull often used interchangeably (Hopp and Spearman 2004). In the mid 1990s the definition of pull became distorted and synonymous with MTO. Hopp and Spearman (ibid) cite Womack and Jones' (1996) introduction to pull as a key catalyst of this distortion:

> Pull in simplest terms means that no one upstream should produce a good or service until the customer downstream asks for it…

Hopp and Spearman (2004) caution against distinguishing pull/push by either MTO or MTS, arguing that both can be either pull or push. King (2009, p. 241) argues that Ohno "didn't explicitly define pull" with Hopp and Spearman (2004) describing Ohno's (1988) picture as a high level, conceptual view of pull as opposed to the means to make it work. They (ibid) distinguish between "strategic" and "tactical" pull, or what Bicheno and Holweg (2009, p. 148) term "principle" and "mechanism" arguing that it is here that the ambiguity has arisen.

Hopp and Spearman (2004) suggest that the literature requires a definition of pull based on what is needed to obtain its benefits rather than on how it is executed, concluding that unlike push, pull explicitly limits system WIP. The over-riding distinction between the two then is that the pull system takes account of system status, preventing both the system from becoming overloaded and the queue from growing exponentially resulting in stable and minimal cycle and lead times.

Hopp and Spearman (2008) suggest that Toyota's success was achieved as a result of a pull based system which improved material flow, lead time, quality, flexibility and hence stability and service. However, their conclusions are discrete industry founded with a lack of evidence regarding the applicability of discrete mechanisms (see Table 2) in process manufacture (Abdulmalek et al. 2006; Yoho and Rappold 2011).

There remain gaps in the literature as the vast majority of research is focused on the implementation of pull in discrete manufacturing environments (Belvedere and Grando 2005; Crama et al. 2001; Yoho and Rappold 2011). Furthermore there is a lack of evidence but the literature suggests that discrete pull mechanisms do not directly transfer to process manufacture (Abdulmalek et al. 2006; Pool et al. 2011). However, with a contingent approach, opportunities to create flow may exist in terms of aligning demand and capacity and minimising interruptions (Lyons et al. 2013).

It is interesting to note discussion regarding the lack of process industry lean/pull literature and case implementation in the 1990s (Billesbach 1994;

Table 2 Literature summary of pull production characteristics

Pull production characteristic	Literature discrete manufacture overview	Literature process manufacture issues
WIP limit	Systematically limits releases to limit the total work in the system (Hopp 2008) ensuring system is not overwhelmed	• WIP is often bounded by equipment so blocking occurs naturally (Hopp and Spearman 2004)
	Targeted at reducing cycle time (Little's Law) and both reducing and stabilising lead time (Hopp 2008) and inventory	• In a process environment finished product inventory can build as a result of poor flow (King 2009, p. 25) and so like discrete WIP it may also be bounded (Liberopoulos and Dallery 2002)
Setup/batch size reduction	A consequence of pull-based production is small lot sizes which results in many setups, in turn disrupting flow (Thun et al. 2010)	• Small batch sizes impact capacity resulting in longer lead times when batch sizes are large, but saturation when batches get so small that setups create a constraint (Kim and Tang 1997; Schragenheim et al. 1994; Hopp and Spearman 2004)
	Changeovers are a source of variation (Bicheno and Holweg 2009) and if the degree of variation is large, scheduling becomes more difficult and both lead time and cycle time less predictable	• Setups disrupt flow (Thun et al. 2010) so facilitating "flow with minimal interruptions, delays and variations" (Lyons et al. 2013, p. 477) is an alternate approach for process industries
Production smoothing/ level loading	Discrete industries have benefitted from level loading or Heijunka (Liker 2004; Yoho and Rappold 2011) which balances work, supporting pull (Hopp and Spearman 2004) and flow (Hüttmeir et al. 2009; Liker 2004)	• Makes discrete industry assumptions that demand can be buffered by capacity in the form of people, changeover time can be eliminated and using time to drive down batch size (Bicheno and Holweg 2009) is optimal
	Liker (2004) and Duggan (2002) advocate a mixed model approach where demand is smoothed through the schedule by volume and product mix	• Mixed model is not suitable for all environments (Bicheno and Holweg 2009). The elimination of setup time (Liker 2004) and other setup waste is a pre-requisite
		• Yoho and Rappold (2011) claim that production smoothing is not yet defined for the process industries proposing predictable production cycles to stabilise manufacturing lead times supported by an inventory policy to absorb random demand (Liker 2004; Yoho and Rappold 2011)
	Level loading delivers responsiveness/flexibility for the customer, improved quality, higher utilsation, balanced use of resources and even demand on upstream processes (Duggan 2002; Hüttmeir et al. 2009; Liker 2004)	• Fixed cyclic schedules reduce manufacturing flexibility (Pool et al. 2011) and total costs increase (Jamshidi 2009) so not suitable for off-diagonal process manufacture

(continued)

Table 2 (continued)

Pull production characteristic	Literature discrete manufacture overview	Literature process manufacture issues
Takt time and pitch	Once demand is established it can be divided across an available time to establish takt, the pace needed to work at to meet that demand (Brown et al. 2006, p. 8)	• Where product/process characteristics are variable or process times are fixed and can't respond to demand fluctuations, takt is not appropriate and a time based view of capacity is required
		• In theory the products being scheduled shouldn't matter but in environments with variable product/process characteristics the products do matter and consequently takt/pitch are less applicable where resources are shared, demand is highly unstable or production cycle times are variable (Bicheno and Holweg 2009; Duggan 2002)
Variation reduction	To combine high capacity utilisation with low inventory (De Treville and Antonakis 2006, p. 102; Suri 2003, cited in Hüttmeir et al. 2009) in discrete industries there is a focus on variation reduction (Hüttmeir et al. 2009)	• In process manufacture variation is unavoidably inherent (e.g. natural materials) and as in service organisations (Frei 2006) variation must be accommodated
	Variation reduction is "critical for the effectiveness of pull systems" (Samaddar and Hill 2007, p. 250)	
Inventory reduction	Lean paradigm often associated with inventory reduction (Hall 1983; Hopp and Spearman 2004)	• Association of lean with inventory reduction "misunderstands lean" (Yoho and Rappold 2011, p. 61)
	Appropriate inventory can support flow (Bicheno 2006, p. 46). While one of the aims of Ohno's supermarket inspired system was inventory reduction, a supermarket always maintains a level of inventory on the shelves (Huang and Kusiak 1996, p. 169)	• Targeting a low inventory policy may be wholly inappropriate for process manufacture. An inventory policy which absorbs demand, maintains service and accounts for equipment limitations is required (Yoho and Rappold 2011)
Process layout	Discrete manufacturers have facilitated flow through process layout (Emiliani and Seymour 2011; Hounshell 1984; Liker 2004)	• Flow must be facilitated in a different way, minimising interruptions, delay (Lyons et al. 2013) and setup waste and maximising asset productivity (King 2009)
	Cell layout in particular is associated with improving capacity, flow and productivity in the discrete industries (where people = capacity) through waste reduction, line balancing, single piece flow, inventory and movement reduction, visibility and labour flexibility/productivity (Bicheno and Holweg 2009; Liker 2004)	• In the process industries much of this doesn't apply as equipment dictates capacity and is often fixed and inflexible (King 2009)

Schragenheim et al. 1994) and the fact that over a decade later the literature is still making the same point (Belvedere and Grando 2005; Pool et al. 2011; Yoho and Rappold 2011).

2.4 Conclusions on the Literature

In conclusion, further examination of flow and pull based PPC models in the process industries would add to the current body of knowledge.

The bulk of the literature is focused on MTS environments and research on MTO is scarce (Germs and Riezebos 2010). The fact that most process businesses are a combination of both carries questions with regard to how pull should be implemented, when capacity is shared and consumed by competing value streams and production for both real orders and stock. This forces the issue of prioritisation (Germs and Riezebos 2010), which in process manufacture brings trade-offs and decisions regarding production sequence where there is a deficiency in the lean literature.

This is particularly striking when the "unparalleled" (Kouvelis et al. 2005, p. 462) extent of the traditional operational literature on scheduling and sequence is considered.

3 Methodology

A single case study of a process industry that supplies commercial fish food has been selected with triangulation achieved through the existing body of knowledge on the process sector, PPC approaches and pull, with case company data comparison and discussion, accompanied by simulation to combine theory and case environment.

The research was conducted at Skretting UK's operation in Longridge, England.

Nutreco is a global animal nutrition company with approximately 10,000 employees in 30 countries of which Skretting is a global subsidiary specialising in the manufacture of high energy pelleted fish feed for commercial fish farms, being part of the aquaculture value chain. Skretting has operations in 14 countries, selling approximately 1.9 million tonnes of feed for over 60 species of farmed fish and shrimp.

Skretting Longridge is the UK's speciality feed plant manufacturing in excess of 200 different products, for 7 species of fish, on a single extrusion line for more than 400 customers UK wide. An increasingly diverse product portfolio accompanied by pressure on customer lead time and shared capacity has led to an increased focus on PPC and flow as a means to improve responsiveness (Schonberger 2015), which provides a suitable environment for the research.

The case company will be compared with the literature characteristics and taxonomies of process industries and the case environment considered in terms of the fundamentals of demand, capacity and variation, the PPC literature and suitability for pull. A sequencing simulation will be carried out to compare typical pull scheduling methodologies with that of the case company's pull system.

4 Case Study Analysis and Discussion

Comparing the case company to the literature on process and discrete industries highlights some differences (see Table 3).

Table 3 Characteristics of Skretting as a process business

Relationship with market	Process industries	Discrete industries	SKRETTING
Product Type	Commodity	Custom	Hybrid
Product assortment	Narrow	Broad	Hybrid
Demand per product	High	Low	Hybrid
Cost per product	Low	High	High
Order winners	Price	Speed of delivery	Price
	Delivery guarantee	Product features	Delivery guarantee and product performance
Transporting costs	High	Low	High
New products	Few	Many	Hybrid
The product process			
Routings	Fixed	Variable	Fixed
Layout	By product	By function	By product
Flexibility	Low	High	Low
Production equipment	Specialised	Universal	Specialised
Labour intensity	Low	High	Low
Capital intensity	High	Low	High
Changeover times	High	Low	Medium
Work in process	Low	High	Low
Volumes	High	Low	Hybrid
Quality			
Environmental demands	High	Low	Medium
Danger	Sometimes	Hardly	Hardly
Quality measurement	Sometimes long	Short	Hybrid
Planning and control			
Production	To stock	To order	Hybrid
Long term planning	Capacity	Product design	Capacity

(continued)

Table 3 (continued)

Relationship with market	Process industries	Discrete industries	SKRETTING
Short term planning	Utilisation capacity	Utilisation personnel	Trade offs—capacity/service/waste
Starting point planning	Availability capacity	Availability material	Availability capacity
Material Flow	Divergent + convergent	Convergent	Divergent + convergent
Yield variability	Sometimes high	Mostly low	Sometimes high
Explosion' via	Recipes	Bill of materials	Recipes
By and Co products	Sometimes	Not	Always
Lot tracing	Mostly necessary	Mostly not necessary	Necessary
Additional characteristics			
Material variability	Yes	Low	High
Material availability	Variable	Stable	Variable
BOM/recipe	Sometimes variable	Stable	Always variable
Quality variability	Yes	Reasonably stable	Yes
Process variability	Yes	Reasonably stable	Yes
Contingent capacity	Depends on product	No	Yes
Material cost	Low	High	High
Trade-offs	Sometimes	Low	Significant, always
Changeover waste/contamination	Depends on product	No	Always

Adapted from Abdulmalek et al. (2006), Crama et al. (2001), Fransoo and Rutten (1994), Rice and Norbrack (1987), Soman et al. (2004), Voss (1995)

This analysis confirms both the inadequacy of comparing process and discrete industries and the generalisation that process industries consistently show the same characteristics. Skretting is not an exact fit with either classification and in addition to hybrid and certain unique characteristics, clearly displays aspects of both process and discrete manufacture.

Skretting is typical of the literature which considers that many process industry products become discrete late in the transformation. However, in contrast to Pool et al. (2011) Skretting demonstrates significant complexity and commonality in characteristics on both sides of this point (see Fig. 2) suggesting that the additional complexity of batch/mix process businesses brings elements of both process and discrete manufacture.

Despite fitting the APICS (2013) definition of batch/mix production, when Skretting is considered in the context of Fransoo and Rutten's (1994) model of process industries it is found to be atypical of batch/mix businesses and as such its place within process industry taxonomy remains unclear. This is confirmed using a qualitative view (supported by Lyons et al.'s (2013) descriptions) of Skretting's position on Dennis and Meredith's (2000a) four criteria model where Skretting displays two

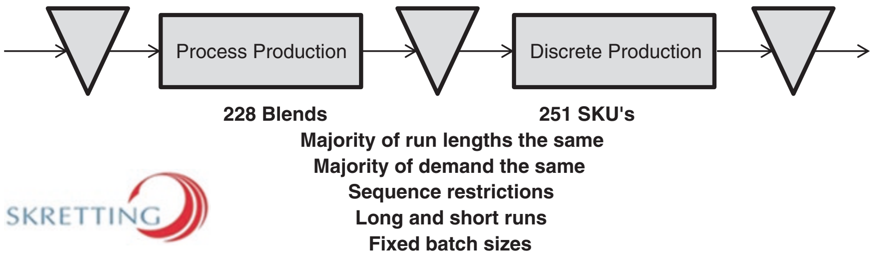

Fig. 2 Skretting process versus discrete manufacture (adapted from Pool et al. 2011)

significant differences which bring trade-offs between equipment flexibility and variety, impacting on PPC:

- **Equipment v Materials Diversity**: Skretting had a significantly higher number (×10–20) of raw materials and finished goods than those businesses which had similar equipment characteristics (and displayed the lowest material diversity). This raises PPC issues in terms of flexibility and responsiveness, cost, fulfilment strategy and service level;
- **Equipment v Run Time**: Average run time at Skretting was 10 times shorter than the lowest run time average and more than 50 times shorter than those plants with similar equipment characteristics. In the context of process manufacture this brings PPC issues in terms of run length, changeover, waste and capacity.

In conclusion, analysis suggests that while clearly a process manufacturer, Skretting arguably displays complexity not described by the literature and exhibits characteristics of process/flow, batch/mix and discrete industries.

4.1 Skretting Manufacturing, PPC and Fulfilment

Typical of the process industries (Crama et al. 2001), the Skretting facility is V plant oriented (Cox and Spencer 1998). Skretting has three points of differentiation which typically provide opportunity to alter fulfilment strategy by relocating the decoupling point (Naylor et al. 1999) but this is practically and economically unviable. This combination of inflexible plant and limited decoupling means that Skretting fulfilment is a combination of MTS decoupled at finished goods inventory and MTO decoupled at raw material inventory.

Skretting's continuous layout means that intermediate process WIP is both constrained and almost non-existent. It could be argued at a mechanistic level that as a result of this natural bounding of WIP, the Skretting system cannot be overloaded and is already pull based. However, demand and capacity can still be misaligned and the wrong product/quantity manufactured, resulting in over-production waste, slow moving inventory and poor flow to the customer despite this apparent bounding of WIP. As such it could be argued that the mechanistic definition of discrete industry pull in terms of bounded WIP does not apply to process manufacture.

Skretting's V plant configuration includes shared capacity common routing which, consistent with the literature, brings trade-offs between cost/waste, capacity and service which render scheduling critical. In V plants, scheduling is typically focused at constraints and points of differentiation where traditionally opportunities for decoupling exist. Due to decoupling limitations, Skretting scheduling focuses on the former, where due to the combination of early product commitment and resulting setups, extrusion is the dominating process constraint. Historically, Skretting scheduling has been MRP push (Hopp and Spearman 2004). This push approach has resulted in misalignment of demand and capacity with off-peak over-production, and a finished goods inventory curve which doesn't reflect seasonality. As a result Skretting has implemented a pull based system which is discussed in Sect. 4.2 below.

Skretting's hybrid MTO/MTS fulfilment is an industrial reality, but is not well described in the literature creating issues for PPC frameworks which regard MTO and MTS as mutually exclusive fulfilment strategies requiring disparate manufacturing characteristics. In the case of Skretting, this is not practically possible and so a solution must be found in terms of PPC, however the literature PPC frameworks do not adequately describe hybrid fulfilment. As such in the context of this paper, it is considered necessary to examine PPC fundamentals to determine opportunities for hybrid fulfilment solutions and the implementation of pull.

Annual demand is seasonal fluctuating significantly with customer growing strategies, harvest plans, water temperatures and oxygen levels. Product demand follows typical Pareto behaviour. Order demand follows a similar pattern with the majority of customer orders smaller than the minimum run length. This 'long tail' (Anderson 2009) provides further PPC challenges where early committed products are manufactured on inflexible process industry equipment. This supports both the need for a MTS/MTO fulfilment strategy with finished goods inventory buffering based on robust demand analysis (King 2009) and the equipment/variety conflict highlighted by the analysis of Skretting using Dennis and Meredith's (2000b) model.

Arrival variation is atypical of the process industry literature and confirms Skretting's off-diagonal position. Several decision points/handovers are present in the Skretting supply chain and manufacturing is decoupled from real demand resulting in amplification (Lee 1997). Numerous countermeasures have been implemented but short term demand is still subject to significant biological and environmental variation. This variation is confirmed using demand class analysis (Boylan et al. 2008; Syntetos et al. 2005) where over 50 % of Skretting SKU's are higher variation 'lumpy' or 'management control' with significant variation within these demand classes. Furthermore, only 3 % of volume has a low coefficient of variation (CV).

Analysis demonstrates that Skretting process variation is consistent with the process industry literature:

- **Material Variation**—processing functionality variation (not explicit until processing has started) due to natural sourcing and seasonal availability;
- **BOM Variation**—variability of material quality, availability and price results in BOM variation which can cause significant change in processing functionality impacting product quality, yield and capacity due to changing proportions of variable materials;
- **Machine Variation**—equipment is large scale, capital intensive and processing is inexact cooking/chemical reaction giving rise to significant process variation of which changeovers are a significant proportion impacting on time, capacity, material waste and quality;
- **Yield/Quality**—The combination of material, BOM and process variation results in variation in both yield and right first time (RFT) quality, impacting flow, system predictability and service levels.

In conclusion the Skretting case demonstrates a significant degree of variation in processing, materials, BOM and yield/quality that is consistent with the process industry literature providing less opportunity for reduction than that within discrete manufacturing and so any buffering strategy should take this into account.

This, coupled with long tail demand, arrival variation and off-diagonal fulfilment not typical of the process industry literature results in a particularly high variation environment for Skretting as a process manufacturer (see Fig. 3).

Skretting setups/changeovers are frequent and constrain capacity (Schragenheim et al. 1994). Changeovers are also sequence dependent (Yoho and Rappold 2011) consuming different amounts of time and so capacity varies with product mix, and the number (lot size) and type of changeovers. In addition to lost capacity, setups/changeovers also incur energy cost and generate material waste.

The significant impact of setups/changeovers are consistent with the literature and indicate that the typical discrete-pull focus on setup/batch size reduction (Thun et al. 2010) is less suitable for the process manufacturing environment at Skretting, due to increased waste and potential capacity constraint (Kim and Tang 1997; Schragenheim et al. 1994).

Consequently, typical discrete industry workload levelling would also be unsuitable in the Skretting process environment (Bicheno and Holweg 2009) due to the increased number of changeovers (Powell et al. 2009).

Analysis shows that Skretting Capacity is contingent on:

- **Product Mix**—due to the processing speeds of different sizes and product types which require varying difficulty of production effort (Seidman and Holloway 2002);
- **Constituent Materials**—due to their processing functionality which can cause the bottleneck to shift;
- **Bill of Materials**—due to changing proportions of variable raw materials;
- **Yield/Quality**—due to large scale, inflexible inexact processing and variable BOMs/Materials.

Figure 4 illustrates the cumulative capacity impact of each variation source contrasted with the capacity contained within MRP.

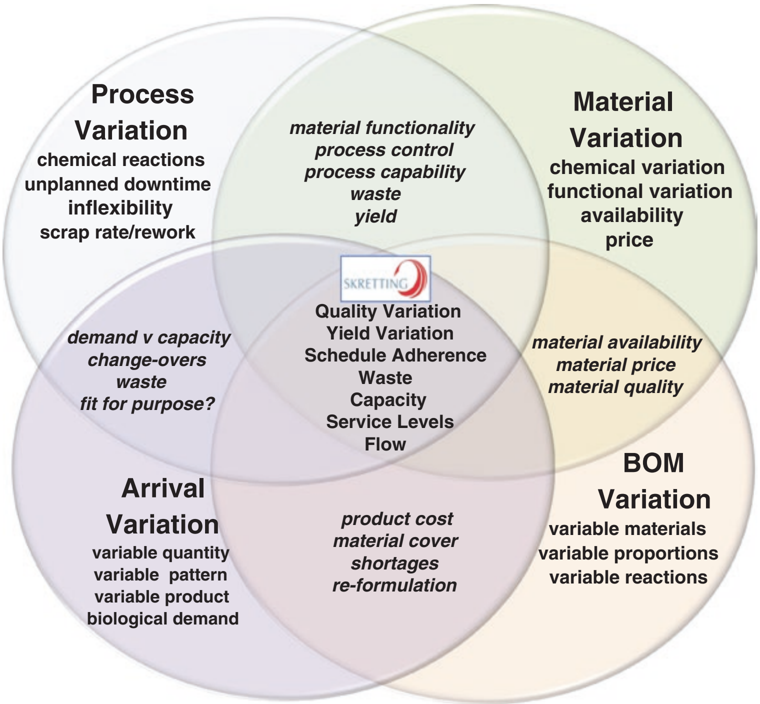

Fig. 3 Euler diagram illustrating Skretting variation complexity

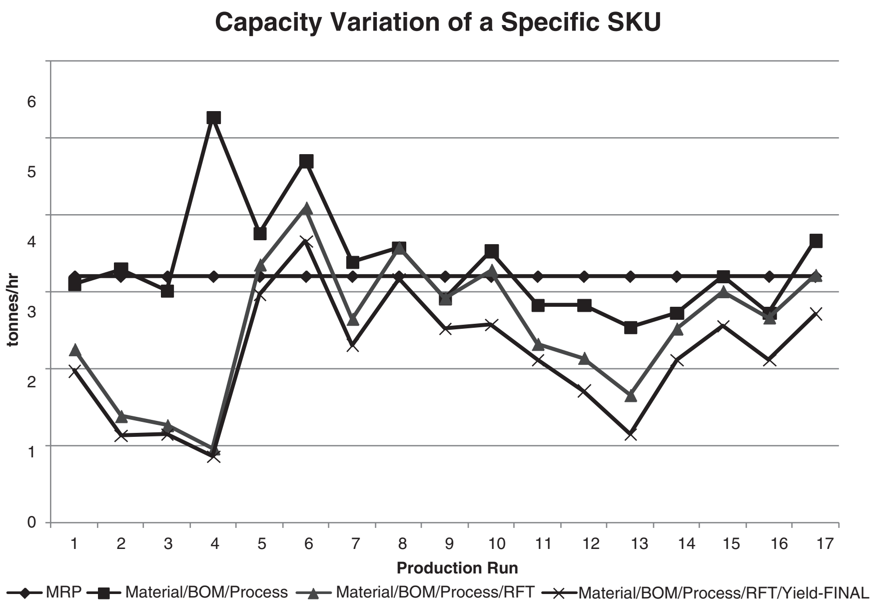

Fig. 4 Cumulative impact of variation on capacity of a specific SKU

This contingent capacity has implications for PPC and establishing flow, while in the context of pull mechanisms, the variable product/process characteristics and cycle times, also confirm the unsuitability of discrete industry takt for the Skretting environment.

4.2 Pull in the Skretting Process Environment

Analysis of the Skretting production environment suggests that many of the traditional mechanisms of discrete pull may not be applicable to process manufacturing at Skretting (see Table 4).

However, a pull system has been introduced at Skretting, which is consistent with the principles of flow and pull and the fundamentals of demand, capacity and variation (see Table 5).

In summary, Skretting now employ hybrid MTO and demand based pull replenishment MTS using a combination of time and inventory buffers and Advanced

Table 4 Summary of implications of Skretting manufacturing environment for pull

Skretting environment factor	Implications for pull
Differentiation/ decoupling	• No opportunities for intermediate decoupling due to equipment restrictions. Only able to pull from decoupled Raw Material (MTO) or Finished Goods (MTS)
WIP	• WIP is already bounded due to equipment restrictions so Skretting pull cannot and should not be defined by limited WIP. However demand and capacity can still be misaligned resulting in poor flow so pull should be defined in another way
Demand	• Long tail, variable nature of Skretting demand conflicts with fixed, inflexible process industry equipment (confirmed by Dennis and Meredith 2000b analysis). Results in lack of ability to MTO all products due to resulting setup constraint so can't pull from raw material. WIP restrictions mean Skretting can't pull from intermediate buffers so confirms need to pull from MTS FG buffer. Demand is not actual consumption so subject to amplification—demand analysis to support the MTO/MTS decision
Capacity	• Capacity is shared, highly contingent, subject to significant variation and impacted by setup and sequence. Product/process characteristics and highly variable cycle times confirm an environment not suitable for using takt. Time based view of capacity is required
Setups	• Setups are sequence dependent and have a significant impact on capacity, waste and flow. Confirms that traditional discrete industry MMS level scheduling and batch size reduction are likely to be unsuitable. Time buffer will enable smoothing of the schedule to reduce setup interruption and waste
Variation	• High level of inherent variation results in unpredictable output further advocating MTS FG buffering to achieve stable flow to the customer. Downtime and setup process variation to be focused on to maximise equipment uptime. Operator competence extremely important to manage/accommodate variation

(continued)

Table 4 (continued)

Skretting environment factor	Implications for pull
Waste	• Setups generate time, material and energy waste and interrupt flow. Despite bounded WIP, poor alignment of demand and capacity can result in overproduction and inventory waste
Inventory	• High variation and requirement for high service level mean that inventory is a justifiable option. Raw Material inventory required due to nature of sourcing, FG buffers required due to unpredictable processing and combination of long tail variety and lack of equipment flexibility
MRP/ERP	• Use of fixed lead time, average throughput and setup result in issues of schedule adherence and frequent re-running of the schedule. Inability to account for sequence dependency leads to suboptimal sequencing resulting in longer manufacturing lead times and increased material waste. Supports use of pull to execute the schedule but system must account for sequence

Table 5 Elements of Skretting pull system and their consistency with the literature

Pull system

Element	Description
On time in full (OTIF) measure	• to monitor flow performance to the customer (Womack and Jones 1996) and service levels pre and post pull system introduction
Demand analysis	• to understand the nature of demand and its variability and support MTS/MTO decisions (King 2009)
MTO/MTS Policy	• (by product) based on demand analysis
Periodically reviewed demand based pull inventory replenishment	• for MTS products (using historical demand and statistical algorithms to set stock levels) to align demand and capacity and stabilise production cycles (Fernandes and Filho 2011; Huang and Kusiak 1996; Yoho and Rappold 2011)
Finished goods stock 'bounding'	• (as opposed to discrete-pull WIP) (King 2009) by actual warehouse space
Use of advanced demand information (ADI) in combination with pull	• to further optimise production run lengths, inventory levels and manage finish goods inventory limitations (Claudio and Krishnamurthy 2009)
Time (customer lead time) and Inventory (finished goods MTS) variation buffers	• (Bicheno 2011; Hopp and Spearman 2004) which allow smoothing of the schedule and responsive service to the customer
Sequencing by product size and family	• (Shahin and Janatyan 2010) to improve flow by minimising changeover interruptions, delays and variation (Lyons et al. 2013) and reduce material, energy and capacity waste
Time based capacity planner	• to better understand capacity, bottlenecks, sequence and product mix impact and the ability to provide promise dates to the customer. While the production line itself is 'naturally bounded' (Yoho and Rappold 2011), in combination with the lead time buffer this avoids overloading the system

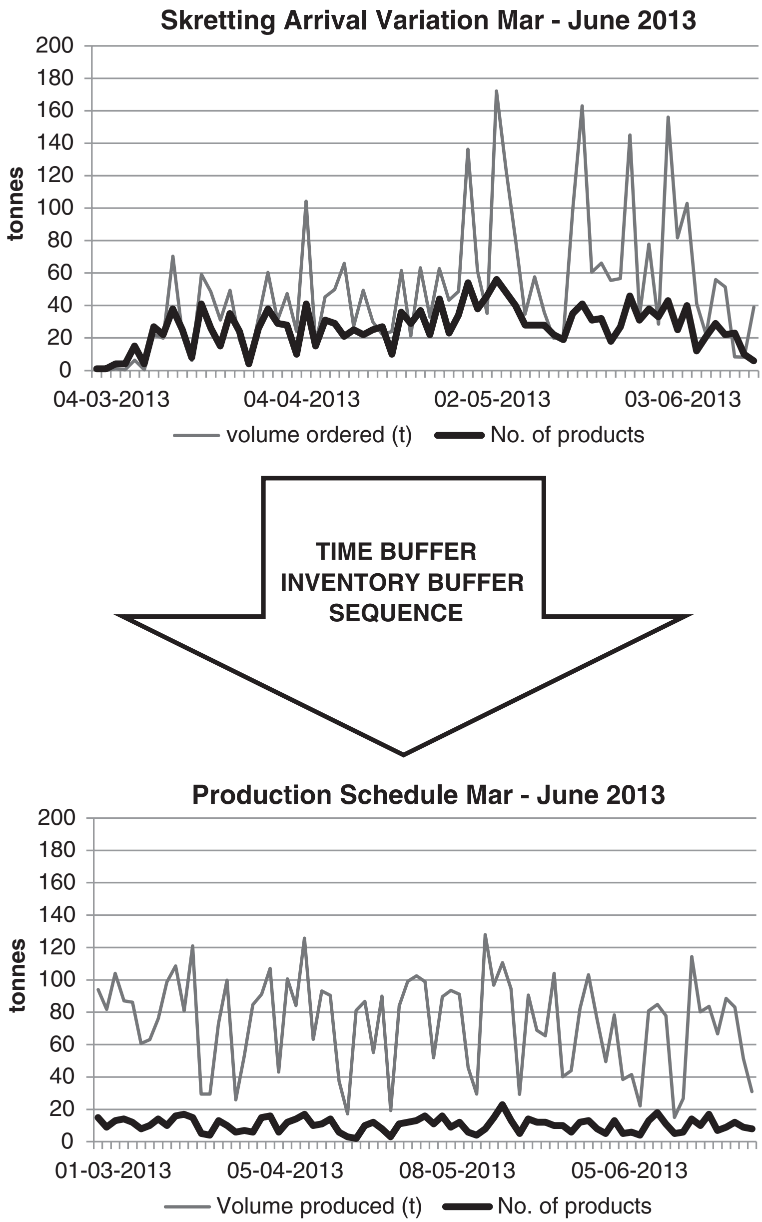

Fig. 5 Buffering of arrival variation to smooth the schedule at Skretting

Demand Information (ADI) (Claudio and Krishnamurthy 2009) to reduce changeovers and enable schedule smoothing (see Fig. 5) on a product group basis to deliver high service levels while mitigating the trade-off impact of changeovers to reduce waste and improve flow.

As a result of this demand based pull, run lengths and inventory levels for higher demand, more stable products have been extended reducing material waste and shortened for lower demand, more variable products improving obsolescence. The periodic review system has also stabilised manufacturing cycles (Yoho and Rappold 2011) reducing the standard deviation of time between cycles. However, Skretting did not experience an improvement in quality/yield (ibid) as a result of more stable production cycles. As a result of this improved alignment of demand and capacity, system flow is improved resulting in a more stable inventory profile and an upward trend in OTIF.

Since the original research, analysis by a third party working capital consultancy one year after the pull system was implemented has confirmed the reduction of weighted average maximum and minimum system lead time by over 50 %.

4.2.1 Conclusion on Pull in the Skretting Process Environment

From the analysis above, the authors conclude the potential for and benefits of pull production control in a process environment as demonstrated by the Skretting pull system case, further proposing that sequence is an important element of the Skretting pull system and a critical element of achieving flow and pull in a process environment which will be examined next.

4.2.2 Importance of Sequencing in the Skretting Pull System

In this section simulation will be used to evaluate the importance of sequence as a constituent element of pull in the Skretting case.

To simulate sequencing the production demands generated by the Skretting pull system for 15 separate weeks in 2013 were re-sequenced using the following scheduling methodologies associated with lean/pull production (Bicheno and Holweg 2009; Hopp and Spearman 2008):

1. Shortest Processing Time (SPT)
2. Earliest Due Date (EDD)
3. Level Scheduling/Mixed Model (Level)

The results of the three lean scheduling methodologies are compared, (Table 6) with that of the actual Skretting sequence (Skr Seq).

The SPT sequence gave the worst performance and in contrast to the literature (Hopp and Spearman 2008) did not decrease average manufacturing times. Rather than consolidating short runs (GT) to reduce setups and waste, SPT separates them to complete them first, exacerbating the number and severity of changeovers.

The impact of EDD and Level Loading are similar, increasing changeovers to either prioritise due dates (EDD) or spread workload (Level Loading). In contrast to the literature, level loading did not deliver higher utilisation, or when feasibility was accounted for, responsiveness for the customer (Hüttmeir et al. 2009).

Table 6 Summary of sequencing simulation results

Summary Impact of Sequence				
Measure	Sequencing Method			
	SKR Seq	**SPT**	**EDD**	**Level**
Total Setup Time (hrs)	236	448	397	411
Total Time (hrs)	1,277	1,489	1,438	1,452
Ave. Manuf. Lead Time (hrs)	2.30	2.68	2.59	2.60
Ave. Capacity (t/hr)	4.42	3.79	3.92	3.88
Total Material Waste (£)	£ 18,081	£ 27,960	£ 25,747	£ 26,183
Total Energy Waste (£)	£ 5,449	£ 10,293	£ 9,100	£ 9,336
Initial OTIF % (factory floor)	*98.7%*	*89.0%*	*99.6%*	*99.6%*
FEASIBLE OTIF % (factory floor)	98.4%	87.4%	96.4%	96.2%
Ave. Utilisation	79.3%	92.5%	89.3%	90.2%
CV of Capacity	0.32	0.36	0.38	0.36
CV of Setup Variance	1.10	0.63	0.74	0.70

KEY
best performance
worst performance

As would be expected, Skretting setup variation was highest due to the combination of small changeovers where feasible, accompanied by large setups where unavoidable.

However, significantly and somewhat unexpectedly, the Skretting sequence delivered the lowest capacity CV. Although this result could be a function of the higher SKR sequence capacity, this suggests a degree of what in this environment could be considered level loading achieved by the Skretting methodology, the performance of which compares favourably with the discrete founded level loading sequence.

The importance of sequence was particularly apparent at higher levels of utilisation, which sequence impacted further, where schedule feasibility was a greater issue for the lean scheduling methodologies (see Fig. 6).

In high utilisation weeks, the superiority of the SKR sequence in terms of both material, energy and time waste was most pronounced. When schedule feasibility was taken into account, at high utilisation the SKR sequence also delivered better OTIF. Unsurprisingly, sequence was of lesser importance when product mix complexity was low where the SKR sequence did not deliver significant advantages in either manufacturing lead time or capacity.

The sequence simulation also serves to confirm the contingent nature of Skretting capacity. When the run by run capacity of the (least variable) SKR sequence is plotted against the average capacity (Hopp 2008), the variable and contingent nature becomes evident (see Fig. 7) bringing into question the suitability of this discrete founded capacity definition for building and executing the schedule in process manufacture.

4.2.3 Conclusion on Sequence

In conclusion, the process industry trade-offs identified in the literature are present within Skretting. Consistent with the literature, these trade-offs can be mitigated by a production sequence appropriate for the environment.

	Utilisation % (5 day week)			
	SKR Seq	SPT	EDD	Level
Wk 14	72%	79%	76%	82%
Wk 15	67%	83%	81%	85%
Wk 16	62%	76%	74%	73%
Wk 17	69%	72%	74%	69%
Wk 18	82%	102%	93%	99%
Wk 19	86%	96%	90%	94%
Wk 20	103%	125%	124%	120%
Wk 21	75%	88%	83%	81%
Wk 22	61%	73%	69%	71%
Wk 23	74%	87%	84%	86%
Wk 24	57%	66%	66%	64%
Wk 25	70%	83%	79%	81%
Wk 26	66%	77%	74%	74%
Wk 27	89%	110%	101%	100%
Wk 28	78%	83%	84%	81%

< 80%
< 90%
< 95%
> 95%

	Utilisation % (Overtime)			
	SKR Seq	SPT	EDD	Level
Wk 14	66%	72%	69%	75%
Wk 15	61%	75%	73%	77%
Wk 16	56%	69%	67%	66%
Wk 17	62%	66%	67%	63%
Wk 18	75%	92%	84%	89%
Wk 19	78%	86%	82%	85%
Wk 20	93%	113%	113%	109%
Wk 21	68%	80%	76%	73%
Wk 22	56%	66%	63%	65%
Wk 23	67%	78%	76%	78%
Wk 24	52%	60%	60%	58%
Wk 25	64%	75%	71%	73%
Wk 26	60%	70%	67%	67%
Wk 27	80%	99%	92%	91%
Wk 28	71%	75%	76%	74%

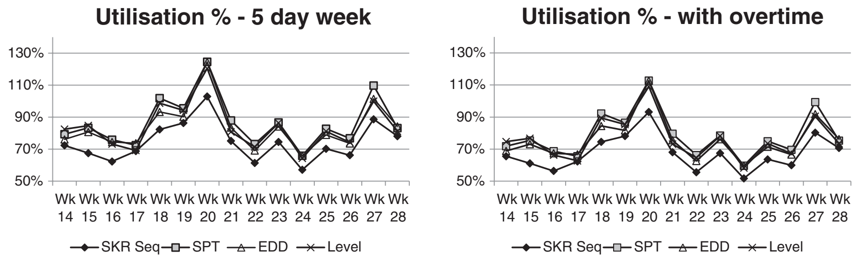

Fig. 6 Impact of sequence on utilisation

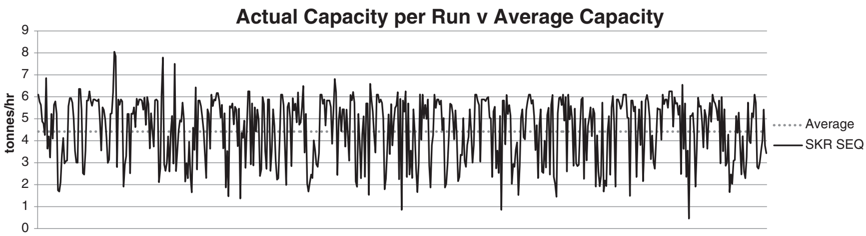

Fig. 7 Actual Skretting sequence capacity against Hopp's (2008) average capacity

In contrast to the sequencing methodologies founded in discrete industry pull, the Skretting sequence provided highest performance in mitigating the trade-offs of capacity (throughput, lead time and variation), waste (material and energy) AND service (OTIF) identified in the literature (see Fig. 8).

In terms of the principles of flow and pull, the Skretting sequence better aligns capacity and demand, minimises waste and optimises flow to the customer and as such in the Skretting case is an essential element of pull in process manufacture.

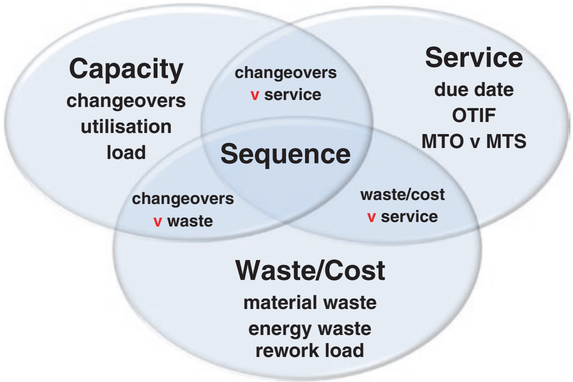

Fig. 8 Literature derived model illustrating analysed Skretting process industry trade-offs and the importance of sequence

5 Discussion

5.1 Pull in the Process Industries

The literature view of pull is both ambiguous and strongly founded in discrete manufacture, focusing on the mechanisms of pull as opposed to the general principles that inspired Ohno. This is particularly evident, for example in Hopp and Spearman (2004), where make to forecast is regarded as pull if it is executed using kanban and takt. Forecast-based overproduction using kanban and takt is nevertheless overproduction and here Hopp and Spearman (2004) are arguably losing sight of the fundamental principles of demand-based flow to the customer in favour of the manufacturing mechanisms of executing pull.

The literature suggests that the process industries have been slow to adopt pull production and this paper concludes that the limitations of discrete based mechanisms contribute significantly to this (Table 7).

The authors agree with the literature distinction between principle and mechanism and conclude that as a result, the principles of pull can be executed in different ways.

The alignment of demand and capacity is at the heart of lean thinking (Lyons et al. 2013) and as such by focusing on the principles of flow and reduction of waste and addressing the PPC fundamentals of demand, capacity and variation rather than prescriptively applying discrete founded mechanisms, pull can be achieved in a process environment.

If we try to define process industry pull purely in terms of mechanisms which constrain inventory, then without the capacity flexibility of discrete firms, the process industries will have issues managing both demand and inherent variation.

This unavoidable process industry variation results in a significantly more hostile environment requiring alternate buffering and a variation accommodation strategy (Frei 2006), as opposed to the variation reduction typically found in discrete manufacturing.

Table 7 Conclusion on discrete lean imperatives and limitations (adapted from Yoho and Rappold 2011)

Lean imperative	Process industry—research conclusions
Smooth or "level-load" production (heijunka)—establish production plans that are smooth with respect to volume and product mix	Discrete type EPE/heijunka increases setups/changeovers to the point where schedules become infeasible and waste generation is high
Establish capacity buffers—scheduling the factory less than 24 h per day	Capacity constrained by equipment which is generally highly utilised. Additional capacity buffers expensive
Reduce setups on equipment—reduce setups, institute single-minute exchange of dies (SMED), convert internal setups to external setups, abolish setups	Batch size and setup not separable, and in contrast to discrete industries setups disturb flow, generate waste (material, time, energy) and impact capacity and utilisation (additional process industry impact on Kingman) ultimately affecting flow of value to the customer (reduced OTIF)
Single piece flow	Impossible/impractical in non-discrete capital intensive process environment
Cross-train workers—because labour is a critical capacity input it is desirable to cultivate a multi-skilled workforce	Labour not a critical capacity input but worker competence critical to 'accommodate' inherent variation so focus on workforce competence as opposed to flexibility
Improve plant layout—adjust plant layout to accommodate less movement of material and employees	Plant is fixed and continuous and as such inherently inflexible
Reduce work in progress	Work in progress often negligible/not visible or non-existent giving no **intermediate** opportunity to decouple at, or pull from WIP buffers. Similar to WIP in a discrete environment Finished Goods can build as a result of poor flow (King 2009) and therefore require more focus and provide an opportunity to pull
Takt—the pace that a facility needs to work at to meet demand	Takt an unsuitable tool due to unstable demand, contingent nature of capacity, shared resources, product/process characteristics and in some cases fixed processing times

Table 8 concludes potential process industry pull mechanisms based on literature principles and the Skretting case environment where continuous and inflexible equipment forces a different solution to discrete industry flexible capacity buffered, intermediate WIP bounded, single piece flow.

The Skretting case approach to pull provides the same benefits of throughput (increased capacity), inventory (reducing age profiles), rework (reduced waste) and customer service (high OTIF) championed by Hopp and Spearman (2008) on behalf of WIP bounded discrete industry pull. In Goldratt and Fox's (1986) terms, inventory is improved, operational expenditure (in the form of material, obsolescence and energy waste) is reduced and service is improved for existing throughput whilst increased capacity is provided for additional throughput.

Table 8 Pull in the process industries: potential process industry approaches based on principles of flowal process industry approaches based on principles of flow and pull (adapted from Yoho and Rappold 2011)

Lean imperative	Principle	Process industry—research solutions
Smooth or "level-load" production (heijunka)—establish production plans that are smooth with respect to volume and product mix	Level loading/ align demand and capacity	• **Stable (but not fixed) periodic production cycles** which align demand and capacity but mitigate changeovers (King 2009; Pool et al. 2011; Seidman and Holloway 2002; Yoho and Rappold 2011) • **Sequencing** which minimises capacity variation
Establish capacity buffers—scheduling the factory less than 24 h per day	Buffering/align demand and capacity	• **Combination of time/inventory buffers** which is most appropriate to the environment and supports the alignment of demand and capacity (De Treville and Antonakis 2006; Lyons et al. 2013) - Promise to 85 %, schedule to 100 % - **sequencing** to mitigate impact on both capacity and Kingman fundamentals
Reduce setups on equipment—reduce setups, institute single-minute exchange of dies (SMED), convert internal setups to external setups, abolish setups	Flow/waste	• Reduce impact of changeovers—**sequencing**. Use of Time/Inventory buffers to allow smoothing of the schedule using **sequence** to reduce changeovers, improve flow and minimise waste. (Bicheno and Holweg 2009; Thun et al. 2010)
Single piece flow	Flow	• Single family flow—use of group technology and **sequencing** to schedule like products together to reduce interruption/ waste and improve flow (Hubbard et al. 1992 cited in Shahin and Janatyan 2010; Soman et al. 2004)
Cross-train workers—because labour is a critical capacity input it is desirable to cultivate a multi skilled workforce	Profound knowledge /variation accommodation	• Competence train workers to enhance process knowledge/understanding and enable accommodation of variation to minimise waste
Improve plant layout—adjust plant layout to accommodate less movement of material and employees	Flow/waste	• Maximising uptime of highly utilised plant is crucial therefore <u>maintaining</u> flow (TPM for example) may be higher priority than creating flow. Higher focus on impact of plant inflexibility on **movement, management and waste of material**
Reduce work in progress	System status/ flow/waste (overproduction)	• Buffer with, pull from and BOUND Finished Goods to improve response time (Hopp and Spearman 2008) support **sequencing** and improve flow at the critical constraint. *Toyota—flow where you can and pull where you can't* (Rother and Shook cited in Liker 2004, p. 108)
Takt—the pace that a facility needs to work at to meet demand	Flow	• **Time based view of capacity** which accounts for process/product characteristics and shared/contingent capacity

In conclusion, the Skretting case provides a process industry pull solution that is supported by the literature, the specific mechanisms of which will not necessarily apply to every process business but the principles arguably will. The majority of the literature's attempts to define discrete pull do so referring to the mechanisms rather than the concepts and principles of flow, in response to which the authors propose the following principle based definition of pull in the process industries:

"The alignment of demand and capacity to provide the optimal trade-off between capacity, waste and service that delivers stable and predictable flow of that demand to the customer".

5.2 *The Importance of Sequence*

Expanding on Kingman and the opportunities it presents within PPC, the traditional operational literature suggests that there is an additional element at play within process manufacture—that of sequence which can help mitigate trade-offs. This was supported by the Skretting case analysis where the Skretting sequence not only improved capacity and waste, but less expectedly improved service and unexpectedly reduced capacity variation.

However, the influence of sequence on PPC and the fundamentals of Kingman in the process industries whilst also unexpected, is further concluded here.

Lead-time in a queue is a product of time, utilisation and variation all of which are impacted by sequence in a process industry environment as shown in Fig. 9. In the Skretting case analysis a difference of between 10 and 20 % was seen in total process time, utilisation and capacity variation depending on the sequence used.

Expanding on Kingman, the Skretting case analysis demonstrated that during weeks where utilisation was highest, sequence was extremely important and actually determined schedule feasibility. Changeovers are a source of variation and accordingly in the process industries, sequence impacts capacity in terms of the

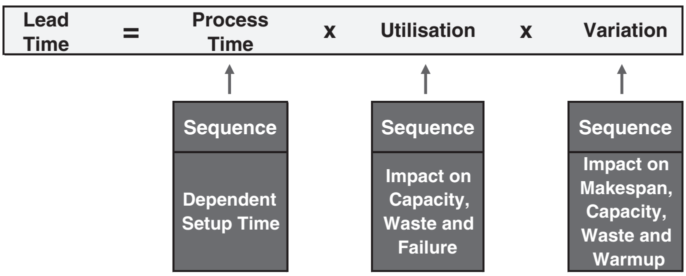

Fig. 9 Model showing proposed process industry impact of sequence on Kingman (adapted from Bicheno 2011)

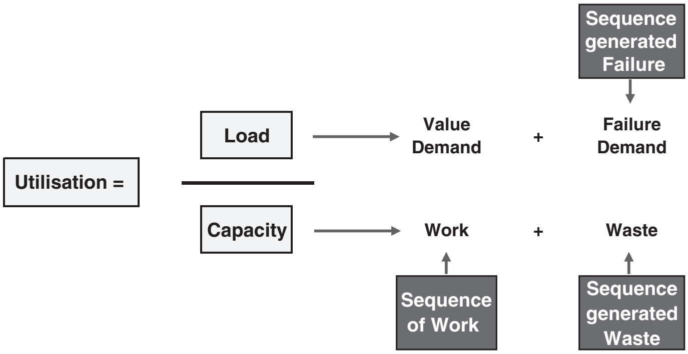

Fig. 10 Model showing proposed process industry impact of sequence on utilisation (adapted from Bicheno 2011)

sequence of work and the generation of waste and load through waste generated failure demand (Seddon 2003) (see Fig. 10).

6 Conclusion

The increasingly competitive environment and resultant ‘off diagonal’ activity within process manufacture causes issues for traditional literature models founded on the linear product/process approach. Existing literature frameworks are both discrete founded and taxonomy focused, inadequately describing underlying process industry complexity which is both inherent (e.g. complex BOMs, material variation and inexact processing) and relative to the environment (e.g. inflexible capacity combined with significant variability in demand and fulfilment). This complexity brings practical challenges for PPC where literature models do not satisfactorily describe the realities of hybrid MTS/MTO fulfilment and so a contingent approach based on PPC fundamentals and the trade-offs that can be influenced is required.

Discrete manufacturers have benefitted from pull production control resulting in improvements in lead time, cost, inventory and service but the process industries have been slow to follow this approach typically advocated for more stable, predictable production environments. The literature definitions of pull are ambiguous and research is focused on discrete industry implementations and the mechanisms as opposed to the principles of pull and flow. Commonly accepted discrete industry pull mechanisms lack applicability in process manufacturing but the principles of pull and the fundamental alignment of demand and capacity can be used to derive environment appropriate mechanisms which accommodate variation and support flow.

Such mechanisms must consider the process manufacturing trade-offs between capacity, waste and service which can be mitigated by sequence, the significance of which is not explicit in the lean literature. Here it should be noted that the case company sequence outperformed traditional lean scheduling approaches, generating outcomes contrary to the literature.

In process manufacture Yoho and Rappold (2011, p. 60) propose the use of a "complementary inventory policy" with "finished goods inventories *in the right product at the right time*…" (ibid, p. 67) asking "in what quantities and in which specific products should inventory be carried?" (ibid, p 59). In implementing demand based pull in a process environment we should add: "…*and in what order should they be manufactured*?"

Merging the significant operational literature on scheduling with the principles of flow/pull and the Skretting case analysis demonstrating both the influence of sequence on the fundamentals of Kingman and the impact of sequence on flow and waste, the authors conclude that the critical element of pull in the process industries is that of sequence.

7 Limitations and Future Research

Whilst the research accessed a longitudinal study of flow within the case operation, the data collection period, being less than one year does not represent the full extent of case company seasonality. The majority of this data is secondary data, not collected for the purposes of the research and therefore subject to bias and the context in, or purpose for which it was collected.

The conclusion whilst founded in the literature is triangulated using a single case study and, as such, it is not possible to generalise. The process industries encompass a wide variety of manufacturing with differing points of product commitment, differentiation and decoupling (between push and pull) ranging for example from petrochemicals where the vast majority is process based, to food and other FMCG where batch processes exist and products becomes discrete at some point. As a result, further research is recommended to determine if the research conclusions and the criticality of sequence apply to the implementation of pull in other process industry environments.

Additional research including multi-variant analysis is recommended to understand the degree to which each variable impacts flow. This may (dependent on the dominant variable) enable some reduction of influence and consequent reduction of buffers.

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Internationalisation of Lean Manufacturing: The Influence of Environmental Conditions

Thomas Bortolotti and Stefania Boscari

Abstract In the last decades many manufacturing firms have launched lean internationalisation initiatives so as to develop high performance foreign subsidiaries and/or suppliers. Several worldwide cases of successful lean adoption suggested the power as well as universality of this managerial method, thus motivating firms to diffuse their knowledge towards geographically-dispersed partners. However, previous projects also shown the difficulty in internationalising lean manufacturing, which sometimes even precluded its effective transfer. In fact, as advocated by some scholars, lean implementation effectiveness can be affected by environmental differences between countries. Although previous studies pointed to several inhibiting factors for lean internationalisation and provided some evidence of their negative impact on diffusing lean management across different countries, the literature is still lacking a holistic framework explaining such relation. In the attempt to provide a more comprehensive examination, this study takes a broad view on factors describing the international environmental conditions—i.e., socio-cultural, political-legal, economic, and educational dimensions—and analyzes their influence on lean internationalisation projects, in terms of problems in diffusing internally related as well as externally related lean practices. To this purpose, we conducted a single in-depth case study concerning two lean internationalisation projects launched by an Italian manufacturer so as to diffuse its lean knowledge towards a Chinese peer subsidiary and suppliers, respectively. Findings from the study can support managers in acknowledging the main criticalities in the internationalisation of lean manufacturing as well as in better understanding reasons behind them, thus helping to reduce lean internationalisation projects' failures.

Keywords Lean manufacturing · Global operations management · Knowledge diffusion

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1 Introduction

In the last decades, globalisation has led a growing number of manufacturing firms to internationalize their operations. In order to attain a superior competitive advantage, some manufacturers have taken a global view in selecting suppliers and/or choosing markets in which sell their products; in some cases internationalisation has also resulted in the establishment of new production facilities in geographically-dispersed countries. A new challenge rose for firms which had based their local operations on world class manufacturing methods that is to diffuse their knowledge and best practices across global actors. In particular, many firms have levered on lean manufacturing so as to develop high performance foreign subsidiaries and suppliers. In fact, lean manufacturing is widely recognized as a managerial method powerful in enhancing operational performance of a factory (Shah and Ward 2003; Liker 2004). Moreover, evidence exists of greater benefits obtainable when implementing lean in conjunction with supply chain partners (Womack and Jones 1996a; Hines and Rich 1997).

Although lean manufacturing has been successfully implemented worldwide, some previous studies have found that environmental differences between countries can affect lean implementation projects and their effectiveness (e.g., Hofer et al. 2011; Kull et al. 2014). For example, Kull et al.'s (2014) contribution showed that some socio-cultural values can hinder lean internationalisation, causing difficulties when adopting lean practices within a factory. In addition, economic conditions such as high turnover can affect the diffusion of internally related as well as externally related lean practices by causing loss of transferred knowledge, which can even threatening the sustainability of a project (e.g., Mefford and Bruun 1998; Wallace 2004; Hofer et al. 2011). According to Prasad and Tata (2003), it is crucial to provide a thorough understanding of the various socio-cultural, political-legal, economic, and educational factors that can affect internationalisation of best practices so as to define how effectively manage and take advantage of the unique conditions of each country.

A first important step towards integrating studies on internationalisation of lean manufacturing was done by Prasad and Tata (2003). However, they failed in providing a comprehensive view of the phenomenon since their focus was specifically directed towards a sub-bundle of lean practices (i.e., customer focus and satisfaction, strategic quality planning, human resource development and management, information and analysis, management of process quality). Other scholars adopting a broader perspective on practices (e.g., Wallace 2004; Hofer et al. 2011; Kull et al. 2014), instead considered only one or few dimensions describing international environmental conditions; to date most studies have focused on the impact of socio-cultural factors.

As a consequence, the literature is still lacking a holistic framework on the internationalisation of lean manufacturing, which helps to explain the influence of international environment differences between countries in determining main criticalities in lean implementation. This study attempts to fill this gap by discussing two lean internationalisation projects successfully carried out by an Italian manufacturers: the first concerns diffusion of internally related lean practices to the Chinese peer subsidiary, the second the implementation of externally related lean practices in the Chinese supply base. In doing so, we take a broad view on factors describing the international environmental conditions, considering all the socio-cultural, political-legal, economic, and educational dimensions. Findings from the case study are compared with evidence from previous significant contributions on the internationalisation of lean (or sub-bundles of lean practices).

Although we also acknowledge the importance of organisational factors in affecting lean internationalisation projects, in the interests of parsimony our study focuses specifically on the impact of international environmental conditions. This is particularly important because, while several researches on lean manufacturing concentrated on organisational factors (see for example Rich and Bateman 2003; Achanga et al. 2006; Bortolotti et al. 2015a), literature on differences in environmental conditions is largely unexplored.

Our framework can be also of use to managers, as it helps to identify the main criticalities affecting the internationalisation of lean manufacturing as well as reasons behind them, thus helping to reduce lean projects' failures.

The remaining of the paper is organized as follows. In the next two sections we review studies on the internationalisation of the operations and of lean manufacturing, respectively. Then, a description of the methodology employed in the study is provided. Section 4 describes the background and presents an overview of the lean internationalisation projects. Section 5 discusses findings from the case study along with evidence from previous research. Finally, contributions and implications of the study are outlined in the conclusions, together with limitations and indications for future research.

2 Literature Review

2.1 Internationalisation of Supply Networks

Different aims can lead a manufacturer to internationalize its operations. For instance, Ferdows (1997) distinguished three main strategic reasons which can determine the location of a foreign factory: (1) access to low-cost production, (2) access to skills and knowledge of advanced suppliers, competitors, research laboratories, or customers, (3) or proximity to market. However, foreign direct investment is not the only alternative for a firm to develop an international supply network. Depending on the reasons that drive the internationalisation, it can be more appropriate to opt for exports, direct investments, or intermediate solutions such as equity or non-equity entry modes (e.g., joint ventures and franchise or license agreements, respectively) (Rugman et al. 1985; Douglas and Craig 1995). These are strategic decisions concerning the *configuration* of a manufacturer's supply network; however, it is also crucial to properly *coordinate* such network,

Table 1 Dimensions and factors describing the international environmental conditions

Dimension	Factors
Socio-cultural	Attitudes toward managers, perceptions of authority, inter-organisational cooperation, attitudes toward achievement and work, class structure and individual mobility, attitudes toward wealth and material gain, attitudes toward scientific management, attitudes toward risk, national ideology, beliefs about foreigners, and the nature and extent of nationalism. Cultural effects of customs, languages, attitudes, motivation, social institutions, status symbols, and religious beliefs have all been documented in the international business literature
	Societal cultures have been measured along a number of dimensions; two main models have been developed: (1) Hofstede's (1980) model, including individualism-collectivism, power distance, masculinity-femininity and uncertainty avoidance; (2) GLOBE model (House et al. 2004), including power distance, institutional collectivism, in-group collectivism, future orientation, performance orientation, gender egalitarianism, assertiveness, uncertainty avoidance, humane orientation
Political-legal	Defence/military policy, foreign policy, political stability, political organisation, flexibility of law, the role of government, labour organisations, local needs, industry standards, political ideology, political stability, relevant legal rules for foreign businesses, international treaty obligations, import-export restrictions, international investment restrictions, profit remission restrictions, and exchange control restrictions
Economic	Central banking systems and monetary policy, fiscal policy, economic stability, organisation of capital markets, market size and type, social overhead capital, exchange rate stability, market taste and demand, geographic dispersion, the quality of infrastructure, international trade patterns, membership and obligations in international financial obligations, international competition and international standards
Educational	Local literacy levels, specialized vocational training and education, higher education, and management programs

Source Adapted from Oliff et al. (1989) and Prasad and Tata (2003)

by defining how to effectively and efficiently share resources and diffuse knowledge between the dispersed factories (Porter 1986). This implies that firms make multiple and correlated decisions about the configuration (size, location, scope, and specialisation of the factories) and the coordination (degree of centralisation policies, incentives, measures, and controls) of a supply network (Hayes et al. 2005). This paper focuses on the diffusion of best practices (i.e., lean manufacturing practices) among actors of a manufacturing network; in fact, while scholars have extensively explored configuration, less attention has been devoted to coordination issues in general, and knowledge diffusion in particular, thus requiring further research (Pontrandolfo and Okogbaa 1999; Netland and Aspelund 2014).

It is widely recognized that best practice diffusion can help firms developing high performance networks, thus achieving a superior competitive advantage (Womack and Jones 1996a; Jensen and Szulanski 2004). However, several knowledge transfer projects have been characterized by problems and some even failed to attain such benefits (Jensen and Szulanski 2004). Differences in countries' conditions (e.g., socio-cultural characteristics) have been recognized to be a major obstacle to best practice implementation among geographically-dispersed supply network partners (e.g., Kostova 1999; Jensen and Szulanski 2004; Kull et al. 2014). According to Oliff et al. (1989) and Prasad and Tata (2003), we consider four main dimensions in describing differences in the international environment: socio-cultural, political-legal, economic, and educational. Moreover, a number of factors are covered by each dimension; Table 1 summarizes main factors investigated by global operations management studies.

In addition, the difficulty of knowledge diffusion can also be influenced by the typology of best practices transferred (e.g., Teece et al. 1997; Kostova 1999; Maritan and Brush 2003). In particular, the diffusion of complex knowledge, such as lean manufacturing, it is likely to come across many criticalities (Maritan and Brush 2003).

2.2 Internationalisation of Lean Manufacturing

Lean manufacturing is a managerial method for eliminating waste from and continuously improving production processes within a factory, thus improving its operational performance (Womack and Jones 1996b; Shah and Ward 2003). Superior benefits can be achieved when individual efforts are linked up and down the value chain by cooperating with suppliers and customers, thus creating greater value for the final customer (Womack and Jones 1996a; Hines and Rich 1997; Shah and Ward 2007; Danese et al. 2012; Bortolotti et al. 2013).

Scholars have described lean method as a complex set of practices (Teece et al. 1997; Maritan and Brush 2003; Bortolotti and Romano 2012). According to Shah and Ward (2003), lean practices at factory-level can be grouped into four “bundles”: just-in-time (JIT), total quality management (TQM), total preventive maintenance (TPM), and human resource management (HRM). By adopting a broader perspective, some previous studies have classified between internally related lean practices and externally related (or supply chain) lean practices (e.g., Shah and Ward 2007; Hofer et al. 2011). Setup time reduction, equipment layout for continuous flow, kanban, statistical process control, autonomous maintenance, small group problem solving, training employees, top management leadership for quality, and continuous improvement are the most important internally related lean practices, while JIT delivery by suppliers, supplier partnership, and customer involvement are among the main externally related lean practices (Shah and Ward 2007; Hofer et al. 2011; Bortolotti et al. 2015a, b).

Lean manufacturing originated from the production system of Toyota, a leading Japanese manufacturer in the automotive sector. For many years both the academics and practitioners have debated the transferability of lean practices outside Japan and the automotive industry. Although seminal books about JIT gave rise to the view of the Toyota production system (TPS) as a “Japanese thing”, the success of the NUMMI’s (New United Motor Manufacturing) experience—the joint venture between Toyota and the American General Motors—was a first main evidence of its transferability to the Western world (Holweg 2007). The book *The Machine that Changed the World*, which also coined the term "lean manufacturing", strongly contributed in straitening and diffusing the idea of the "universality" of lean method (Womack et al. 1990). Several successful cases of lean firms in different countries and of various industries have followed, thus further proofing this second stance (Hines et al. 2011; Shah and Ward 2007).

However, as studies on NUMMI and other cases of lean internationalisation showed, successful implementation of lean depends on some organisational conditions such as the presence of a lean culture within a factory, the wide implementation of the various lean practices, and the existence of cooperative relations with customers and suppliers (e.g., Dyer and Nobeoka 2000; Shook 2010; Bortolotti et al. 2015a). For example, Bortolotti et al. (2015a) found that successful lean factories distinguish from manufacturing units that implement lean obtaining lower operational performance in terms of a lower assertiveness.

The environmental conditions of a country can favour or hinder lean implementation. For example, countries such as India, Malaysia, or Thailand are characterized by a high score on assertiveness (House et al. 2004); such incongruence between socio- and ideal lean cultural values is likely to make lean implementation more difficult (Wincel and Kull 2013). Similarly, also political-legal, economic, and educational conditions can influence lean implementation and its effectiveness (Mefford and Bruun 1998; Prasad and Tata 2003). In order to successfully internationalise lean manufacturing, it is thus fundamental to understand how factors describing the international environmental conditions affect lean implementation. Although a number of studies have focused on such phenomenon, they provided a partial perspective and literature is still missing a holistic framework on the internationalisation of lean manufacturing. In the attempt to enhance the understanding of such topic, our study provides a broader perspective, considering the impact of all the four dimensions describing international environmental conditions on the implementation of internally as well as externally related lean practices.

3 Methodology

In order to explain how international environment differences, in terms of socio-cultural, political-legal, economic, and educational environmental conditions, influence the internationalisation of lean implementation by determining criticalities in the implementation of internally related as well as externally related lean practices, an empirical research based on a single case study was designed. In fact, this methodology allows to provide an in-depth description of the phenomenon under examination (Yin 1994; Voss et al. 2002).

Theoretical sampling approach guided the selection of the case study (Eisenhardt 1989). First of all, we chose a case in which the phenomenon under

Table 2 Overview of the case

Firm's general information	Factory which designed and implemented lean internationalisation projects	Recipient non-lean factories	
		Project 1—Chinese subsidiary	Project 2—Chinese suppliers
The firm including nine manufacturing units in three continents (Asia, North America, and Europe) Headquarters in France Products range: critical power, power control and safety, energy efficiency, and solar power solutions	Italian factory It produces products and services relate to high-availability power supplies to critical applications for the European market	Subsidiary located in Shanghai (China) About 40 employees—mainly local—work in the factory It provides products and services relate to high-availability power supplies to critical applications for the Chinese market	Factories located in China (the majority in Shanghai) Typically more than 100 employees—mainly local—work in each factory It provides various sub-systems and materials

study was "transparently observable" (Pettigrew 1988); longstanding collaboration between the firm and researchers was crucial for assuring access to sensitive data. Second, we selected a firm which had recently launched lean internationalisation projects towards a foreign subsidiary as well as foreign suppliers so as to provide evidence of problems in diffusing internally related as well as externally related lean practices. Moreover, we verified that the factory which had designed and implemented lean internationalisation projects had a high competence in the lean method and that the lean internationalisation projects were successful (i.e., lean practices persisted in the recipient factories over time), while the foreign subsidiary and suppliers were non-lean factories at the beginning of the lean knowledge transfer project. This process resulted in the selection of an Italian factory excellent in lean that transferred lean towards the Chinese non-lean subsidiary and its supplier base (see Table 2 for further details). To preserve confidentiality, we did not disclose the name of the firm.

As suggested by Yin (1994), we created a case study research protocol before embarking upon the research so as to enhance the reliability and validity of the case. This protocol guided the overall study design and execution. It comprised six main sections descended from the literature on the internationalisation of supply network and lean manufacturing. These sections are: (1) socio-cultural differences, (2) political-legal differences, (3) economic differences, (4) educational differences, (5) problems in the implementation of internally related lean practices, and (6) criticalities in the implementation of externally related lean practices. For each section the protocol listed some issues to be examined, thus assuring the researchers to gather complete and useful data on the lean internationalisation projects. In particular, this research protocol guided a series of semi-structured interviews.

Managers in charge of every lean internationalisation project and their close collaborators were interviewed in the period between March 2013 and November 2014. Both the researchers participated at all the interviews, which ranged from 90 to 160 min. We recorded and painstakingly transcribed each interview. In addition, we analyzed firm's documents (e.g., firm's internal documents on lean internationalisation projects, handbook of lean practices, documents on KPIs trends, etc.). Finally, we also participated to guided-tours of the Italian factory and two main suppliers which allowed direct observations of internally related and externally related lean practices used by the firm. As suggested by several scholars (e.g., Eisenhardt 1989; McCutcheon and Meredith 1993), in order to increase research reliability we triangulated information from interviews with those in firm's documents and collected through other methods.

Data analysis relied on an iterative approach, which involved frequent steps back and forth among the data. This is also a result of frequent discussions of preliminary analysis among the researchers and managers involved in the lean internationalisation projects.

4 Background and Overview of the Lean Internationalisation Projects

In 2005 the Italian factory started the implementation of internally related lean practices, while first lean initiatives with local suppliers—i.e., the adoption of externally related lean practices—were launched a year later. The joint effort in implementing lean method allowed to significantly improve the quality of the products, which was crucial to guarantee no damages to customers' production machineries. Moreover, it led to reduce costs of manufacturing as well as to enhance delivery performance. Considering these important improvements, the headquarters made the Italian factory responsible for developing a new subsidiary in China and its supply based according to lean method.

First, a lean internationalisation project was launched in late 2008, when was established the new Chinese subsidiary. After various weeks of training in the Italian factory (only for key foreign managers), some Italian lean managers moved to China to support training activities and production start-up. Since this overseas factory would have provided products and services specifically for the Chinese market, it was necessary to involve Chinese suppliers to create highly valuable solutions for foreign customers. Therefore, a second project was launched in late 2009 to create a lean supply base in collaboration between Italian and Chinese lean managers.

Several problems occurred during both the projects, which can be linked to the environment conditions. Table 3 illustrates some of the major problems encountered during the implementation of internally related as well externally related lean practices. Next section discusses these problems with respect to socio-cultural, political-legal, economic, and educational environmental conditions.

Table 3 Main problems occurred during the internationalisation of lean manufacturing

Sub-bundles of lean practices	Problems
Internally related practices	Lack of self-initiative, little participation to improvement and problem-solving initiatives, difficulties in providing suggestions (e.g., how to improve an activity) or even simpler information (e.g., whether they feel safe or are satisfy about work conditions, elucidations of lean standards during training, etc.); problems in the start-up of the foreign subsidiary such as in importing machineries and materials from Italy, selecting qualified employees, defining effective incentives; slowdowns in lean activities and stop of some improvement actions, precluding continuous improvement and resulting in declines in the subsidiary's productivity; need for several adaptations, such as for tools, work instructions, suggestion systems, and KPIs boards, towards more visual solutions; need for easier solutions when implementing lean practices, such as fewer operations for each work station, less automation, stock division to make flow of materials more visible, etc.; communication problems and misunderstandings
Externally related practices	Sub-systems which not met Italian factory's quality requirements and/or the planned delivery time; problems in Chinese supplier involvement in quality improvement programs; problems in exporting some products made only by the Chinese subsidiary to Europe; difficulties in involving customers and suppliers in joint improvement initiatives; difficulties in developing close relations with customers and suppliers; difficulties in implementing JIT (e.g., high cost, need for controlling inflow materials, etc.); problems in communications with suppliers; difficulties with making suppliers accept high levels of standard quality; defective sub-systems sent back several times

5 The Influence of Environment Conditions on Lean Manufacturing Internationalisation

As shown in Table 2, several problems affected the lean internationalisation projects launched by the Italian factory towards China. With regard to the internally related lean practices, some criticalities, such as lack of self-initiative and little participation, are likely to be explained by socio-cultural differences between the countries. For example, the high power distance seems to be a prominent cause of the little participation of Chinese workers in learning sessions as well as in team-based improvement initiatives. An Italian manager involved in the lean internationalisation project towards the Chinese subsidiary reported:

> We have struggled with making them participating in improvement activities. Operators used to wait for supervisors' orders, thus had difficulties in providing suggestions on how to improve activities or solve problems. They were worried about providing even the simplest information, such as if they have encountered problems in performing a particular job. […] During learning session they've never asked for clarifications.

Coherent with our findings, some previous studies on the internationalisation of lean manufacturing have shown that the lack of self-initiative and little participation are common attitudes of Chinese workers that reflect Hofstede's (1980) cultural value of high power distance, which have generally hindered the implementation of internally related lean practices (e.g., Aoki 2008; Chen and Bo 2008; Paolini et al. 2005; Hofer et al. 2011). In particular, high power distance was found to impede the involvement of employees—especially of operators at lower level of the organisation—in training, suggestion and improvement programs and problem solving teams (Aoki 2008; Hofer et al. 2011). Mefford and Bruun (1998) explained that paternalistic relations between managers and employees are a cultural obstacle to lean that is common to various developing countries. For example, Kenney and Florida (1994) have indicated the lack of responsibility-taking and active participation of the workforce as a barrier in lean implementation in the Maquilas (Mexico).

More recently, Kull and his research team have taken a global perspective in exploring the role of national culture in determining the effectiveness of internally related lean practices (see Wincel and Kull 2013; Kull et al. 2014). Their analysis conducted on the Global Manufacturing Research Group dataset—which includes 1453 facilities from twenty-four countries and twenty-two industries—showed that the GLOBE culture dimensions of future orientation, performance orientation, and assertiveness have a negative effect on lean implementation effectiveness. Basing on these results, they suggested to rank countries from ones that tend to be "the most hospitable" to lean to those where lean is likely to be more difficult to implement. They concluded that (Wincel and Kull 2013, p. 104): "Many of the Western industrialized nations, including the United Stated, demonstrated a relatively low level of lean effectiveness. Many Eastern European and Asian-Pacific nations showed the highest effectiveness. It can be interpreted from the data that countries like Croatia, Korea, Albania, Macedonia, and Taiwan have country cultures that are more aligned with the key underlying lean values than countries such as New Zealand, Italy, Canada, and the Unites States."

Socio-cultural differences are likely to explain also various criticalities in the implementation of externally related lean practices. Our observations show that there were supply problems for some sub-systems which not met Italian factory's quality requirements and/or the planned delivery time. As Italian managers explained, these problems occurred because Chinese suppliers paid no grate attention to performance requirements; in turn this attitude is likely to be a reflection of the low level of performance orientation of the Chinese country (House et al. 2004; Naor et al. 2010). In addition, as for internally related lean practices, the high power distance is likely to explain observed problems in Chinese supplier involvement in quality improvement programs:

> We had also problems in making suppliers participating in improvement activities. As for Chinese subsidiary's employees, suppliers had difficulties in providing suggestions and feared in giving also simple information.

These findings are in line with some previous studies analyzing the impact of national culture on externally related lean practices. For example, Zhao et al. (2006) indicated China's unique cultural characteristics as a leading reason to challenging collaborations with supply chain partners. Similarly, Dyer and Nobeoka (2000) observed that Toyota initially had difficulties when interacting with suppliers of the factory in Georgetown (Kentucky) because of the low inter-organisational cooperation, which was typical among supply chain counterparts in the US.

Second, the analysis of the lean internationalisation projects launched by the Italian firm towards China suggests that some of criticalities affecting the implementation of internally related as well as externally related lean practices can be traced to political-legal conditions. For example, the Italian managers reported problems in the start-up of the foreign subsidiary due to the presence of differences in rule setting and enforcement between various areas of China:

> We found a lot of difficulties during the initial phases of the [lean internationalisation] project. We had to learn rules concerning the introduction of the material… we initially imported everything – machineries, materials, etc. – from Italy; but some things were not allowed, thus needing changes. We didn't know how to find right workers and which incentive systems were more effective to promote lean implementation in China. […] Differences between the Italian and Chinese rules were the first obstacle; differences in rule setting and enforcement between areas were a further challenge. For example, districts in Shanghai are more expensive, and then you need to pay a higher salary to retain workers.

In line with these findings, Shie (2004) observed that in China most regulations are mere guidelines and do not represent formal laws; in addition, marked rivalries between areas (e.g., provinces, towns, and local administrative districts) contribute in determining differences in rule setting and enforcement (Handfield and McCormack 2005), which can hinder lean implementation projects (Hofer et al. 2011). Some scholars also found that the Government can negatively influence lean practices concerning people management and training programs (Dian-Xiang and Willborn 1990; Ehrenberg and Stupak 1994). This is also the case of China, where programs can not be in contrast with "the policies of the Government" (Dian-Xiang and Willborn 1990). According to some authors (e.g., Cole and Deskins 1989; Kenney and Florida 1995; Liker and Meier 2006), labour unions such as those present in the U.S. or in other developed country can also hamper lean practice implementation, and in particular cross-training and teamwork.

As for internally related lean practices, political-legal characteristics of a country can also hinder supply chain lean practices. Our observations suggest that, for example, the Italian firm has encountered problems with some products made only by the Chinese subsidiary but sold also to European customers. Such products included a sub-system that was produced by Chinese suppliers in accordance with Chinese certification's requirements; unfortunately, such requirements were less demanding then ones essential for the commercialisation and use in the European Union.

The literature provides other examples of a negative impact of political-legal conditions of a country on externally related lean practice implementation. For example, Forker (1990) observed that quality levels remained stagnant in countries characterized by closed market—e.g., the former Soviet Union. Jayaram et al. (2010) analyzed 2000 manufacturing firms in 48 states in the U.S. and Puerto Rico and found that there were significant differences between unionized versus non-unionized factories in the approach and effectiveness to managing supplier quality efforts.

Third, economic differences between the countries were also found to hinder the internationalisation of lean manufacturing. From the analysis of the case study it emerges that the high employee turnover was a major cause of problems in the implementation of internally related lean practices in the Chinese subsidiary. Dismissal of several operators and of the operations manager caused repeated slowdowns in lean activities, which resulted in declines in the subsidiary's productivity. An Italian manager observed:

> The high employee turnover is a main criticality of China; it put a strain on the sustainability of the lean project. Much time had to be spent for training new and new employees [i.e., workers who replaced dismissed ones] on lean working method. Instead of focusing in enhancing lean knowledge of more experienced operators, we needed them to train new operators. […] [After operations manager dismissal,] some improvement initiatives needed to be momentarily stopped, thus precluding continuous improvement.

Several previous studies in the literature pointed to economic conditions of a country in general, and high turnover rate in particular, as a barrier to lean implementation. Many authors indicated high employee turnover as a main impediment to employee involvement in China (e.g., Taj 2005; Aoki 2008; Hofer et al. 2011). Similarly, other scholars observed that high turnover rate also hindered lean implementation in other developing countries, such as Brazil (e.g., Humphrey 1995; Wallace 2004) and Mexico (Kenney and Florida 1994; Mefford and Bruun 1998).

Economic conditions can also hider the implementation of externally related lean practices. The Italian managers reported a number of criticalities in lean initiatives involving supply chain partners linked to economic conditions. In particular, the high employee turnover characterizing both suppliers' and customers' factories has been an obstacle for their involvement in joint improvement initiatives as well as for the development of close relations. In addition, the great distance from qualified suppliers together with poor conditions of infrastructure hindered the implementation of JIT. In fact, frequent deliveries were too expensive, and the need of controlling the qualities of supplied materials precluded the creation of a pull system with suppliers.

Some scholars dealing with the internationalisation of lean manufacturing provided similar findings. For example, Lawrence and Lewis (1993) indicated high employee turnover as a major economic factor hindering inter-organisational relationship development in China. In addition, Yavas and Burrows (1994) and Paolini et al. (2005) observed that the geographic distances combine with poor infrastructures seemed to affect quality problems in China and other Asiatic countries. They explained that, for example, poor road conditions can cause traffic jams, breakdowns of delivery vehicles or extensive vibrations during transport, which in turn are likely to affect delivery and quality performance. These findings are also consistent with observation of Mefford and Bruun (1998), which indicated poor infrastructure among the main obstacle for JIT implementation in Mexico.

Finally, lean internationalisation project effectiveness can vary according to educational differences between the countries. Our case study shows that educational conditions in China hindered the implementation of internally related practice. For example, low literacy rate required several adaptations of tools, such as work instructions, suggestion systems, and KPIs boards, towards more visual solutions. Local managers were not proficient in the English language, while operators only spoke local language; this hindered the transfer of lean knowledge and forced the Italian managers to opt for easier solutions when implementing lean practices (e.g., fewer operations for each work station, less automation, stock division to make flows of materials more visible, etc.).

In a similar vein, Prasad and Tata (2003) argued that basic education is crucial for the success of training in quality management practices. In particular, a lack of training in statistical tools is among the main causes of the lag on quality management practice implementation in China respect to Western countries (Rao et al. 1999; Zhao et al. 2006). In contrast, higher levels of mathematical education in developed counties such as former communist countries led to faster implementation of quality management practices (Lee et al. 1992; Young 1992). Lack of knowledge and poor education level among shop floor workers were also mentioned as obstacle to lean implementation in other developing countries, such as Brazil (Humphrey 1995; Wallace 2004), Mexico (Kenney and Florida 1994; Mefford and Bruun 1998) and India (Dhandapani et al. 2004; Seth and Tripathi 2005). In particular, Seth and Tripathi (2005) observed that low education reflected in a common view of maintenance as expenditure and not as an investment in India.

Educational differences can also affect the implementation of externally related lean practices. In our case study the Italian managers reported problems in communication with suppliers due to poor language skills (as in case of employees in the Chinese subsidiary, suppliers were not proficient in the English language). In addition, different meanings attributed to words such as "quality" concept led to supply problems; for instance, materials not always met the requirements specified by the Italian factory.

> Our products are critical for the production activities of our customers. We can't sell a defective product – also if the defect is little –, then risk a failure that can damage customers' machineries. Also suppliers must respect the same quality standards. […] At first there were several problems with Chinese suppliers; we sent back defective sub-systems several times. They have had difficulties with accepting such high levels of quality. It was not easy to explain them our quality standards.

Similarly to internally related lean practices, factors such as lack of training and education can also hider the implementation of JIT or the development of quality improvement programs with suppliers. For example, Ismail Salaheldin (2005) found that among the main problems in implementation JIT in Egyptian manufacturing firms there was a lack of formal training/education for suppliers.

Based on the findings from our case study and evidence from the literature, it appears that the the socio-cultural, political-legal, economic, and educational differences in the international environment can influence the implementation of internally related as well as externally related lean practices. Hence, we propose the following proposition which summarizes the general relation between the environmental conditions and lean practice implementation:

Proposition *International environmental conditions will influence the implementation of lean manufacturing*.

6 Conclusions

Many firms which had significantly improved operational performance of the headquarters and local factories through lean implementation have recently launched lean internationalisation projects so as to extend such benefits to foreign subsidiaries and/or suppliers. In fact, lean is almost unanimously recognized as a "universal method", i.e., a method effective in eliminating waste from and continuously improving production as well as supply processes of factories located worldwide (Womack and Jones 1996b; Shah and Ward 2007). Nevertheless, environmental differences between countries can affect lean implementation projects, causing difficulties when adopting lean practices in foreign factories, which can even threatening the success and sustainability of lean internationalisation projects.

This research contributes to the literature by enhancing the understanding of the impact of international environmental conditions on lean internationalisation projects. Previous studies failed in providing a comprehensive view of the phenomenon since they focused on sub-bundle of lean practices and/or only one or few international environmental conditions. Instead, our study based on a holistic framework which involves socio-cultural, political-legal, economic, and educational environmental dimensions, and internally related as well as externally related lean practices. Findings from the case study were compared with evidence from previous significant contributions on the internationalisation of lean (or sub-bundles of lean practices), providing a description of main criticalities affecting the internationalisation of lean manufacturing towards different countries and shedding light on reasons behind them. These results can also guide practitioners in anticipating adaptations and countermeasure definition, thus helping to reduce lean projects' failures.

In concluding on our results, it is important to keep in mind the limitations of the study which can be the basis for interesting future research. In particular, the use of a single case study limits the generalisability of the conclusions. Future multiple cases can be conducted so as to augment external validity. Moreover, the selection of cases belonging to similar versus different environments can be useful so as to outline a taxonomy of main problems affecting lean internationalisation projects. For example, we observed that some contextual conditions are common between developing nations, but different to ones characterizing developed countries (e.g., high power distance/paternalistic relations between managers and employees or high turnover rate in China, Mexico, Brazil, etc. versus well-established labour unions in U.S. and other developed nations); this reflects on the presence of similar problems within a type of nation, and different criticalities between developing and developed countries (e.g., lack of self-initiative and low participation to problem solving activities versus difficulties in effectively applying cross-training). Classifying problems between macro-areas—such developing and developed countries—can be useful for supporting practitioners in countermeasure definition, by helping them in defining solutions effective in various countries.

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Lean Supply Chain Model and Application in an Italian Fashion Luxury Company

Gionata Carmignani

Abstract Since many years the lean production paradigm has found many applications in a lot of different organizations. The necessity, for every organization, to reduce wastes and to make more efficient the way to operate has become a dogma. However, there are many cases of failure in the implementation of lean methodology that can be found in the literature. These failures are due to the fact that the techniques and tools of lean production must be accompanied by a careful analysis of the market environment, the product, the field in which the organization operates and not least the characteristics of the supply chain. The field of fashion and luxury has very particular characteristics in the way of realizing the products along the supply chain. Therefore, it is necessary to establish the appropriate methods and techniques to implement the methodologies of lean production. In this paper an structured approach for the development of a lean management project is presented highlighting what are the characteristics of this particular sector. Thanks to the application and integration of the principles of Lean Production and Total Quality Management it was possible to line up the suppliers craftsman production with the management requirements of the luxury industry, in order to obtain a better interaction between the actors of supply chain, higher product quality and maximize productivity. A case study, applied in a major Italian company in the fashion industry, is reported to validate the proposed approach.

Keywords Lean production · Fashion/luxury field · Supply chain management · Quality management

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1 Introduction

Nowadays getting the right product, at the right price, at the right time to the consumer is not the linchpin to competitive success but also the key survival (Christofer and Towill 2001). For this reason companies have defined some critical factors to line up their strategies for the future in order to assure them a long term success. One of these factors is Flexibility. Because of shorter product lifecycles and a rising product variety the industry today faces enormous challenges concerning the satisfaction of the customers demand (Matternich et al. 2013). But what does really flexibility mean? Flexibility is the ability to realize changes within a certain band width, which has been predefined in the planning phase of the production system, in order to react to expectable variations (Nyhuis et al. 2008). One of the most important theories, or better philosophies, to manage flexibility is Lean production (LP) (Sohal and Egglestone 1994). LP is more than a manufacturing technique, it is a different to way of viewing the internal activities: labor relationships, the way operations are done, and the way value is added. Therefore, the way used to measure it should be different (Duque and Cadavid 2007). All instruments about LP have the important goal to reduce waste and to bring the organization to maximize efficiency. In addition, the principle of LP significantly shifts the trade-off between productivity and quality (Holweg 2006). Regarding quality, there is a very successful methodology that has its roots in LP, that however has a different way of implementation, this instrument is Total Quality management (TQM). Thanks to TQM's principles the decision to implement quality has moved up from the quality assurance level of inspection into the boardrooms of top executives who seek to integrate quality into the strategic game plan of their organizations (Almaraz 1994). Moreover, TQM's adoption has significant correlation with production performance and customer-related performance. To meet the increasing demand of high quality goods from sophisticated local and overseas markets, manufacturing companies must continuously improve their efforts in quality operations. Furthermore, TQM has a particular attention towards the control of processes, which allows to manage all organization's elements with synergy to obtain goals. TQM provides a vision, in which everyone in an organization focuses on product, production, and quality improvements (Arawati and Hassanb 2011). During the last twenty years, as we have seen before, many instruments and theories were born and applied to manage the flexibility; but special importance is placed on the relationship between the organizational system and its operative environment (Garrido-Vega et al. 2014). In this context the Supply Chain management (SCM) is considered fundamental to react to change and to customer's needs efficiently. The supply chain (SC) performance, in fact, pushes for initiatives that strive to match supply to demand thereby driving down costs simultaneously with improving customer satisfaction. According to this, the major Japanese car manufacturers have made substantial investments in suppliers development teams (Sako 2004). Moreover, Herron and Hicks (2008) said that LP and SCM can be integrated to bring the superior performance of lean manufacturing systems into non-automotive and non-Japanese industrial realities. For this reason it is very important to create a homogeneous management system inside the supplier's network, that allows each company to cooperate and perform efficiently through the application of identical principles. Generally, methods like SCM, TQM, and LP are applied in industrial organizations separately. However, the integration between the different viewpoints can optimize all processes. TQM and LP have similar goals: continuous improvement, waste reduction, and improving performance (Teeravaraprug et al. 2011). TQM can be considered a base for a variety of concepts, methods, and production tools (Juran 2008). So TQM can be defined a first step before implementing LP (Besterfield 2009). According to this, numerous studies report that LP and TQM create more benefits to a company, but there is still a lack of case studies on companies that have implemented both initiatives in the supply network (Salleh et al. 2012).

The present paper belongs to this stream of research and focuses on the use of principles of LP, TQM, and SCM in the luxury fashion industry. In particular the presented approach want to integrate all principles in a unique and structured framework. The rational among these choices derives from the peculiar characteristic of this sector, which is ruled by complexity, flexibility in types, and volume (Mehrjoo and Pasek 2014). In addition, it is a new sector where it is possible to apply a new approach "to find the best balance between quality and speed" said Patrick-Louis Vuitton. In this context it is important to define the fundamental elements of the luxury field, that can be summarized in the follow points: high level of quality, heritage of craftsmanship, exclusivity of products, emotional appeal, brand reputation, recognizable style, association with a country of origin (Caniato et al. 2008). But what elements create the real needs to apply these principles? First of all the quality of products, which is considered basic in the luxury field, that can be manage efficiently through TQM. Second, the variety of the product, the tight time of production and small volumes create a necessity to apply and adapt some methods of LP to react to discerning guests. Third, the use of many suppliers, not only for the purchasing, but also as outsourcers bring the luxury companies to manage a very high complex flow between partners, so SCM is fundamental. Some companies are investing time in the application of TQM in the luxury field, but actually the result is quite unexpected. Those companies whose quality issues are more relevant (high-luxury) appear to adopt an overall less structured approach to TQM (Brun and Moretto 2014). In addiction there are many studies on SCM in literature, but they are not applied to the luxury sector (Caniato et al. 2011). By contrast the study of SCM in the luxury context is considered a strategic element to obtain the long-term success (Brun and Castelli 2008). Therefore, the application of the principles of LP and TQM within the luxury industry is not immediate and it needs special care compared to other manufacturing industries where these principles have already taken root.

The goal of this paper is to show a homogeneous model of SCM in the luxury context. Thanks to the application and integration of the principles of LP and TQM, it was possible to line up the suppliers production with the management requirements of the luxury industry, in order to obtain a better interaction of the actors of the SC, higher product quality and maximize productivity.

The paper is organized as follows: Sect. 2 pinpoints the main steps of the operating framework to create a interaction between the different principles with the application of specific instruments adapted to luxury industry context. Starting from here in Sect. 3 one relevant industrial case of the real application of the framework is proposed. Finally, conclusion and future developments end the work.

2 The Framework to Implement the Lean/TQM Model in a Luxury Supply Chain

The principles of LP and TQM have been widely diffused and adapted in many sectors. The industry has been implementing such techniques for at least 20 years, instead in the luxury sector they still do not find a real application. Recently, the luxury-fashion context has wanted to test the fusion of craftsmanship and industrial principles, to meet the increasing demands of product variety and quick response. The high fashion companies have always given great importance to product quality and craftsmanship rather than to production efficiency and distribution, as the wide operative margins have always allowed luxury companies satisfactory results. At the same time less expensive brands have developed techniques and methodologies that can identify demand trends quickly and provide the stores with necessary products promptly (every 15 days), by achieving maximum flexibility, maximum efficiency, and customer satisfaction. Their success has induced high-fashion brands to rethink the way they do business: customers do not just want a luxury product, but want it to be available and easily obtainable. “It’s about finding the best balance between quality and speed” said Patrick-Louis Vuitton, the fifth-generation member of the family of the luxury giant.

A very important aspect to be highlighted is the difficulty of implementing LP and TQM standards in the luxury sector, that is characterized by items that require special arrangements and unique adjustments. Carmignani and Zammori (2015) have summarized these characteristics as follows:

- High demand variability and forecasting difficulty;
- Short product lifecycle;
- High product variety and customization;
- High product quality;
- High-rate of production outsourcing;
- High craftsmanship in the production.

These characteristics of luxury companies have an impact on the reality of their suppliers, leading to an increasing network complexity. Outsourcing the production certainly allows luxury companies to have greater flexibility, however as the suppliers are mostly characterized by a craftsman approach with a not structured management system and where know-how is centralized in few people that make decisions based simply on their past experience. Therefore, their working activities

Table 1 Negative influence of the characteristics of luxury-fashion market on Lean techniques

		L_Sc	Sb_C	H_Dv	H_Pc	S_Pl	H_Qr	A_Cr
Culture	Leadership							
	Training	L	L	M				H
	Communication	M	L					
	Customer's focus	L	L					
	Kaizen events				L	L		L
Visual control	One point lessons			L		L		L
	5S technique				L			L
	PokaYoka			M	M			M
	Value stream mapping	L	L	M	L			
	Process KPI	L	L		L	L		L
Just in time	Lot size reduction	H	M	H	H	H	M	
	Pull/Kanban	L	L	H	H	H		
	Load levelling		M	H	H	H	M	
	One piece flow		M	H	H	H	M	
	Quick set up (SMED)				M	M		M
	Cell design		M	M	H	M		
	Mixed model production		L	M	H			
Total productive maintenance	Autonomous maintenance							L
	Focused improvement			M	H			M
	Planned maintenance				M	L		M
Total quality management	Teams	M	L		M			H
	Standardization	L	L	H	H	H		
	PDCA					L		L
	Root cause analysis			L	M			L
	Statistical process control		L	M	H			H

Notes: *H* High negative influence, *M* Medium negative influence, *L* Low negative influence

are not methodical and well organized. Consequently, the management burden for luxury companies increases. Thus, LP and TQM principles must be customized for this reality in order to be applied effectively and reduce the complexity and improve the efficiency. In Table 1 Carmignani and Zammori (2015) show how the tools of LP can influence, positively or negatively, the previously mentioned critical aspects of the luxury sector. It represents a starting point in the definition of the appropriate tools to be applied to each context.

Table 2 Critical factors

Analysis's elements	TQM	Lean production	The integrated framework
Scope	Quality Stakeholder's satisfaction	No wastes, customer's value efficiency	Homogeneous and efficient system of SCM
Processes	Improvement of all organization's processes	Improvement of all production's processes	Manage by processes: define the control points
Continuous improvement	PDCA	Kaizen	– Company's commitment – Responsibility and autonomy of employers – Training and attendance about new principles
Engagement	All stakeholders	All stakeholders	Engagement of employers about operational activity and company's life
Method	– Process control – Objective data – Problem solving	– Just in time – Jidoka – Kaizen	– Processes' mapping – Handy control tools – Reorganization of production flow
Effects	– Company as a "system" – Stakeholder's satisfaction	– Production efficiency – Less wastes – Less flaws	– Systematic company – Structured flows – More capacity of production planning – Less flaws – More accuracy of lead time delivery

As described in the previous section the interaction between TQM and LP is the baseline of the framework necessary to manage efficiently the luxury suppliers network. At the beginning it is important defining which are the different "philosophies" that can contribute positively in the obtainment pre-arranged goals. Furthermore, it is necessary to choose the methods that give the best results during the transition from theory to reality. According to this, Table 2 shows the relation between the principles and the way to adapt and apply them in the luxury supply chain. In particular, in the table the key elements, on which one should make a comparison between the principles of TQM and LP, are explained. In addition, the last column represents the new framework characterized from the integration of the above principles and adapted to luxury sector. This can represents the guideline for implementing these kind of management skills.

At first, it is necessary to act on the processes, by identifying those that are considered fundamental and structuring a process control system that can detect and resolve issues rapidly. In order to obtain a continuous improvement, the higher corporate functions must be committed to the concept, operators must be trained, given responsibility, be motivated, and capable of working independently. It is also crucial to see the company as a system, where each person interacts and

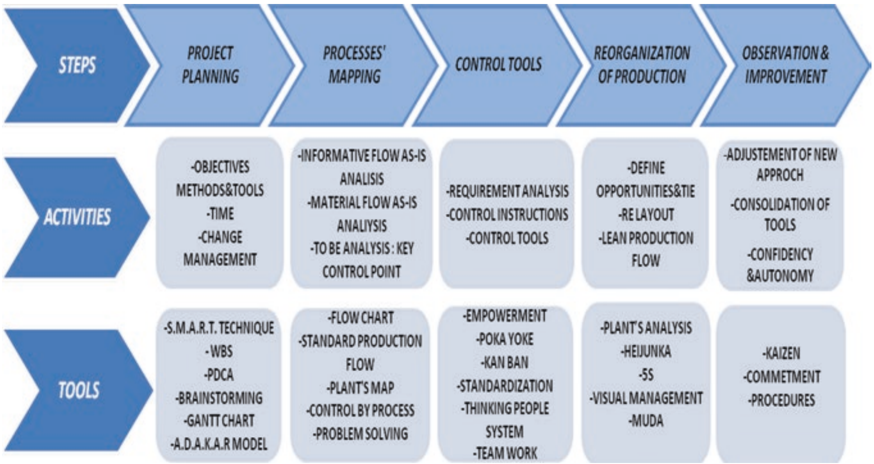


Fig. 1 The integrated framework

co-operates for the common goals; in this context each operator must be involved not only in operative aspects but also in corporate life. This can be achieved thanks to the awareness and knowledge of business processes, by the introduction of handy tools that support production and information activities, and thanks to a smoother production reorganization. With this kind of framework it is possible to achieve positive results in terms of product quality improvement, respect of delivery time, and production management simplification. This positive results are achieved thanks to two fundamental effects: systematic management and a structured production flow. Once the concept behind the framework and the applicable tools are known (Tables 1 and 2), it is necessary to identify the macro-steps to implement the new framework, defining the correct activities and specific tools for each phase. Figure 1 represents the main pillars of the proposed integrated framework.

Before starting the SC improvement process it is necessary to create a project team between the company and its supplier in order to have a sharing of both parties needs. The team must be composed from different professional roles: technical figures, who know very well the sector, the production flow, and product group; quality figures that are focused on the concept of quality assurance; third party production figures that are external to the sector, but have expertise in LP and TQM systems and are able to identify the adjustments required for each different production reality. The steps are the following: Project planning: this step is fundamental to define the strategic objectives. Accordingly the main activities necessary to obtain the objectives are identified. During the planning phase the time interval is establish considering the needs of all the SC actors, the tool used is the Gantt chart. Operative objectives, methods, tools, and monitoring activities for each step of the framework are implemented according to the Gantt chart. To simplify a WBS (Work breakdown structure) is used. Another important part of this stage is the change management activity. This project could be considered invasive by suppliers, which receive external suggestions on how to reorganize their production facilities. For this reason the ADKAR (Hiatt 2006) model is used with training and engagement of both companies. In particular, this model is characterized by the follow points:

- Awareness: an organization must know why they need the change they are willing to implement;
- Desire: every member of the organization must be interested to participate in the change management process;
- Knowledge: recognizing that change is necessary is not enough; we must identify the required tools;
- Ability: an organization that really wants to change has to develop the skills of its members in order to be able to implement and sustain the change over the time;
- Reinforcement (support): people should be supported during and after the change in order to avoid that they feel abandoned and tend to return to the previous situation.

At the end of this step a document denominated “Project Charter” is created that allows to collect and update the planning activities.

Process Mapping: it is necessary to define the suppliers information and material flow “AS-IS” situation. The analysis of these two aspects give the possibility to study both the operational and managerial organization of a company. Therefore, obtaining an overview of the whole management system. This analysis represents the starting point to establish the critical elements to change and the possible solutions. Through an information flow chart and thanks to the studies of different suppliers production system, it is possible to identify the common points and create a general modus operandi to manage the network complexity. This model is the result of the analysis of various “TO BE” scenarios, which are based on the theory of “control by processes”, which requires “key control points” (KCP). KCP are particular steps of the information and material flows, in which established points intercept the problems and solve them on the spot. The mapping is considered the project guideline towards the obtainment of improvement in all the supply chain. Control tools: different kind of tools allow to weaken the management centralization in manner that each employee can be more confident and independent on his activities. Once defined the control points and the several operative instructions, each supplier can realize some handy tools, based on each organization’s needs, to develop and formalize the companies information and establish the empowerment process. The important goal of these tools is to “do right at the first time”. According to this, the main tool characteristics are summarized in the follow points: useful, practical, clear, simple and immediate, easy updatable, comprehensive information content, easily available and easily transportable.

Reorganization of production: this step is necessary for the development of the LP flow, that can be obtained through the plant’s improvement and the use of typical "lean" techniques. This kind of production flow allows to manage efficiently the flexibility and the product variability that characterizes the luxury sector. The LP flow means a homogeneous and manageable flow, in which the employee takes part to the value creation process. In this context it is fundamental to model the standard production flow to the plant's characteristics through the re-layout process. Furthermore, the application of 5S and Visual Management creates a more structured flow. Finally, this will optimize space, allow to reduce effort, cost, speed operations, and above all limit defective output; leading the suppliers towards confidence and professional management.

Observation and improvement: at the end of the application of the previous steps there is a consolidation moment, during which all companies requirements are line up to the project. Moreover, all organization levels have to make confidence with the new integrated framework and obtain the appropriate autonomy in respect to their management. This aspect is realized though managers commitment, sharing of the new principles to employees and training. With these assumptions the company will be able to operate in the systematic way and will be focused on continuous improvement.

3 The Case Study in a Italian Luxury Fashion Company

The new integrated framework has found its first application at a famous Italian Luxury Brand (ILB). This company is considerate one of the best 10 luxury companies in the world. Since 2013 the ILB started a continuous improvement in its production field. This strategy is considered an extension, in matter of production systems, of the holding policy of which ILB is part. To respect holding's policy the ILB, having the 90 % of leather goods production outsourced, decided to line up its suppliers to TQM and LP principles, with the intention of simplifying the management of the complex production system by making the SC more efficient. The ILB's project has been called "Lean and Quality Management in the Supply Network" in order to emphasize the desire to create a new management model, leaded by the integration of these LP and TQM philosophies, and capable to overcome the boundaries of craftsman production realities. Following this idea, Table 3 illustrates the relationship between the critical factors of the supplier and the project objectives set by the ILB.

The first column represents the limits of the AS-IS supplier situation that must be overcome, while in the second column is defined the strategic objective with a description of the foreseen improvement. It is important to point out that each step of the new framework has been applied in the ILB project in order to achieve the goals previously defined. On the contrary, it is possible to apply only specific aspects of the framework according to the needs. In particular, over the six month project period, six different suppliers were analyzed, two of small leather goods and four between bag suppliers; each supplier with its peculiar structure and management skills. The improvement process was activated almost simultaneously so as to identify the project effects on the supply chain in the short-term. Following the phase introduced in the previous section, the approach's steps are described in the next.

3.1 Project Planning

In addition to the definition of the objectives described above (Table 3), the production planning outlined the project time scheduling (Fig. 2), by means of a Gantt chart, and the necessary operational activities for the framework implementation. The following WBS, for example, allows to schedule tasks regarding a particular process: in detail the WBS has been developed in order to evidence the preliminary work necessary to study the main process, the operative activities, the tools required and the monitoring activities.

3.2 Processes Mapping

For the information and material mapping three different organization areas are defined on which the analysis should be focused: office (the administrative point), warehouse (the transit and storage point of materials and products), production division (the operative area). At the same time some key processes have been determined to establish the baseline of the mapping. In particular, the analysis of the information flow allows to have a clear vision of how the company creates relationships with the different actors of the network. This kind of mapping allows to highlight data, information and documents that are exchanged. There are

Table 3 The goals of changement

Supplier profile	→	Goals of changement	
Final inspection of finish product	→	Control by processes	Establish a formal control during the steps of production, to intercept and solve the problems timely
Management centralization	→	Autonomy and responsibility	Each employer has to work in autonomy, being the own responsible of his operation. the empowerment brings more motivation and efficiency
Unstructured production flow	→	Lean production flow	Useful to manage the flexibility and the mix of production
Craft quality	→	Quality assurance	Certain and uniform quality, with the standardization of some activities

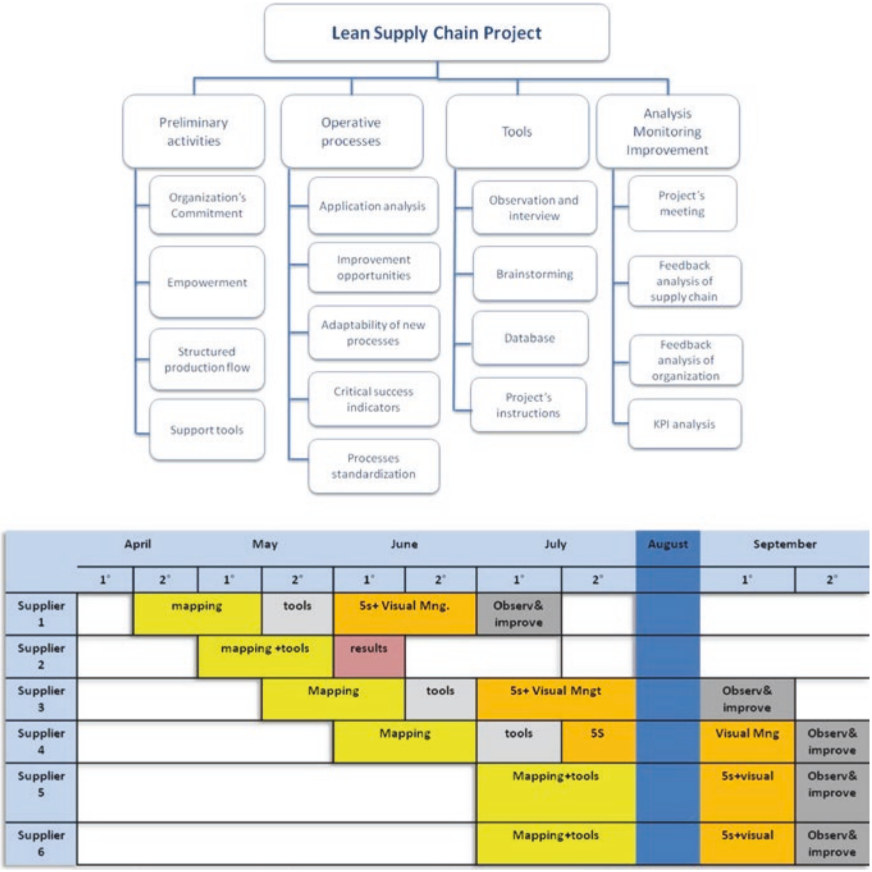


Fig. 2 WBS and GANTT chart for planning phase

several techniques to perform this mapping. This project has decided to use the flowchart (Fig. 3) because it represents better the dynamicity of the information management.

To obtain a more useful maps it was necessary to identify the key processes of the company. The main stages that affect the supplier-ILB relationship during product production were identified. The TO-BE mapping has focused on creating a control during the process production system, by identifying the key control points that can be adapted to each supplier management system, in order to align all suppliers to the same working method. Table 4 shows the relation between the key processes and their scope, with the third column representing the established control points. These points emphasize aspects that vary from production planning to stage by stage production control, with the purpose of assuring quality and maximizing productivity.

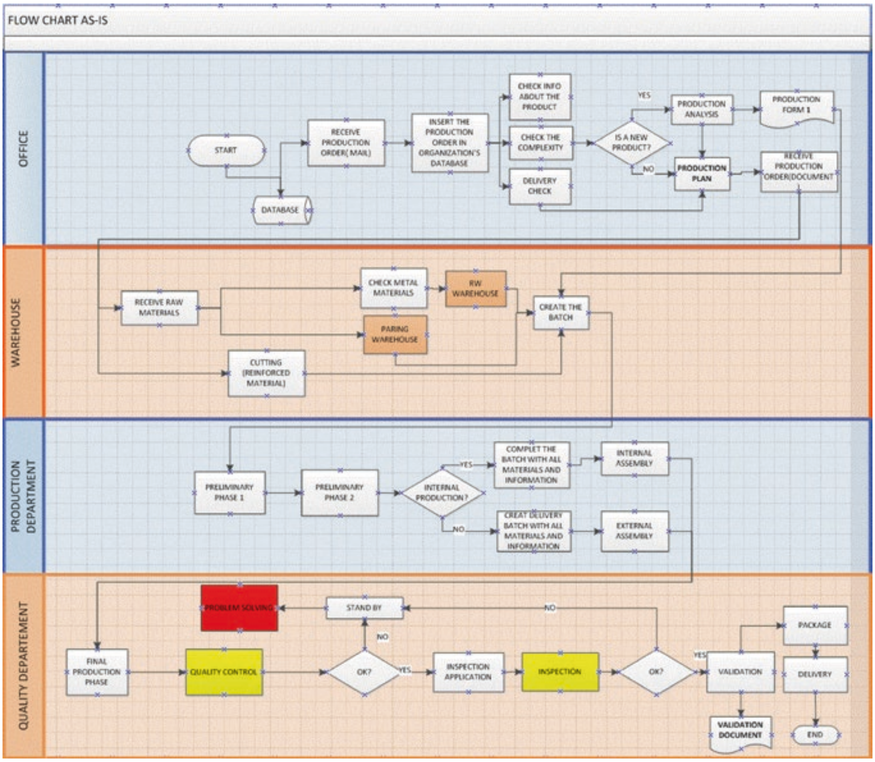


Fig. 3 Flow chart AS-IS

3.3 Control Tools

The definition of the control tools can be considered the main project's step, because the different type of tools support the important transition to "control by processes". For this reason each key control point has to be fitted out with handy and useful tools that allow each operator to work in autonomy and without errors thanks to appropriate instructions. Therefore each supplier was able to create a structured information system that follows simultaneously its supply chain, from planning to delivery. In Table 5, a set of appropriate tools and performance indexes are presented.

The most important tool is the "Work record", which has the fundamental function to record and systematize the production process control. With this tool, it is possible to keep trace of the "history" of the production lot and formalizes the control activities.

Table 4 Relation between processes and key control points

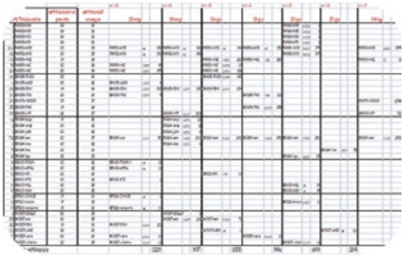
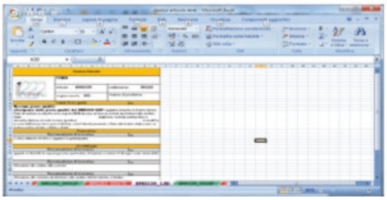
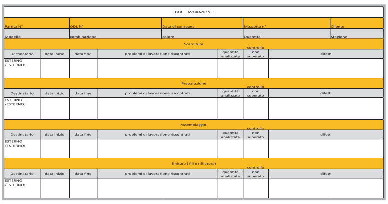
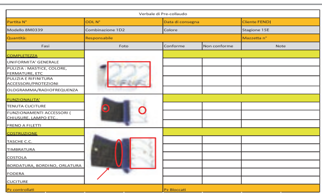
Key processes	Description	Key control points
Production scheduling	Process is extended from the arrival of the ILB order to the creation the internal production organization	Order's management
Realization of production kits	Process from receipt of materials to the physical creation of job batches. This phase is focused on the warehouse activities and information	Control at the entrance of raw materials
Internal production	Process that shows the information and the physical flows of the batch in the production area: preparation and assembly phases. In particular are analyzed the replenish management of materials	Control during production process: preparation; assembly; finishing
External production	A part of suppliers production is demanded to sub-contractors, so it is important to understand the logic of order assignment and the interaction between the parties	Control at the entrance of external production
Final step	This process is consisted in a control of the finished product, that thanks to the collaboration of the ILB quality inspectors, intercepts defected products	Final control

3.4 Production Re-design

The production re-design phase is fundamental to create a manageable production flow; usually suppliers plant is organized with a Job-Shop layout because of the variety in volumes and type typical of the luxury-fashion production. According to this, the main goals of this step are to define: (i) plant space optimization, (ii) movement of materials and people should be accelerated and structured and (iii) the organization of the different production divisions is based on the standard production flow. The positive element of this stage is the adaptability of the machines, in fact they work in autonomy and do not need particular assets, except power units. In Fig. 4 an example of a re-layout analysis of a bag supplier is reported.

In each company the application of 5S's bring to have a more structured and systematic flow. Furthermore, this method has created many daily procedures about separation, accommodation, organization, and control. These are essential to obtain a smooth and efficient flow of activities. On the contrary, visual management is focused on visibility of the production development in real time, the

Table 5 Control tools

Key point control	Handy tools	Application
Planning of production	**Weekly scheduling**: Production plan: q.nty tot; q.nty weekly; target delivery date; expected delivery date; allocation to subcontractors	
The raw material control	**Master of materials**: Physical examples of raw materials conform to acceptable levels defined for a quantitative and qualitative control	 
Internal production control Esternal production control	**Master of production phases**: Examples of physical working cycles of each article **The product's story**: Collection of all technical notes of working through an updatable database in Excel **Working paper**: Formal document that is drawn and batch control for each stage of processing both internal and external	   
Final control	**Check list of final control**: It is a guide to the process of final inspection, which are defined for each item the most critical aspects and the data is plotted on the compliance of the final lot	

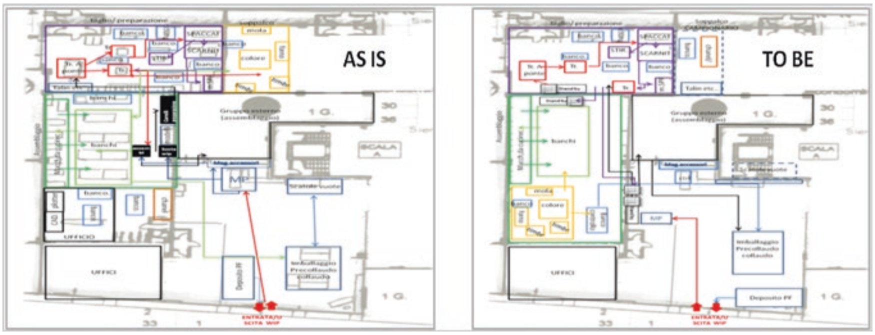


Fig. 4 The re-layout

Fig. 5 5S and visual management application

information is more immediate, and it represents an instrument to engage the employee with production life. In Fig. 5 the results of 5S and Visual Management application are illustrated, passing through the warehouse, production division, and physical control points.

3.5 Results

The application of the new integrated framework in the luxury SC has obtained tangible results. This can be derived from objective data and they are the immediate consequence of the project. One of the most important result concerns the Defective output which is reduced dramatically, as shown in Fig. 6. This is

Fig. 6 Defective output

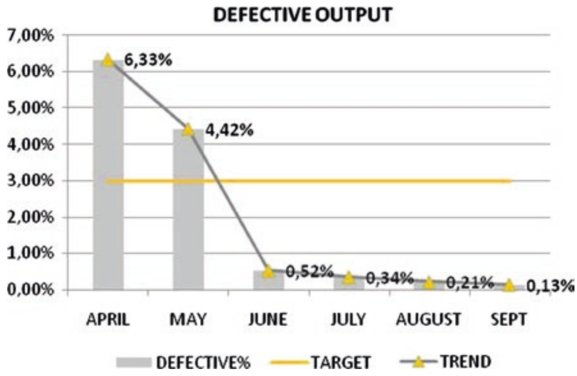
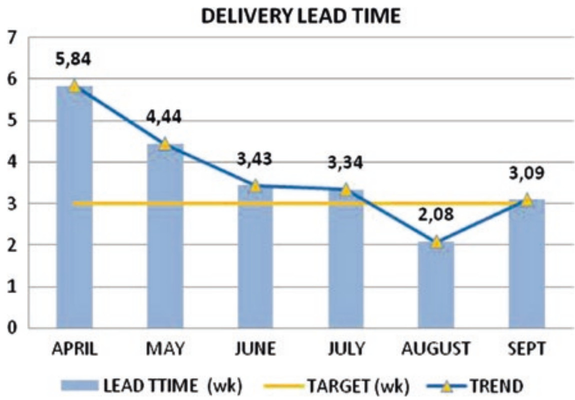


Fig. 7 Delivery lead time



obtained through to the gradual introduction and application of the process control, control tools and formalization of information.

Another aspect regards the respect of Lead time delivery and Forecasted capacity. This result (Fig. 7) leads to the achievement of a better management of the whole system: planning, production flow, and staff involvement.

In particular the Forecasted capacity in the second part of the project tends to respect the tolerance band (Fig. 8). It should be emphasized that this aspect requires time to be assimilated, especially within a not very structured craftsman context.

Another important result concerns the ability of the organization to maintain and improve in a systematic way the new management system. The real effect of the project will be found in the medium-long term, when the suppliers will identify opportunities for improvement autonomously.

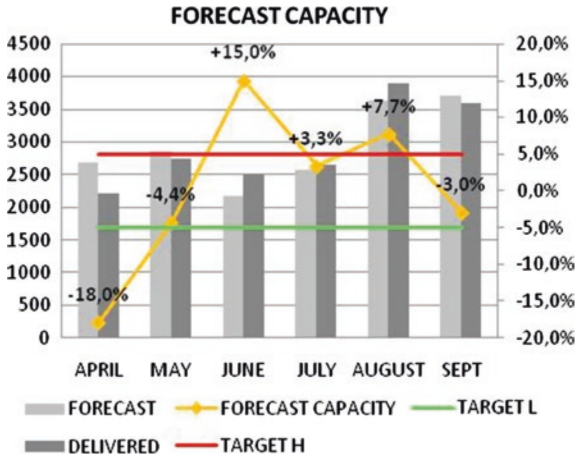


Fig. 8 Forecast capacity

4 Conclusion

This paper has shown that industrial principles such as LP and TQM can be implemented and integrated in a structured framework of SCM also in the luxury sector, without limiting the exclusivity and the attention to detail that characterize the luxury products. A very important aspect to be highlighted is the difficulty of implementing these approaches in the luxury sector, characterized by items that require special arrangements and adjustments. Moving from this premise, the paper identified the LP and TQM techniques that can be integrated and adapted to the context. Then, an empirical path was traced, based on the main pillars that allow to study the AS-IS situation and to define the TO-BE scenario, which is considered an improvement thanks to the introduction of handy tools that are useful to create a more smooth production flow. This new framework can be considered a starting point to define different models to manage a Luxury Supply Chain, standardizing the way of working of the suppliers to the corporate standards. It is desirable, in the future, that there can be a technology uniformity, applying to the entire network the same IT system, so the suppliers can speak the same language and use standardize procedures. Another opportunity for growth, about the control of processes, regards the possibility of computerizing the information, in such a way the data concerning the control are collected in a database and used to evaluate indicators such as: defects, production times, extra-production, etc. useful for the company to monitor its performance about production progress giving also a feedback to the luxury company. Of course to do this, it is important to develop the skills and expertise of its operators. It is also important to emphasize how this model can be applied not only to outsourcers companies, but also to contractors of raw materials and especially to the sub-contractors, so the network is aligned to the same framework. This way brings to have independent companies but which act with the same principles and above all the luxury targets become common and shared, bringing greater efficiency of the Supply Chain Network.

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Strategic Planning for Lean Production, Comparing Hoshin Kanri with Balanced Scorecard

Andrea Chiarini and Emidia Vagnoni

Abstract Some authors believed that Lean has to be strategically implemented just in a bottom-up way, involving production processes and trying to reduce waste in the so-called *Gemba* or shop-floor. However, since the 1990s many companies have implemented the Balanced Scorecard, integrating economic and financial strategies with strategies linked to operations management in general, to widen the satisfaction of their different stakeholders. In this way it can be affirmed that BSC is a well-consolidated system for deploying Lean strategies. However, BSC is not the only system that can be related to Lean deployment. Since the 1960s, a similar system has been put forward in Japan. The system is named Hoshin Kanri and it has been implemented by companies all around the world. This research wants to contribute to the debate concerning how to implement Lean Production from a strategic point of view. In this sense two different systems, Hoshin Kanri and Balanced Scorecard will be compared. The research is based on three manufacturing case studies investigating in particular how to combine the top-down and bottom-up approaches and the techniques used for the deployment and implementation. Interesting findings show a difference in terms of workers involvement and day-by-day performance measurement.

Keywords Strategic management · Hoshin Kanri · BSC · Workers involvement

1 Introduction

Lean Production as other management systems surely requires a strategic planning process (Krajewski et al. 2012). This process initially defines results to be achieved in a middle- to long-term period, which can subsequently be developed

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by using a shorter deployment process. This approach is based on the Deming's *Plan, Do, Check, Act* (PDCA) wheel (Bertezene and Martin 2012) and can linked with the strategical Vision and Mission, finding a solid basis in the *Key Performance Indicators* (KPIs). Total Quality Management (TQM) and Lean have, for this purpose, encouraged organizations to use deployment methods such as Balanced Scorecard, Hoshin Planning that are vital to get the ball rolling and to maintain a system for the excellence.

Lean Production, like many other systems for excellence, is based on the core engine that is continuous improvement or kaizen. In Japanese, the word *Kaizen* is formed by putting together the two words *Kai* and *Zen*. Kai means "to take something apart, to analyze critically", and Zen "to do well": Kaizen literally means taking something apart and then building it up again. Organizationally speaking, the equivalent meaning of Kaizen in the Western world is continuous improvement (Teehan and Tucker 2014): continuously analyzing every process/activity and removing obstacles that stand in the way of improvement. Continuous improvement applies to every process and leads to performance increase and economical/financial results. However, continuous improvement requires strong commitment and effort from management in each and every department. Kaizen is a useful aid that immediately highlights the road that must now be taken. This road, which is rugged and steep and has no final destination for rest and celebration, has to be walked by every worker. Unfortunately many companies are satisfied with the first meager results, and stop there to celebrate, whereas only a few continue their journey towards gold.

Many practitioners and academics believe that Kaizen has to move in a bottom-up direction, from the traditional productive processes and service implementation towards directive processes. However it seems that the so-called classical manufacturing organizations prefer to introduce improvements using a more top-down approach, whereas Japanese organizations tend to concentrate first on production processes (*Gemba*) and subsequently on other functions. In this sense, this research wants to contribute to the debate concerning how to implement Lean Production from a strategic point of view. In this sense two different systems, Hoshin Kanri and Balanced Scorecard will be compared. The research is based on three manufacturing case studies investigating in particular how to combine the top-down and bottom-up approaches and the techniques used for the deployment and implementation.

2 Strategic Management for Lean, Background

Some authors believed that Lean has to be implemented just in a bottom-up way, involving production processes and trying to reduce waste in the so-called *Gemba* or shop-floor (Suarez Barraza et al. 2009; Imai 2012; Mann 2014). By contrast, according to other authors, a top-down approach is more important for implementing Lean (Aaltonen and Ikävalko 2002; Camillus 2008). The approaches illustrated in Fig. 1 have been debated for over twenty years and according to Chiarini (2012), this way of thinking in both cases is not precise and has been surpassed by a different approach which comes from many European (Chiarini and Vagnoni 2015).

Lean organizations prefer a strategic top-down planning and implementation mostly in production/service processes (where most waste is hidden) and later in the remaining functions/processes. To measure these results senior managers have to deploy bottom-up towards production processes starting from strategic objectives. Figure 2 synthesizes this complete approach. It is vital to involve the whole production/service processes; however, if managers only concentrate on improving production, without a strategic plan, the following problems can often arise:

- Launching Kaizen events on behalf of production management, without ensuring that higher management is indeed committed, can result in the system “dwindling” out;

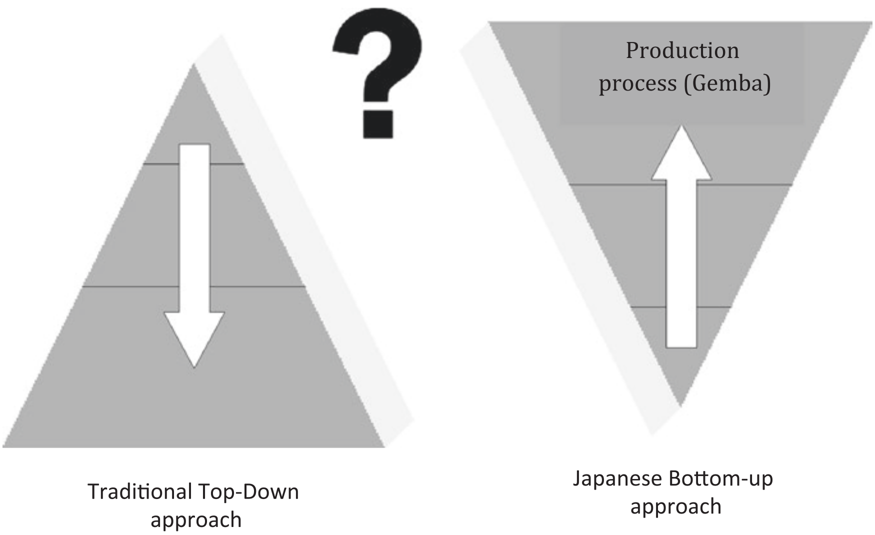

Fig. 1 How improvement should not be approached

Fig. 2 Deployment of a lean system

- Reduction of kinds of waste that is not a priority in company's strategy;
- Using up resources to reduce waste whose root causes lie in other functions such as design, development, trade, sales, etc.;
- Managing improvement projects without adequate resources.

Lean has been implemented so much recently that it has become almost a trend, and many books suggest methods to identify waste without, unfortunately, indicating a strategic route to follow. By analyzing various companies it has become clear that some have launched improvement projects without a clear idea regarding results and goals. According to Chiarini (2012) sometimes managers even do not know how much savings they have achieved through Lean implementation.

Since the 1990s many companies have implemented the Balanced Scorecard (BSC), integrating economic and financial strategies with strategies linked to operations management in general, to widen the satisfaction of their different stakeholders. In this way it can be affirmed that BSC is a well-consolidated system for deploying Lean strategies. However, BSC is not the only system that can be related to Lean deployment.

Since the 1960s, a similar system has been put forward in Japan. The system is named *Hoshin Kanri* and it has been implemented by companies all around the world, companies such as Bridgestone, Hewlett-Packard, Nissan, Xerox, Texas Instruments, Tyco, to mention but a few. Hoshin Kanri is a Japanese system, it stems from the world of Total Quality Management (TQM) and Lean production and it is considered a typical system for quality management (Karaszewski 2010).

Hoshin Kanri has a different approach to the deployment of strategies into actions and performance indicators; in particular, there is no classification into perspectives (Kaplan and Norton 1996; Heavey and Murphy 2012) of the strategic objectives as the BSC does. BSC typically divides the strategic objectives into four perspectives, customer, financial, internal processes, learning and growth. The four BSC perspectives are specifically used by companies for setting strategic goals and objectives related to the market (Braam and Nijssen 2004) even if they can also be used for all operations processes. Moreover, BSC allows managers to link strategies with other strategies; for example, a specific objective for the production or supply chain can be easily linked to its economic and financial impact on the company. Hoshin Kanri offers a similar approach called 'X matrix' for deploying and linking strategies and evaluating correlations among the goals, objectives and measures.

The top-down Japanese target deployment process (development and application) *Hoshin Kanri* is the Japanese equivalent of the American Policy Deployment (Akao 1991; Tennant and Roberts 2001). Hoshin Kanri is managed by various teams, from senior management (business level) to middle management (operation level), reaching the entire workforce that is involved in the Kaizen events.

According to Chiarini (2012) Hoshin Kanri is the fundamental way for implementing Lean achieving measurable results. Through a cyclic process that never ends, every year companies can define short-term goals and Key-Performance-Indicators (KPIs), which are then developed into improvement projects; the results are checked, standardized and then reported to the management, thus allowing result analysis that is then used to set new targets. This complete approach that begins with Mission-Vision is typically found in many systems for excellence such as TQM, Six Sigma and obviously Lean.

3 Methodology

This research is based on a typical qualitative inquiry using three case studies. The case studies are represented by three large sized companies which have been implementing Lean in the last ten years. The companies belong to the manufacturing sector and year in year out they have implemented both the systems, BSC and Hoshin Kanri, comparing the results achieved. The authors conducted observations to collect data and information for the research without interfering with the project (Savage 2000). In order to better analyze and discuss the findings of the observation the findings were discussed with some managers from the companies. Participant and direct observation are typical qualitative methods that lead to the development of theory in an inductive way (Bryman 1988). Limitations of this method are due to the fact that is difficult to generalize the developed theory to other organizations.

The case study format presents some weak spots that could affect the research. In particular it is practical, context-dependent knowledge and it is not as valuable as general context-independent knowledge. Ultimately it is quite difficult to generalize on the basis of few cases.

The three organizations have shown their documents related to the strategic process. However, for confidential reasons, some information and data have been slightly changed.

4 Results from the Observations and Discussion

All the three companies have implemented either BSC or Hoshin Kanri in a typical top-down process. According to the managers, there are five precise steps for the deployment of the Lean strategies:

- Issuing the Mission
- Issuing the Vision
- Issuing the Business Plan (BP)

In particular Mission and Vision are linked to long term planning (3–5 years), while BP is developed in a medium—short period (1–3 years). BSC and Hoshin Kanri are implemented in the third stage of the Business Plan.

Observing the first kind of document, we can say that for all the companies, the mission is the reason why the organization exists and it seems to be:

- As brief as possible
- As motivating and orientating for the staff as possible

According to the managers, when formulating the mission, the following questions must be answered:

- Who are the customers?
- Which customers are the (possibly) more interesting ones?
- What are their needs?
- How do they measure performance?
- Which products/services do they receive?
- Do products/services supplied exceed their expectations?

The below box shows an example of Lean Mission from one of the three companies.

> We aim to supply quality, solutions and profitable products to the members of our community by using our talented human resources. We acknowledge a social and ethical responsibility and strive for the continuous reduction of waste within our processes. We shall respond continuously to the requests of the global hydraulic component market, supply products free from faults, and surprise our customers with our service and ready smile.
>
> The organization's value guides are usually somewhat linked to the Mission; they are the pillars and foundation of the organization itself, basic conduct rules that everyone has to follow. This is yet another example of an excellent manufacturing company.

It is interesting to notice how one of these companies has also issued a list of values which are used as a guide for all the staff; the values are linked to the Mission. The following box shows this particular values guide.

> The fundamental values of our company that we believe in are:
>
> - Every workers' goal is to satisfy our customers 100 %
> - Health and safety must always be kept at excellent levels
> - Continuous and unconditional reduction of any form of waste in every process at every level
> - Respect towards staff regardless of their position, gender, religion, race, political orientation, or membership of any legal organization

- Respect towards our environment because it is our only resource and must not be damaged
- Sales and profits must be achieved using the highest business ethics
- The added value of our products and processes and the contribution of our technological innovations will benefit all of society
- Creating common welfare through our business for everyone: workers, suppliers, customers, shareholders, and the community

For instance the basic values of this manufacturing company focus on satisfying the customer (effectiveness), unconditionally reducing waste (efficiency) and improving health and safety conditions.

As a second particular document, all the three companies have issued the Vision. This represents the long-term (over 3–5 years) strategies of the company; like the mission, it simply has to supply a few but precise goals that need to be achieved. In particular, according to the managers, the Vision is:

- An image of the future that pushes the company in a precise direction
- Possibly made up of metaphors, models, images, slogans, comparisons, and similarities
- Stimulating for both staff and outsiders
- A reminder of the strategies that need to be applied and the goals that need to be achieved

Many Visions and Missions of the past have provided inspiration to other organizations. Canon's Vision of the 1970s is particularly famous (*Beat Xerox*) or the current Mission of the main Chinese car manufacturer, Geely (*make sure that Geely cars are known all over the world*). Anyhow, according to the managers, when a company implements Lean, it has to think about a particular kind of Vision with long period goals more linked to quality, efficiency and waste reduction. The following box shows an example of Vision which comes from one of three observed companies.

Our vision is to become the first in class of the sector through our performance in profitability, added value, quality, service and ethics, making every member of our staff proud of this and making it clear to everyone, including our rivals, that this is the way forward for everyone.

The Vision of our plants all around the world is to continuously improve the qualitative standards of our services and products, reducing year by year the existing waste and making these results public and comparable.

Table 1 Hoshin Kanri processes, teams and management

Period	Process	Management
Over five years	Vision, mission	Hoshin team and top management
Three years	X-matrix	Hoshin team
One year	Yearly Hoshin (*team charter*)	Hoshin team and management
Month, three months, year	Managing KPIs	Middle management
Day, week, month	Andon, Heijunka (visual control and management)	Workers, middle management

At this point, according to the observations and the managers, the organization which wants to implement Lean has to issue a Business Plan (BP). This can be done using BSC or Hoshin Kanri. In any case the BP leads to the deployment of the long-term Vision goals, which are usually set for three years. Thus, in the process of deployment, the goals of the lower level become the tools and methods to achieve the goals of the next level. The company which declares in Table 3 that its Vision is to become first in class within the sector through performance in profitability, will have to measure performances such as *Earnings Before Interest and Taxes* (EBIT). EBIT is a three-year goal that can be achieved through a yearly measure that can become goal itself.

The BP can be structured by using various methods, such as Balanced Scorecard developed in the US, or Hoshin Kanri used by many Japanese companies like Toyota, Komatsu, and Bridgestone. According to some authors, Hoshin Kanri is the natural companion of Lean because it was born in Japan along with TQM and Lean (Witcher and Butterworth 2001). Hoshin Kanri requires a series of documents and checks according to the type of deployment that need to be done. Table 1 lists the various processes used by Hoshin Kanri, the length of time they need to be applied for, and the teams that manage them. The top-down Hoshin Kanri deployment process starts with long-term strategic targets and is managed by different teams, as shown in the third column of the table.

It is very important to notice how in the last row the deployment leads to daily processes such as Andon and Heijunka. According to the three managers, this day-by-day managed process is the real novelty introduced by Hoshin Kanri and it is one of the Kaizen principles (Bhuiyan and Baghel 2005). From the observations and the discussion with the managers it has also emerged that the different teams involved have different roles and responsibilities in the deployment process. Table 2 summarizes these differences.

The last row of Table 2 refers to Kaizen workshops. These are the quick initiatives for reducing waste carried out by operative teams every day. Naturally these are not the only methods used by organizations which are applying Lean tools and principles. Toyota itself uses Kaizen workshops that usually last a week, together with teams that work on long-term problem solving (Herrmann et al. 2008; Ng et al. 2010). These types of initiatives usually generate data and information,

Table 2 Different roles and responsibilities of the Hoshin Kanri teams

Team involved		Managed processes		
1	Directional team (Hoshin team, steering committee, senior management team)	1	Defining long-term targets	General *action plan* with strategic goals over 5 years that strive to align the company to vision and mission
		2	Defining medium-term targets	Targets over 3 years that arise from long-term targets. Creation of a BP that strives to improve the abilities of the operations, moving towards the long-term targets
2	Operational teams	3	Defining yearly targets or Hoshin	Precise action plans that strive, within the year, to align operations with targets
3	Kaizen team	4	Kaizen workshop	Rapid operations (up to 10 working days) and full-immersion that strive to reduce waste according to annual targets

which are then summarized on a particular sheet called A3. A3 sheet or A3 problem report is usually employed for better managing Kaizen workshops. Table 3 illustrates an example of this. The A3 size was also useful in the past, before the computer era, because it could be sent through A3 format fax.

The Hoshin team, which is usually made up of members of staff at high levels in the organization, prepares the BP by using the *X-matrix* that contains the long-term targets, the tactics (actions to achieve these targets) and deployment, based on processes evaluated with yearly targets/indicators. The X-matrix is prepared and supported by other reports according to the indications of Table 4.

The intelligence report is the first document that starts the strategic planning process according to Hoshin Kanri; it contains a review by the Hoshin Team, which states the targets of the previous year and formulates a hypothesis for the new three-year goals (each year rolling). Table 5 illustrates an example of this report concerning sales and marketing strategies.

Table 6 instead shows a different report from another company concerning how to increase EBIT.

It is clear that the report analyzes the situation related to the previous activity, leading to the definition of a strategic target; this will then be inserted in the X-matrix as a new three-year goal. In the case of Table 5 the target involved focusing on increasing the turnover in the American market; this turnover had been suffering due to the lack of dealers. In the report illustrated in Table 6, however, the poor situation of the EBIT that is decreasing year by year is analyzed. This

Table 3 A3 problem report for Kaizen workshops

DESCRIPTION:

CURRENT STATE:

COUNTERMEASURES:

ANALYSIS:

IMPLEMENTATION PLAN

What	Who	When	Outcome	Check

FOLLOW UP AND CLOSURE:

Table 4 Documents linked to the Hoshin Kanri strategic planning

Document	How to use it
Intelligence report	It is used (in the phase before issuing the BP) by the senior management (Hoshin team) to analyze the previous trend and formulate speculations and implications for the future
X-matrix	It lies at the heart of deployment, it is the equivalent of a BP, and relates long-term strategies to the tactics, thus leading to annual targets (processes) and the economical-financial results expected
Team charter	It is used to plan the moves, targets, the subsequent analysis and checks to reach an annual goal (processes); it is also used to manage improvement programs that are not directly coordinated by the X-matrix; it is filled out by a team and discussed with the Hoshin team
Status report	It is a monthly progress report regarding the annual goals discussed in the team charter; it is filled out by the team leader and discussed with the Hoshin team
Problem report	It is a chart that suggests a way to solve a problem that was not discussed in the annual planning phase (team charter); it is filled out by the team leader and discussed with the Hoshin Team

Table 5 An intelligence report regarding sales and marketing

Observation and data	Analysis
In 200× the US turnover was: – 1.800.000 $ in the East zone; – 600.000 $ in the West zone; – 2.300.000 $ in the remaining states; – 1.600.000 $ in Canada The trend is: – −10 % in the East zone; – −29 % in the West zone; – −16 % in the remaining states; – −5 % in Canada	The evident drop in the market, especially in the West (California leading) is surely due to the arrival of the Mexican competitor "Zonda"; Zonda is very aggressive in prices and has a very high on-time delivery rate (as described by US customers), but, fortunately for us, products that are less reliable than ours. Zonda sells directly in most of the center and western area and uses a sole dealer in Canada. This dealer is surely not better than ours in service, although it obviously did not exist before eroding our 5 %
	The problem lies in the whole of the USA, where we have few dealers (2). We suggest, therefore, a quick inquiry (within a year) for new dealers (at least 3) to be able to keep pursuing our difficult target of +30 %
	Implications for the business
	Further decline in 200× for the USA (of at least another 20 %) if no dealers are found Stabilization in the Canadian market

Table 6 Intelligence report regarding how to increase EBIT

Intelligence report	
Competitive information report	Theme: increasing EBIT
Observation and data	Analysis
In 200x, EBIT was: +1.3 % The business revenues show stability of turnover and various costs (% variation to the previous year) – 52,300,000 €: +0.8 %; – Commercial and administrative costs: +1.1 %; – Design and R&D costs: −0.9 %; Overhead and production costs, however, have considerably increased: – Direct production costs: +3.4 %; – Raw material and semi-finished product costs: +3.6 %; – Overhead: +6.7 %.	The increase in production costs is due to the recruitment of new workers in the assembly departments and due to reprocessing hours. Overhead costs, however, have increased partially due to the recruitment of a maintenance engineer (+1.7 %). Overhead costs also hide around 288,000 € linked to managing waste and customer returns, and around 236,000 € of handling to and forth from lines and warehouses. Adding these two together almost 1 % of the EBIT is eroded. The increase in price of various raw materials, in particular of steel, caused an increase in purchasing prices of 3.6 %. These increases have been now registered for the fourth year, eroding around 1 % of EBIT every year. Reducing the code variability, a project now postponed for the third year in a row could surely increase EBIT by 2 %.
	Implications for the business
	A project dedicated to reducing variability of components needs to be launched urgently, otherwise EBIT could reach 0 within two years

company could regain EBIT percentage points by reducing waste or by improving standardization and reducing the variability of components of the products.

The X-matrix transforms the strategic goals into tactics and yearly measures. In the Intelligence report, the left-side columns contain long-term strategic goals (objectives) and their relative targets. In the rows above, the tactics needed to achieve these strategic three-year goals can be found. The X-matrix follows this pattern as shown in Fig. 3. When the strategic goals are deployed into tactics Hoshin Kanri introduces the principle of different correlations.

Three symbols indicate either a strong correlation (two circles with the same center), or an existing correlation or a weak/non-existent correlation (a triangle). Moving from the tactics, these are then deployed into annual measures named processes.

The deployment thus leads to the calculation of yearly goals, which are measured using KPIs and the targets that need to be reached. Among KPIs, those of Lean Metrics (indicators that are actually part of Lean) can be found. Each annual KPI has to be managed by a specific team. For each annual KPI, the team has to fill out a new registration form known as the team charter, which analyzes and pinpoints the actions needed to reach the target of the KPI. Table 7 illustrates one of these forms, in this case regarding the goal of reducing cost of poor quality compared to the turnover. When observing the X-matrix it becomes clear that this goal comes from the deployment of the goal that involved improving EBIT by 1 %. In the registration form of Table 8 the team called Six Sigma involved in these projects, analyzes the current situation and basically pinpoints too many hours of redoing and reworking.

In the control part of the team charter in Table 8 it can be noticed how the involved team has to control day-by-day indicators such as redoing hours and lead time. These daily indicators are monitored through a Visual Board. This particular

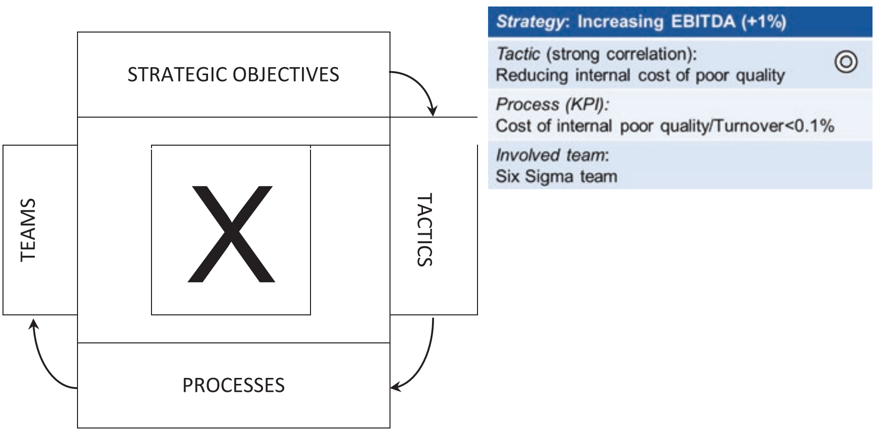

Fig. 3 X matrix process

Table 7 Team charter

TEAM CHARTER	
Proposed Team Charter	Team: Six Sigma team

DEFINE-STATEMENT
Reducing internal cost of poor quality

DEFINE-TARGET STATEMENT
Cost of internal poor quality/Turnover*100 < 0.1%

MEASURE & ANALYSIS
Last year reworking and redoing hours turned out to be about 2%. This is the most important cost of poor quality Engineering department redid 3 important projects. One of these was redone starting from scratch, for a total amount of 5,200 reworked hours

IMPROVE-PROPOSED ACTIONS
1-Value Stream Mapping and Makigami of the Engineering department 2-'De-bottlenecking' of the process 3-Poka-yoke of the process (more IT automation)

IMPLEMENTATION PLAN		
Action	*Responsibility*	*Time*
VSM and Makigami	Kaizen Team	2 wks
Visual Control of the process	Six Sigma Team	3 months
5S and poka-yoke	Six Sigma Team	2 months
New SAP implementation	ICT	6 months

CONTROL
- Monthly KPI = Redoing hours (0.9-1.1%) - Monthly KPI = Lead-time (<20%) - Day by day=redoing hours check (Visual Board) - Day by day= Lead-time check (Visual Board)

way of controlling performances is part of the so-called Japanese Visual Control or Management (Parry and Turner 2006) and it represents one of the Kaizen principles. Anyhow, as an essential principle, Hoshin Kanri in this way links the strategic goals with the daily indicators involving all the workers and creating awareness on the company's strategies.

The three companies have also tried to implement the BSC system, therefore a comparison between Hoshin Kanri and BSC can be done and discussed.

For instance, Table 8 shows how the deployment from the strategic goals to the processes can be managed through a typical BSC divided into the four perspectives.

The table demonstrates how the same strategic objective concerning increasing EBITDA has been written in the financial perspective and managed in a similar way. Indeed in the third column this objective has been deployed into the yearly KPI of cost of poor quality divided by the turnover. The appointed team (the goal owner) has to reach this target mainly through a reduction of the redoing hours and product reworks.

Table 8 Deployment through BSC

Perspectives	Strategic objectives	Measures (KPIs)	Actions	Owners
Financial	EBITDA (+1 %)	Cost of internal poor quality/turnover <0.1 %	Reducing engineering redoing	Six sigma team
			Reducing plant reworks	Lean specialist
Customer	Overall customer satisfaction	On time delivery performance (95 %)	External distribution reengineering	Lean specialist
		Cost of warranty and penalty/turnover <0.02 %	Increasing process sigma levels	Six Sigma team
Internal process	Reducing plant lead time	Average plant lead time <30 days	Kaizen events with TPS tools	Lean specialist
			TPM and SMED applied to all the machines	Lean specialist
Learning & growth	Increasing technical skills	#Certified engineers/workforce Ppm/m^3	Technical training ISO 14001 certification	HR department HS&E department
	Reducing emissions			

However, according to the three managers, the typical BSC does not manage the above mentioned daily indicators as well as does not foster a Visual Control approach. Furthermore, the three managers pointed out how the BSC system is considered something more suitable for managers rather than workers on the shop-floor. This is particularly connected with the lack of daily indicators and Visual Control.

5 Conclusions

This paper has analysed and discussed a possible strategic management framework when a company implements Lean. The results are based on the observation of typical documentation from three manufacturing companies and on the discussion with three managers involved in the deployment process. The three managers belong to the same companies where the documentation has been observed and analysed.

As a first finding, it can be claimed that the strategic approach is a combination of a top-down deployment, followed by a bottom-up review of the results achieved through measurements and control of different indicators.

The top-down deployment is based on a traditional pattern starting from a Mission and a Vision. But when the three companies come to the deployment of three-year-objectives into yearly KPIs, they can use two different systems. The first one is the well-known BSC, which has been less investigated in its pattern. The other one is the innovative and less used Hoshin Kanri invented by some Japanese companies specifically for TQM and Lean. We discussed all the steps within the Hoshin Kanri pattern, finding interesting differences compared to the BSC system.

First up Hoshin Kanri adopts peculiar charts and forms for the analysis, deployment and planning of the actions to be taken; the intelligence report and the team charter are the most important ones. Then Hoshin Konri employs a particular matrix for deploying and bounding together strategic objectives, tactics and processes. This matrix is named X-chart and can be considered the core of the Hoshin Kanri system. A quick comparison with the BSC shows that the X-matrix can offer a similar pattern of deploying without taking into account the four perspectives as categories of objectives.

Anyhow the real novelty introduced by Hoshin Kanri lies in the link between strategic, yearly and day-by-day indicators. In this way strategies are deployed and brought to the attention of the staff as a whole, including workers. In this sense also the Japanese principle of the Visual Control can help the organization in better managing Kaizen principles. Thence, it seems that BSC is less suitable for managing day-by-day improvements which are fundamental for the Japanese Kaizen.

This research has some limitations mainly due to the reduced number of case studies analysed. Therefore academics and practitioners should deeply analyse the differences between BSC and Hoshin Kanri, in particular concerning the involvement of the work-force in getting the strategic objectives. In doing this, practitioners could also explore how useful is the strategic management approach presented by this paper for Lean implementation.

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Lean Management and Product Innovation: A Critical Review

Stefano Biazzo, Roberto Panizzolo and Alberto Maria de Crescenzo

Abstract Nowadays the management of product innovation and development processes is crucial for the survival of firms and it requires that advanced methodologies and tools should be adopted. Many companies are trying to apply the waste elimination philosophy of Lean operations into the innovation and product development processes. The application of Lean manufacturing concepts in innovation processes (Lean Innovation) is not so immediate and presents several problematic aspects. One of the greatest difficulties is not to distinguish the critical differences between the two fields of application. The aim of this work is to identify and discuss the techniques and tools which constitute Lean Innovation practices. First, the Innovation Pyramid model is proposed in order to define an integrated vision of innovation processes which is based upon three levels of activities: absorb, explore and create. Second, an extensive review of the literature has been carried out aiming to recognize the practices that characterize the "translation" of Lean principles in the innovation processes. Finally, the practices that characterize Lean Innovation are analysed throughout the proposed Innovation Pyramid model. The results of this study highlight that the Lean Innovation practices lie mainly at level 3 of the innovation pyramid (i.e. the create level). This evidence suggests that in order to enhance the firm's innovation capability it is necessary to integrate the Lean Innovation practices with other good practices coming from different research fields.

Keywords Product innovation · Lean product development · Lean practices

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1 Lean Management Outside the Factory: Lost in Translation?

John Krafcik—in a renowned article of 1988 focused on spreading the earliest results of the MIT *International Motor Vehicle Program* research—used for the first time the term "Lean" to describe the approach of production management that needs fewer resources—less space, less warehouses, fewer working hours—and simultaneously could realize products more competitive than traditional mass production in terms of time, quality and cost (Krafcik 1988).

From then, Lean manufacturing methods are replacing conventional methods in both manufacturing and service industries. Research has shown how the improvements can be radical thanks to the adoption of Lean logics and methodologies (Alsmadi et al. 2012; Shah and Ward 2003).

Excellence in production is certainly an important factor for firm's competitiveness. But product/service innovation is, in particular for western SMEs, an indispensable asset in order to avoid to succumb to price competition from companies located in emerging low cost production countries.

In this perspective, it is comforting to highlight how the potential of Lean methodologies is even higher in the context of innovation and product development. Even in the product innovation processes (or product development value streams according to the Lean jargon) significant forms of "muda" exist—that is to say waste that does not create value for the customer. The problem is that these wastes are not immediately visible and therefore they are not easily removed if appropriate methodologies to locate them are not adopted. The redesign of product innovation process can release enormous creative energy and knowledge.

Table 1 highlights the wastes that can affect the innovation activities and product development. These wastes are summarized in the classic seven types of waste identified by Taichi Ohno within production systems, with the addition of a specific important category in the context of the innovation processes: the waste of knowledge.

As highlighted by Locher (2008), this is a partial list; different organizations will produce different examples which are specific to their own development processes and corporate culture. However, there are key wastes often found in development processes regardless of organizational context. Moreover, it is important to note that the eight wastes are fundamentally interrelated and may overlap; in other words, the examples of Table 1 may fit into more than one category.

Table 1 was proposed by Locher in order to assist the Lean practitioner in developing "eyes for waste" in the product development processes. Although most people are now familiar with the waste terms proposed by Taichi Ohno, they may still have difficulty in recognizing them in the development process.

After the seminal book published in the 1990 by Womack et al. (1990), there was a progressive understanding of Lean logic implementation as resulted in the book "Lean Thinking" (1996), in which Womack and Jones developed the five

Table 1 The waste in innovation and product development

Waste category	Examples
Overproduction	Features, functionality and product performance that exceed customer requirements ("over-serve" the needs, "over-engineering", "performance over-supply") Completing design elements that are not needed for some time
Waiting	Waiting times for information, test results Waiting times for decisions Waiting times for unavailable resources (human and physical) Waiting times for system response time
Transportation	Unnecessary exchanges of information Unnecessary exchanges of responsibility
Overprocessing	"Reinventing": wasting knowledge already developed in the past Complicated and redundant documentation, not designed according to the internal customer view Unnecessary or excessive reports or paperwork Receiving and discarding useless information Ex-post projects scheduling
Inventory	Too large "information batches" which slow the learning cycles and knowledge creation Retaining documents beyond what is required
Unnecessary motion	Searching for information Meetings not properly structured and focused Work characterized by constant interruptions and changes causing high "set-up" mental time
Defects	Modifications due to design errors Modifications due to inadequate understanding of customer requirements Modifications due to service failures and missing or incomplete information
Waste of knowledge (Underutilized People)	Communication barriers (physical, social) that prevent people to interact effectively in problem analysis and troubleshooting Lack of clarity and accordance on the vision of the product to develop Archiving project information without creating re-usable knowledge Limited authority and responsibility for basic tasks Lack of knowledge sharing

Adapted from Locher (2008)

principles of Lean transformation in any kind of firm process. The five principles are a powerful and fascinating synthesis of what the future state of a "lean company" should be a lean company:

- deeply understands what is the meaning of "value" for the customer;
- knows in detail how the value is created within the company by eliminating all forms of waste;
- strives for the flow (information and materials that move quickly, without waiting) during the activities executions;

- aims to respond promptly to the market (let the customer *pull* value);
- persistently pursues continuous improvement in order to get a (not reachable) perfection.

The application of Lean concepts in innovation processes (Lean Innovation) is not so immediate and it seems problematic as there are substantial differences between manufacturing and product development contexts: during the "translation" we might lose some important issues and introduce dangerous distortions; as Donald Reinertsen has clearly shown (Reinertsen 2009), one of the greatest difficulties in implementing Lean methods in product development is *not* to distinguish the critical differences between the two fields of application. Critical differences regard basically the following aspects: the repetitiveness of the process; the level of uncertainty and risk during the development activities; the presence of explorative activities that involve "trial and error" iterations in the workflow; the intensity of communication flows and difficulty of cross-functional integration.

The objective of this work is to identify and discuss the set of techniques and tools from Lean practices that can be useful to transform innovation and product development processes of the firms.

Concerning the structure of the paper, after having described exactly the methodology employed, an integrated vision of innovation processes will be outlined by proposing the "Innovation Pyramid"model. This model states that the capability to launch new products and services in the market is based on three levels of activities: *absorb, explore and create.*

The successive section describes the main features of Lean innovation which are currently proposed in the international literature. The aim is to completely understand which are the practices that characterize the "translation" of Lean principles in the innovation processes. In the final paragraph, the set of practices that characterizes the Lean Innovation approach are analysed throughout the proposed Innovation Pyramid model. The results of this investigation highlight that the Lean Innovation practices identified lie mainly at level 3 of the innovation pyramid (i.e. the create level). This evidence suggests that in order to enhance the firm's innovation capability it is necessary to integrate the Lean Innovation practices with other good practices coming from different research fields.

2 Methodological Considerations

The paper is based upon a literature review that was undertaken by the authors to establish a multi-perspective view on innovation activities of a firm and main features of Lean innovation principles and practices. For investigating these two phenomena, we adopted an approach that combined elements of systematic literature review (Denyer and Tranfield 2008; Rousseau et al. 2008) with the authors' previous knowledge of the field developed over the past 20 years. Essentially, systematic reviews are formulated around research questions, and the criteria for inclusion and exclusion of papers are clearly defined at the outset.

A four-step process model proposed for content analysis in literature reviews (Mayring 2003, p. 54 cited in Seuring et al. 2005, p. 94) was adopted for this review. The four steps are: material collection, descriptive analysis, category selection and material evaluation. Material collection involves definition and delimitation of materials to be collected and search for relevant literature. At the descriptive analysis step, basic characteristics of the selected materials, such as publication distribution across journals, research methods, and number of publications per year, are examined. Decision on the choice of categories and dimensions to be used in structuring the collected materials is made at the category selection stage. Category selection is followed by material evaluation, which involved review and classification of the selected materials according to the chosen structural dimensions and categories. Only books and journal articles published were considered. The following information sources were searched: Emerald, ScienceDirect, Scopus, Springerlink, Ebscohost, Wiley, ISI, Business Source Premier, and Google Scholar. The reference lists of articles found were also examined for more relevant articles. The succeeding keywords were used for the search: "lean product development", "lean design", "product innovation", "lean practices", "innovation processes". Each publication was analysed independently by single authors in order to extract the tools, methodologies or organizational solutions proposed in the literature for Lean transformation of innovation processes. Then, this set of tools and techniques was analysed in a crisscross pattern with the intent to integrate the different perspectives encountered and to build a framework that defines the most internationally recognized elements of Lean Innovation.

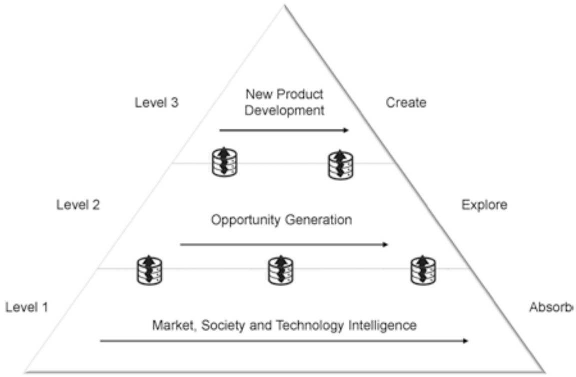
3 An Integrated Vision of Innovation Processes: The Innovation Pyramid Model

In order to completely understand the potential of Lean transformation, it is important to visualize and emphasize the complex and integrated nature of innovation activities. Figure 1 illustrates the systemic nature of innovation processes through the application of the pyramid metaphor.

The capability to launch new products and services in the market is based on a three level system of activities: *absorb, explore and create.*

- The first level concerns all activities designed to absorb knowledge from external environment through intelligence activities on markets, technology and society; intelligence activities can be both formal (e.g. purchase or internal development of a specific study on the cultural trends related to a geographical area of interest for the firm) and informal (e.g. the flow of information that derives from the existing networks of personal relationships). In Fig. 1 a data

Fig. 1 The innovation pyramid: a three-level system of activities



warehouse icon represents the stock of knowledge; the arrow facing up intends to illustrate the flow of that knowledge: intelligence activities accumulate information that, at the appropriate time, may be used by exploration or creation activities.

- The second level refers to the exploration of innovation opportunities. There are different types of activities designed to generate new ideas or new technologies; they represent a "stock of opportunity" that can be the foundation of future new product development projects. Research and technological experimentation represent a classic form of exploration; but, as we will illustrate later, the firm investment in exploration activities may significantly broaden under the logic of the Open Innovation paradigm.
- The third level concerns all the activities designed to create the solutions that will be launched in the market; this is the level of product development projects, where companies try to transform knowledge concerning customer needs, technological opportunities and new product ideas into industrial technical solutions that can be produced profitably.

The pyramid metaphor represents the level of interdependence between creation, exploration and absorption activities. The capability to design new products and services that will be launched on the market is affected by the ability to generate new ideas and to explore technological opportunities; in turn this exploratory capability is influenced by the knowledge that the firm is able to absorb from the external environment and from the relational network developed over time.

It is important to note that the three levels of activities are characterized by *simultaneity*; the horizontal arrows depicted in Fig. 1 highlight this property: the systematically innovative firm is constantly and concurrently engaged in *absorption, exploration and creation* activities. Sometimes it is possible that there is a close temporal sequence between activities at different levels: for instance a "radical innovation" project could be carried out through these steps: (1) investigation on cultural trends; (2) cross-functional brainstorming in order to generate new ideas for product/service able to take advantage of specific trends; (3) selection of the most promising product idea that will be included in the portfolio of product development projects. In general, however, the activities belonging to the different levels are temporally decoupled: for instance, a deep study on the state of the art of a certain technological area of interest for the firm (level 1) is realized in order to generate a stock of knowledge that may be used in the future in various other activities (e.g. technological experimentation and product development—level 2 and 3); the "knowledge transfer" among level 1, 2, and 3 is not planned in advance.

Level 1: Absorb
This level includes all intelligence activities devised to collect and analyse actionable information about the external business environment that could affect a company's competitive position (Ashton and Klavans 1997); we can differentiate two kind of intelligence: market intelligence and technology intelligence.

Market intelligence uses multiple sources of information to create a broad picture of the company's existing market, customers, problems, competition, and social trends. These activities should aim to build an adequate stock of knowledge on three main directions:

- Customer needs: understanding needs does not mean to find out what customers desire or look for (in terms of "solutions"); understanding the needs means to reveal which are the problems that the customer is trying to solve in certain circumstances and what are the metrics that the client uses to judge the products suitability in order to "solve its problems";
- Market and social trends: knowledge of the main trends (technological, cultural, demographic, environmental, etc.) that characterize the competitive environment and more generally the society and awareness of the impact of these trends on the firm;
- Competition: analysis and comparison of competing products and competitors.

Technology Intelligence is the activity that enables companies to identify the technological opportunities and threats that could affect the future growth and survival of their business; each product is a *bundle of technologies* that has to be identified and monitored.

Level 2: Explore
Technological research has always played an important role in the exploration activity: the research and experimentation projects are, in fact, aimed at creating new technologies that could be adopted in product development projects and then incorporated into a new generation of technical solutions.

The problem that arises for small and medium enterprises is the difficulty—and in some cases the impossibility due to the insufficient firm dimension—to invest resources in activities exclusively focused on technology exploration. In these contexts, there are two alternatives:

- shifting the exploration at level 3 by incorporating massive quantity of experimentation in ordinary designing activities; as a consequence we have to accept the risks of increasing the management complexity and technical uncertainty of product development projects;

- developing collaboration and partnership with suppliers, research institutes or universities, embracing the logic of Open Innovation.

Chesbrough (2003), in his seminal book on Open Innovation, has showed that cooperation with external partners in research and technological development is a general trend absolutely independent from company dimension; in a world where knowledge is abundant and distributed, it is becoming increasingly clear that it is no longer possible—even for most relevant multinationals—to innovate relying exclusively on their own internal research strength. The innovation model based exclusively on internal research reflects the paradigm of vertical integration and control: in a hugely interconnected world, isolationism stifles innovation.

Level 3: Create
New product development is the set of activities designed to turn a product idea into a marketable product with an industrialized and profitable manufacturing process. Generally these activities can be divided in the following basic steps (Ulrich and Eppinger 2008):

- concept development, including generating alternative product concepts to satisfy a need in the market, and selecting a few concepts for further development;
- design, which involves defining the product architecture, including its major subsystems and components, and a detailed design with complete specifications of geometry and materials, and tooling design;
- testing, where the product is tested in its intended environment and refinements are made based on the results;
- production ramp-up, including manufacturing the product with the intended production system, training the workforce, and correcting any issues before full production.

There are three areas of intervention that may affect the effectiveness and efficiency of these activities:

- Design of the development process: what is the system of activities, decisions and documentation that has to be adopted as a standard for "good practices" in order to turn an idea into a feasible and marketable product?
- Project portfolio management: how are priorities set and product development projects selected and launched?
- Project management: Which organizational decisions have been adopted for managing individual projects?

4 Lean Management and Innovation: The State of the Art

In order to clearly understand which are the practices that characterize the "translation" of Lean principles in the innovation processes, we have systematically analysed the scientific and management literature by a wide selection of databases.

Each publication has been analysed independently by the single authors of this paper in order to extract the tools, methodologies or organizational solutions proposed in the literature for Lean transformation of processes innovation. Then, this set of tools and techniques has been analysed in a crisscross pattern with the intent to integrate the different perspectives encountered and to build a framework that defines the *most internationally recognized* elements of Lean Innovation. This work has identified 20 Lean Innovation practices reported in Table 2 which shows for each practice:

- the principle of lean to which it refers (in accordance with the five Lean principles proposed by Womack and Jones);
- literature references.

In this paragraph we will give a brief description of the practices.

Table 2 Lean innovation practices

Lean innovation practices	Lean thinking principle	Authors
1. Deep understanding of customer needs	Value	Haque and James-Moore (2004) Morgan and Liker (2006) Oppenheim (2004) Schipper and Swets (2009) Sehested and Sonnemberg (2010) Ward (2007)
2. Early identification of production problems	Value	Haque and James-Moore (2004) Karlsson and Åhlström (1996) Morgan and Liker (2006) Sehested and Sonnemberg (2010) Ward (2007) Womack et al. (1990)
3. Integration of suppliers in the design and development process (co-design)	Value	Hoppmann et al. (2011) Karisson and Åhlström (1996) Morgan and Liker (2006) Ward (2007)
4. Modular design and reduction of components	Value	Hoppmann et al. (2011) Morgan and Liker (2006) Reinertsen (2009)
5. Supermarket of technical knowledge	Value	Hoppmann et al. (2011) Morgan and Liker (2006) Schipper and Swets (2009) Ward (2007)
6. Generation of alternative product concept	Value	Morgan and Liker (2006) Schipper and Swets (2009) Ward (2007)

(continued)

Table 2 (continued)

Lean innovation practices	Lean thinking principle	Authors
7. Systematic problem-solving with set-based approach	Value	Baines et al. (2006) Haque and James-Moore (2004) Hoppmann et al. (2011) Morgan and Liker (2006) Schipper and Swets (2009) Ward (2007)
8. Heavyweight project leader	Flow	Baines et al. (2006) Hoppmann et al. (2011) Morgan and Liker (2006) Schipper and Swets (2009) Womack et al. (1990)
9. Integrated team of responsible experts	Flow	Haque and James-Moore (2004) Hoppmann et al. (2011) Morgan and Liker (2006) Oppenheim (2004) Schipper and Swets (2009) Ward (2007) Womack et al. (1990)
10. Obeya room and visual project board	Flow and pull	Hoppmann et al. (2011) Morgan and Liker (2006) Oppenheim (2004) Sehested and Sonnemberg (2010)
11. Visual pull planning	Pull	Haque and James-Moore (2004) Hoppmann et al. (2011) Oppenheim (2004) Schipper and Swets (2009) Sehested and Sonnemberg (2010) Ward (2007)
12. Integration events	Flow and pull	Hoppmann et al. (2011) Morgan and Liker (2006) Oppenheim (2004) Reinertsen (2009) Schipper and Swets (2009) Ward (2007)
13. One-piece flow in the daily work in order to minimize the inefficiencies of multi-tasking	Flow	Sehested and Sonnemberg (2010) Ward (2007)
14. Takt of single project (stand-up meeting)	Flow and Pull	Morgan and Liker (2006) Oppenheim (2004) Reinertsen (2009) Schipper and Swets (2009) Sehested and Sonnemberg (2010) Ward (2007)

(continued)

Table 2 (continued)

Lean innovation practices	Lean thinking principle	Authors
15. Project portfolio takt	Flow	Reinertsen (2009) Sehested and Sonnemberg (2010) Ward (2007)
16. One-piece flow in the project portfolio	Flow	Hoppmann et al. (2011) Reinertsen (2009) Sehested and Sonnemberg (2010)
17. Integrated problem solving (concurrent engineering)	Flow	Haque and James-Moore (2004) Karisson and Åhlström (1996) Reinertsen (2009) Womack et al. (1990)
18. Anticipated prototyping	Flow	Hoppmann et al. (2011) Schipper and Swets (2009)
19. Value stream mapping	Value stream	Haque and James-Moore (2004) Morgan and Liker (2006) Oppenheim (2004) Schipper and Swets (2009)
20. Hansei events	Perfection	Morgan and Liker (2006) Sehested and Sonnemberg (2010)

4.1 Deep Understanding of Customer Needs

In the literature review emerged a total convergence of recommendations that the principle of Lean Thinking "value", in the context of innovation, is closely linked to wastes coming from a non-depth knowledge of the customer needs. It is not possible to create profitable product development projects if the product does not respond to the expressed and unexpressed customer needs. The "value" is firstly defined in the customer perspective. Therefore all those activities aiming to capture the Voice of the Customer (VOC) are considered central. This means *going to gemba* ("the real place") by targeted interviews and product use observations. In order to integrate the VOC in the process development two well-known techniques are often quoted: the "house of quality" within the Quality Function Deployment (QFD) and Value Analysis.

4.2 Early Identification of Production Problems

Wastes related to the missed consideration of manufacturing implications of design solutions are widely emphasized in the Lean Development literature. Many publications and researches on simultaneous engineering have highlighted this problem since the '90 s. These studies state the need to anticipate as much as possible the involvement of persons from the manufacturing area in the development process. The early involvement is obtained by means of cross-functional teams and thanks to the anticipated scheduling of specific manufacturability “review”. In this way it is possible to work on production compatibility before design completion, eliminating most of the late engineering changes. This front-loading process also isolates much of the variability that is inherent to product development allowing for speed and precision during the execution phase of product development.

4.3 Integration of Suppliers in the Design and Development Process (Co-design)

The increase in expert knowledge needed to achieve innovation, makes essential the activation of specialized knowledge sources external to the firm—in particular the suppliers. The integration with suppliers requires that the firm collaborates with a small base of suppliers, strictly selected and continuously evaluated. The Lean logics suggest that suppliers involved in co-design activities should be characterized by qualified design skills.

4.4 Modular Design and Reduction of Components

In general terms modularity is the degree to which a system’s components may be separated and recombined. In manufacturing, modularity refers to the use of exchangeable parts or options in the fabrication of a product. Companies that operate with products aimed at different market segments and applications often experience a great variety in the needs of the individual customers. Modularity design is the key approach for reducing waste deriving from “useless variety”. It allows to offer high customized products while maintaining efficiency and speed of delivery by standardizing those components/modules without negatively affecting the product performance.

4.5 Supermarket of Technical Knowledge

Capturing and sharing knowledge eradicate a fundamental waste: the great deal of time or effort in creating something that already exists and the repetition of errors or mistakes during the design process. The Lean approach for the development of a knowledge management system supports an approach that differs greatly from the traditional modalities focused on the creation of large database. An effective supermarket of knowledge runs as a pull system: the access and the pursuit of knowledge are simple, immediate. Moreover, it is just simple and quick to add "pieces of knowledge" to the supermarket since some template or simple guide able to capture knowledge without additional work are provided. The use of such supermarkets enhances the reusability of inter-organizational knowledge as knowledge becomes more accessible, usable, understandable and believable.

4.6 Generation of Alternative Product Concept

In general words, set-based concurrent engineering (SBCE) can be defined as engineers and product designers "reasoning, developing, and communicating about sets of solutions in parallel and relatively independently". When applying this concept to the development of product concept this means that rather than trying to identify one solution, members of the project team should instead develop a variety of design options, and then gradually eliminate alternatives, until only one option remains. An deep analysis of alternatives performed in the initial stage of the process development reduces significantly the risk that the selected solution falls short of customer needs in some respect. This "robust" product concept is a powerful method to reduce waste in downstream design activities as it reduces the uncertainties in the development process and the associated costs of reworks due to changes.

4.7 Systematic Problem-Solving with Set-Based Approach

Systematic problem-solving means facing problems with a specific discipline in the analysis and implementation process of technical solutions. Successful problem-solving approach is characterized by the following features:

- go and see: people are encouraged to see the problem with direct observations by going to the place where things happen (the Gemba);
- investigating the causes in depth: the method encourages to wonder several times the reason of the problem ("five times why"), it stimulates the mental attitude for a deep examination aimed to discover the "first cause" or the main causes;
- generating different alternatives of "resolution" (set-based approach): the technical solution is more "robust" if it is found through the exploration of many alternatives; this is especially true when the problem is complex;
- selecting the solution through the use of models, physical prototypes and computer simulations.

4.8 Heavyweight Project Leader

A Lean Innovation system is focused on the crucial importance of the project leader role regardless of the specific responsibility and authority that this role can assume (i.e. Heavyweight vs. Lightweight project leader). The project leader must mediate among trade-offs and tensions which arise from the conflicting needs generated by the functional managers. The project manager is the "father" of the project, he has the responsibility of the planning, execution and closing of the project accomplishing the stated project objectives which are cost, time, scope, and quality.

4.9 Integrated Team of Responsible Experts

The team in Lean innovation system must be integrated, that is it must be characterized by a *cross-functional* composition, so as to represent skills and expertise variety necessary for the development of the product. The use of functional groups is the solution that is most clearly associated to the achievement of significant and innovative results. *Cross-functional team*s must be made up by people who know how to apply *teamwork*. Teamwork requires the ability to listen to others' ideas, ability to display own knowledge, negotiation skills in order to identify the best solutions for the system that is being planned, strict adherence to the commitments made beside the group. Moreover, the team should consist of people who demonstrate to have two basic characteristics: *responsibility* and *competence*. Responsibility for the final result of the development, not only for the partial results of their activities. Competence that must be continually developed with purpose of becoming "experts" in their field, learning from experience and staying updated thanks to the technical and scientific literature.

4.10 Obeya Room and Visual Project Board

It is necessary to create a suitable *physical contest* for the team interactions and integration. The Obeya Room ("large room" or "war room") is the place where the team comes together and where all project information are shown permanently in an easy way visible for all (Visual Project Board). The Visual Project Board normally includes:

- a clear visualization of the project objectives ("product vision");
- the posters of project time scheduling (at various levels of detail, from major milestone to the daily plans, if it is necessary);
- a board with the display of "open issues" and "solved issues" (issue board).

Of course, other information that may be necessary to the group are included, such as the objectives details to be achieved in the various integration events (see below Visual Pull Planning), drawings, drafts, prototypes or parts of the product, etc.

4.11 Visual Pull Planning

Lean thinking recognizes the recent critical reflections on the classic project management methodologies. The central point of "project management reform" initiatives, is the rejection of the project representation as a simple network of activities in favour of a vision that the project is, first of all, a network of people. There are two fundamental consequences of this perspective, that we can define *relational*:

- planning cannot be separated from the action and therefore it is not possible (and it does not make sense) to plan the entire set of activities from the beginning. Planning is a continuous event and the details are formed gradually over time (Rolling Wave Planning).
- the project is a network of threads, commitments and actions and therefore planning must be a collaborative and social event. It is a "conversation" in which the people in charge for the activities assume mutual commitments on the tasks implementation, the temporal relationships between activities are the result of "negotiation" between the activity leaders (and not an intrinsic attribute of interdependence between activities). The duration of an activity is also the result of a "negotiation" that depends on the downstream "customer" requirements.

Pull planning is a coordination activity that must be carried out by that person who performs the operational work. The plans must be simple for upgrading and for reading and readily accessible and visible; first and foremost they must be a working tool, not a reporting tool. Waste means also to have a schedule with unnecessary details and excess information that give a false sense of control.

4.12 Integration Events

An integration event, or target event, is a critical milestone for the project that pulls work through product development and helps teams to identify integration problems early. These integration events require advance preparation, a format that allows for a lot of interaction and attention to detail, and the ability to "go and see" when the team finds problems. Integration events are not meetings of information "reporting" but moments of knowledge creation and efforts integration. Generally, it is suggested to link the integration event to the creation of an "object" (for example: the definition of "product concept", the approval of aesthetic design, the first working prototype, etc.).

4.13 One-Piece Flow in the Daily Work in Order to Minimize the Inefficiencies of Multi-tasking

In Lean Innovation system an important goal is creating a work environment where interruptions are minimized as well as the workflow fragmentation. Aiming at one-piece flow in the work has a number of advantages:

- it increases concentration and engagement in the task, with a likely increase in work quality;
- it reduces the time between the moment in which knowledge is generated and the moment in which it is utilized by others;
- it diminishes the waste due to the adaptation time required to switch from one task to another is minimized.

A simple way to achieve the one-piece flow is the concept of "time-slicing": making structured the working agenda of people by allocating specific time frame of day (or week) to specific projects or activities (e.g. in technical department it is suggested to dedicate just Fridays, or part of the day, to "requests of changing" and to prevent that such disruptions might interfere with the work of projects development, or rather to spend the morning in the high priorities projects and the afternoon in meetings, smaller projects of low priority, support activities, etc.).

4.14 Takt of Single Project (Stand-up Meeting)

Monitoring the progress of project activities must have a rhythm, a cadence (takt). These progress meetings must be planned with high frequency (Daily/Weekly Stand-up Meeting), they should be brief and have, as unique target, the project scheduling updating. These stand-up meetings aim to minimize waste of the project status reporting and simultaneously to improve the team coordination.

4.15 Project Portfolio Takt

Project portfolio takt means defining a standard frequency by which projects are launched (e.g. new products projects every two years; enlargement of the range every year, etc.). This also means defining a standard duration for the different types of projects. The logic of takt aims to create "order" in the product development system and to impose a kind of discipline regarding respect of time-frame. In the context of product development, the allocation of pre-defined "time windows" for projects, plays the same role of low inventory buffers in production: low stocks bring out the problems and require systematic problem-solving actions to ensure the system operation.

4.16 One-Piece Flow in the Project Portfolio

The concept of flow in the project portfolio addresses the problem of resource overloading due to the implementation of many projects in parallel, often without a clear identification of priorities. Aiming at One-Piece flow in the project portfolio means to minimize the likelihood that people are engaged in more than one project simultaneously and the "work in progress" in the product development system. Obviously the ideal situation of "a team—a project" is often difficult to achieve: the search for the flow in the project portfolio simply aims to stimulate the careful management of the project portfolio and priorities. The project portfolio management is the decision-making process through which a list of product development projects is constantly reviewed and updated. Through this process the new projects are evaluated, selected and then sorted by priority. Manage in an inefficient and approximate way the projects portfolio has generally important and dangerous consequences:

- too many projects and overloaded resources: the list of active projects tends to increase too easily; the financial and personnel resources are too dispersed and the execution quality is badly affected. The lack of resources is only one side of the problem; the other side is the inability to allocate resources effectively;
- lack of distinction between the projects, which amplifies the problem of resources effective allocation;
- lack of balance between short and long term orientation. The short-term projects (cost reductions, extensions of product lines, incremental changes in performance) are certainly important; the problem is the excessive consumption of resources by these projects at the expense of riskier projects that aim to build the competitive profile in the future.

4.17 Integrated Problem Solving (Concurrent Engineering)

The integration in the problem-solving refers to the communication modalities between people working in the different phase of the development process. In concurrent engineering problem solving is integrated in the sense that:

- between the different groups there is a two-way communication flow that starts very early with an exchange of preliminary information;
- the downstream groups often start "in advance" their activities on the basis of preliminary data (or rather before that the upstream groups finished their problem-solving cycles) in order to think about the alternative solutions of upstream groups and to provide early feedback on ideas and constraints;
- communication flows are rich, intense and bilateral: they are realized mainly through face to face discussions, direct observations of issues and interactions with physical or virtual prototypes.

4.18 Anticipated Prototyping

In order to effectively explore various alternative solutions it is necessary to be very quick to comprehend the limits and the potential of what it is going to be created and designed. The speed and effectiveness in the alternatives exploration are deeply related to the ability to experiment through prototyping. A prototype can be physical or virtual, general (it represents all the product attributes) or specific (it is focused on certain attributes or subassemblies of interest). There are great differences between traditional and front-loaded prototyping which open up possibilities for more iterative development processes that fit changing environments. In traditional prototyping the number of prototypes is small, they are used late in the development process, the prototype's objective is to "verify", the cost of the prototype is high and its build time is relative high. Front-loaded prototyping means that many prototypes are build up in a quick way, their cost is low, they are used throughout the development process and the prototype's objective is to "learn". Moreover, prototype's scope is broad and vague in traditional prototyping while it is narrow and specific in front-loaded prototyping.

4.19 Value Stream Mapping (VSM)

The focus on VOC is interpretable, in the Lean logic, as the effect of a struggle against two primary kind of waste: the "defects" (products that do not grasp important customer needs) and "overproduction" (product performance that exceed customer needs). In order to set upon other types of waste in the workflow and to imagine new structuring ways of development process, it is suggested the practice of Value Stream Mapping (VSM). The specific nature of product development requires some adaptations to the traditional "manufacturing VSM", since there are not equal conditions of repetitiveness in the activities and workflows.

4.20 Hansei Events

Nowadays it is emphasized that the essential characteristic of the Lean company is to be an organization able to learn constantly and to improve systematically. A key to learning and growing in Japanese culture, is *hansei*, which roughly means "reflection." It is asserted the need to organize regularly reflective events (Hansei Events) in order to sustain continuous improvement in design and development processes. There are different types of Hansei Events, the most popular is post-mortem reflection, a program summary learning event aimed at identifying the encountered problems and to recognize improving opportunities for management methods and projects organization, capitalizing on possible negative experiences.

5 Lean Management and the Innovation Pyramid

In the following Table 3 we have linked the 20 Lean practices previously identified with the Innovation Pyramid framework. What appears clearly is that the main focus of the current Lean innovation literature lies at level 3 of the framework; however, the innovation capability of the firm is in the interplay between product development, opportunity generation, and market/technology intelligence.

Therefore, in order to soundly improve a company's innovation processes, it is necessary to integrate "lean innovation practices" with other "good practices" developed in different stream of research and managerial experimentation.

At level 1, for instance, it is particularly relevant the methodology named strategic and technology roadmapping. In recent years, roadmapping has emerged as a powerful tool to facilitate communication between technical and nontechnical communities of the firm and to capture a high level, synthesized and integrated view of the evolution of markets, products, and technology, in a graphical and visual way (Phaal and Palmer 2010; Phaal et al. 2004; Phaal and Muller 2009). Roadmapping can be thought of as a "lens" through which to visualize market, product and technology trends.

Roadmapping is, therefore, a method for highlighting opportunities for innovation and for identifying knowledge gaps (market trends not addressed by the products currently in development; technological gaps in relation the evolution of customer needs, etc.). It is worth highlighting that the result of roadmapping is not a long term plan; a roadmap is like a *radar*, a tool to capture and share knowledge and to make informed decisions. A roadmap is an evolving document, which reflects the understanding of the situation by a group; the quality of a roadmap is not measured by its forecast accuracy, but through the "movement" that it generates in terms of decisions and actions.

The benefits of roadmapping on product innovation management are twofold: on the one hand it represents the pivot around which intelligence activities revolve; on the other hand, roadmapping encourages a periodical and meaningful debate on the existing projects portfolio and it promotes consensus regarding priorities and resources allocation. The lens of roadmapping allows to "see better" the evolution of products and technologies through the definition of an *information architecture* that allows to capture and represent effectively and visually a large amount of data; the most common and flexible form is illustrated in Fig. 2, comprising a time-based, multi-layer structure addressing a series of key questions:

- The timeframes are concerned with: Where do we want to go? Where are we now? How can we get there?
- The layers address: Why do we need to act? What do we need to do? How can we do it? (Phaal and Palmer 2010)

Table 3 Lean innovation practices and the innovation pyramid

Lean innovation practices	Level 1 (Absorb)	Level 2 (Explore)	Level 3 (Create)
1. Deep understanding of customer needs	+	–	+
2 Early identification of production problems	–	–	+
3. Integration of suppliers in the design and development process (co-design)	–	–	+
4. Modular design and reduction of components	–	–	+
5. Supermarket of technical knowledge	–	+	+
6. Generation of alternative product concept	–	+	+
7. Systematic problem-solving with set-based approach	–	+	+
8. Heavyweight project leader	–	–	+
9. Integrated team of responsible experts	–	–	+
10. Obeya room and visual project board	–	–	+
11. Visual pull planning	–	–	+
12. Integration events	–	–	+
13. One-piece flow in the daily work in order to minimize the inefficiencies of multi-tasking	–	–	+
14. Takt of single project (stand-up meeting)	–	–	+
15. Project portfolio Takt	–	+	+
16. One-piece flow in the project portfolio	–	–	+
17. Problem solving integrated (concurrent engineering)	–	–	+
18. Anticipated prototyping	–	+	+
19. Value stream mapping	–	–	+
20. Hansei events	–	–	+

Layers and timeframes provide a structured framework for discussing, collecting and analysing information on the following three key issues:

- Why do I have to develop certain products?
- What to do? Which products must be planned to meet customer needs and market trends?
- How? Which technologies and resources are needed to design the planned products?

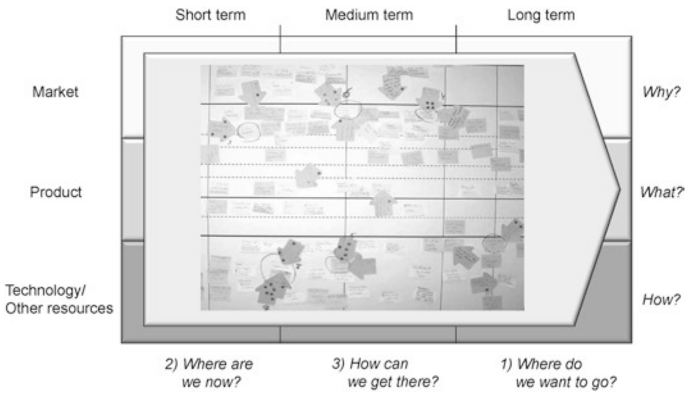


Fig. 2 The architecture of a roadmap. (Adapted from Phaal and Palmer 2010)

This format supports interaction and dialogue between different perspectives and business functions, facilitating the identification of challenges and opportunities and the alignment on action plans. Indeed one of the key benefits of roadmapping is to create a structured context of information sharing and team building in a highly interactive and engaging process.

At level 2, the recent literature on Open Innovation offers an interesting perspective for enhancing the capability of opportunity generation: the systematic management of "innovation tournaments" (Terwiesch and Ulrich 2009). An innovation tournament is a process with a fixed duration that begins with the definition of a challenge where participants must respond with a solution (it may be simply a new product idea at a conceptual level, or a prototype, a new software, etc.). There are two fundamental components of an innovation tournament: the creation of a pool of alternative ideas; and the selection of these ideas in multiple rounds of competition.

A tournament can be run on web platforms or in off-line mode through events and workshops. In off-line tournaments (Innovation Workshop) all participants work together in a creative workshop that allows participants to show their imaginative potential; in online tournaments (Innovation Contest) participants work asynchronously, interacting with a *crowdsourcing* platform—neologism coined by Jeff Howe in an article published in Wired in 2006.

The advent of social networking technologies has definitely given a dramatic boost to the development of the crowdsourcing phenomenon: crowdsourcing is the act of outsourcing a task to a "crowd" in the form of an open call; each agent from the crowd self-selects to work on its own solution to the problem, and the best solution is chosen as the winning solution (Afuah and Tucci 2012).

The real advantage of a crowd is the variety of approaches, skills and experience that individual solvers bring with them (Boudreau and Lakhani 2013). There is vast empirical evidence that the winning ideas often come from people who operate on the periphery of the field of expertise in which it is expected that the solution lies. From a conceptual point of view, a "distant" research (new ideas or opportunities are frequently *distant* from the skills and capabilities that characterize the company) is transformed into a "local" search: for the winning problem-solver the solution is "near", as it is in his own specific field of expertise (Afuah and Tucci 2012).

As Terwiesch and Ulrich (2009) emphasize, "creating innovation opportunities is sometimes compared with lightning or flying sparks—spontaneous and uncontrollable"; the deliberate management of innovation tournaments can greatly improve the sensing, screening, and evaluation of innovation opportunities that happens before development even begins.

6 Conclusions, Managerial Implications and Avenues for Further Research

Lean management can contribute greatly to the improvement of a firm's innovation capability. But it is necessary to deeply understand which innovation processes are addressed by lean-inspired practices. In this perspective we have developed a framework that offers an integrated view of innovation processes—the Innovation Pyramid. The model shows that the capability to launch new products and services in the market is based on a three level system of activities: absorb, explore and create. Therefore improving innovation processes requires a coordinated approach that encompasses the activities of the three levels.

Our extensive review of the literature has identified 20 lean innovation practices that characterize the "translation" of Lean principles in the innovation processes. These practices lie mainly at level 3 of the Innovation Pyramid, suggesting that Lean Innovation practices must be integrated with other good practices coming from different literature streams.

Companies wishing to improve their innovation processes should not merely focus their attention on the third level of the pyramid, forgetting or neglecting the other two levels. Adopting tools and practices commonly described in the lean innovation literature is not sufficient to fully develop the innovation potential of the firm.

From a managerial point of view this means that there are a number of key points that must be kept in mind when adopting Lean Innovation practices.

For example, with regard to the development of a culture for innovation and creativity, lean practices seem to be focused on incremental changes. In this way there is a risk that innovation strategy is not oriented to planning and launch (radically) new products. This is even more problematic when using methodologies such as Variety Reduction Program (which aims to support the diversification of customer needs while maintaining profitability) or Design for Manufaturing & Assembly (that is used by many company to develop product designs that use optimal manufacturing and assembly processes).

Another example is about Quality Function Deployment (which is advocate by Lean supporters as a crucial method for satisfying customers by translating their demands into design targets and quality assurance points). QFD is consistent with a continuously and incrementally approach and causes companies to stumble over disruptive innovations.

Which general lessons can be drawn from the results of this study?

First, in defining a change strategy of innovation processes it must be clear that lean principles have a limited role. Tools and methods of the first two levels of the pyramid are equally important and should be carefully evaluated.

Second, management must define and customize the “Innovation Pyramid”, to clarify the scope of application of lean principles and to highlight which other frameworks of reference are important to improve the firm’s innovation system.

Lastly, change programs regarding management innovation practices must be balanced along with the three levels of the pyramid. Lean thinking focus on waste, flow and pull must be matched with specific investments in the processes of absorption and exploration. The adoption of lean management in innovation requires particular caution; as claimed by Chen and Taylor (2009), “going too lean could be harmful to creativity.” The elimination of waste and the pursuit of flow and pull do not represent the critical success factors in innovation processes belonging to level 1 and level 2 of the Innovation Pyramid, where instead redundancy, divergence and generation of ideas and multiple opportunities are crucial.

There are in our view two interesting research perspectives on the relationship between lean management and product innovation:

1. the identification of good practices in the non-lean-inspired literature on innovation and product development in order to define an integrated system of good practices (both “lean-inspired” and non-lean-inspired). This system could be used as a framework for the definition of a plan to strengthen the innovative capability of the company and could guide solid research studies that comprehensively analyse the impact of lean on different types of innovations.
2. the analysis of the non-lean-inspired set of good practices to identify their overarching principles and to assess their level of consistency with the five popular Lean Thinking principles proposed by Womack and Jones.

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Introducing a Value Improvement Model for Manufacturing (*m*-VIM)

Paul Martin Gibbons

Abstract This paper introduces a value improvement model (VIM) for repetitive processes applicable to any business where people and/or plant provide a service to support the overall business objective. Arguing competitive advantage can be realised through different amalgams of productive and strategic resources, the VIM introduced focuses on aligning resource bundles and influencing factors creating efficacious, efficient and effective processes by applying Lean thinking and Six Sigma tools and techniques more holistically. The research methodology taken incorporated a case study approach complimented by the action research process of planning, observing and reflecting summarized as an action case study research design. The case study data presented examines the possible improvements to an Extrusion manufacturing process that are achieved through the adoption of the VIM. The *m*-VIM is introduced as a useful tool for a visual and systematic framework that enables managers to understand, assess and improve repetitive processes within their businesses.

Keywords Lean · Six sigma · Continuous improvement · Systems thinking · RBV

1 Introduction

As businesses look to remain competitive in their market place they must continuously improve their operations or face closure, as Abrahamson (2000) argues, it is simply a case of '*change or perish*'. Abrahamson (2004) also presents a warning suggesting too much change implemented too fast is not necessarily good for

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businesses and '*change & perish*' can be the result if the consequences of change are not fully realised. This paper looks to overcome some of the problems with change identified by Abrahamson (2000, 2004) applying systems thinking through the development of a value improvement model (VIM) for repetitive processes. The VIM concept introduced builds upon the Lean and Six Sigma conceptual frameworks and strategy literature to understand how systems thinking can support business change and subsequently realise sustainable competitive advantage.

Outlining the structure of this paper, first a taxonomic and captious review of the lean literature is made followed by an introduction to the generic VIM for repetitive processes and the link to Lean, Six Sigma, Systems Thinking and the Resource-Based View of the firm strategy literature is discussed. Taking an action case study approach the case study data is presented illustrating how the VIM was applied in a single manufacturing case study example. Discussing the usefulness of the approach and research limitations, the final section introduces key learning points which can be carried over to further develop the value improvement model for repetitive processes.

2 Literature Review

2.1 The Evolution of Lean

Hines et al. (2004) argue there have been four main stages in the evolution of the lean concept. The "*pre-concept*" awareness stage—1980 to 1989—presented diffuse empirical based material relating to the methods used within Japanese manufacturing industries, primarily in the automotive industry and in particular Toyota (Hayes 1981; Krafcik 1988; Mather 1988; Monden 1983; Ohno 1988; Schonberger 1982, 1986; Shingo 1981, 1989).

The ensuing seminal work of Womack et al. (1990)[1] introduced the "*lean production*" concept, as it is known today, suggesting a focus on waste elimination of individual processes; at what could be considered at the micro level of the overall operation. The conceptual development was based on the findings from a 5-year International Motor Vehicle Project (IMVP 2005) project based at the Massachusetts Institute of Technology (MIT) in America. In summary of the project, Womack et al. (1990) suggest the lean production concept combines the best elements of craft production with those of mass production offering a pluralist approach which focuses on delivering:

> ….reductions in costs per unit and dramatically improving quality while at the same time providing an ever wider range of products and ever more challenging work.

[1]Although Krafcik (1988) first labelled the Toyota Production System as lean, Womack et al. (1990) are widely recognised as producing the seminal work outlining the principles of lean production.

Overall, the study revealed the existence of a 2:1 productivity difference between car assembly plants in Japan and those in the West. These findings lead to extensive industry "*soul-searching*" (Lewis 2000) which resulted in further benchmarking studies confirming the lean production project revelations (Andersen-Consulting 1993, 1994; Boston-Consulting-Group 1993; IBM-Consulting-Group 1993).

In 1994 the tangential concept of a "*lean enterprise*" (Womack and Jones 1994) was introduced as a development of lean production taking a broader perspective of the extant relationships between disparate processes within the overall system of manufacture; at what could be considered a more macro level of the overall operation. The ideas behind the lean enterprise were further complemented by a set of principles presented as "*lean thinking*" (Womack and Jones 1996a, b) summarised as the five steps to becoming lean.

Concurrent with the fundamental conceptual work of Womack et al. (1990) was the dissemination of the lean concept to other areas of operations management research. This research culminated in the "*lean supply*" (Lamming 1993, 1996) and "*lean logistics*" (Jones et al. 1997) concepts. Other simultaneous and tangential work led to the development of new tools to enhance the original concepts: Seven Value Stream Mapping Tools, (Hines and Rich 1997; Hines et al. 2000); Value Stream Mapping (Rother and Shook 1998) and Big Picture Mapping (Jones and Womack 2003). All with the same objective of eliminating the seven non-value elements in processes as originally specified by Ohno (1988).

The most recent phase in the evolution of lean has seen the introduction of the "*lean consumption*" concept (Womack and Jones 2005a, b) which is described as "*…a necessary and inevitable complement*" to lean production and is about "*… providing the full value that consumers desire from their goods and service, with the greatest efficiency and least pain*". Similarly to other dimensions of the lean concept (Lamming 1993, 1996; Jones et al. 1997) the principles correspond closely with the 5 steps to becoming lean (Womack and Jones 1996a, b). This more holistic approach encompasses new ideas and in particular is interested in supplying what the end customer wants, where they want it, when they want it and without wasting their time at any time; an end customer satisfaction focused approach to the lean concept.

2.2 *Critique of Lean*

Despite the great success of the lean concept there have been concerns raised regarding the research that informed it and questions asked about its actual competitive impact (Lewis 2000). It is worth understanding these criticisms in more detail to further facilitate the identification of a potential research question.

Williams et al. (1992, 1994) heavily criticise the validity of the conceptual work of Womack et al. (1990) citing it as "*…a manifest absurdity of evangelical Japanolatory…*" borrowing old productivity measures used in an "*…increasingly loose and rhetorical way*". Williams et al. (1994) argue the research methods employed were ineffective, using constructs of the past based on secondary

Table 1 Comparison of $ value-added per motor-vehicle employee, 1986–1990. Adapted from Pilkington (1998) and Ward (1996)

	Year									
	1986		1987		1988		1989		1990	
Japan	**67,075**		**84,538**		**103,433**		**105,433**		**107,874**	
U.S.A.	77,787	1.16	80,403	0.95	89,034	0.86	94,912	0.90	89,219	0.83
U.K.	32,263	0.48	39,984	0.47	46,720	0.45	50,547	0.48	53,340	0.49
Canada	57,350	0.86	58,649	0.69	71,943	0.70	76,311	0.72	74,105	0.69
S. Korea	18,757	0.28	23,607	0.28	28,069	0.27	34,063	0.32	44,539	0.41
Spain	24,571	0.37	42,146	0.50	49,443	0.48	48,341	0.46	53,891	0.50
Sweden	42,776	0.64	52,413	0.62	63,433	0.61	62,723	0.59	63,229	0.59

Adapted from Pilkington (1998) and Ward (1996)

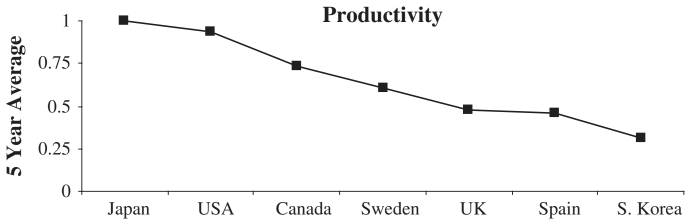

Fig. 1 Average ratio per country 1986–1990. Adapted from Pilkington (1998) and Ward (1996)

data, and constructs of the present which ignore available data such as company reports, accounts and official statistics. This concurs with Katayama and Bennett (1996) who also question the validity of the work suggesting it does not take into account the effects of Japan's "*bubble economy*" of the late 1980s in market conditions where owners were encouraged to scrap their cars and replace them with new ones. Lewis (2000) agrees, suggesting the lean production model may have "*reflected particular market conditions at a specific point in time*". Setting out to quantify these critiques, Ward (1996) and Pilkington (1998) provide data showing how some countries were actually performing much closer than Womack et al. (1990) had suggested (cf. Table 1). Taking the average productivity ratio over the 5 year period using the data from Pilkington (1998) and Ward (1996) the USA actually achieved a level of 0.94; nearly the same as Japan thus nullifying the claim of Womack et al. (1990) that there existed a 2:1 productivity difference between the US and Japan (cf. Fig. 1).

Although worthy of notation in its own right, the criticism of the research methods employed by Womack et al. (1990) are also important as they impact the validity of the research informing the concept of lean. Affecting the usefulness of the lean concept, this has led to further criticism which Hines et al. (2004) classify in the following categories: lack of contingency; lack of consideration for human factors and a narrow focus at the shop floor level.

Reviewing the lack of contingency critique of lean, Hines et al. (2004) present an example of a paradoxical situation where piecemeal applications of lean have resulted in the most productive car plants in Europe producing into the highest levels of finished stock. Overcoming this problem the proposal is made for cars to be built-to-order as suggested by Holweg and Pil (2001) and originally proposed by Monden (1983). Other critiques suggest that truly lean systems lack flexibility in terms of "*space to experiment*" and "*time to think*" (Lamming 1996). Taking a system reliability perspective, Smart et al. (2003) argue high levels of leanness can remove levels of system redundancy or organizational slack that are necessary to deal with contextual uncertainty and non-routine behaviour which in the case of the automotive industry would be consumer requirements. This argument is backed by Lawson (2001) who proposes slack is required to support system interdependencies and when this is ignored entire systems become vulnerable. Presenting an example, Lawson (2001) reviewed the problem encountered by GM in 1998 when its workforce went on strike shutting down all of the North-American operations. Without the parts from the striking plant, 29 assembly plants had no material to build cars. This resulted in the lost production of 576,000 vehicles estimated at $2.2 billion in lost sales (Blumenstein 1998).

Reviewing the human factor critique and narrow focus at the shop floor level together, Hines et al. (2004) suggest viewed through a Marxist lens, lean production can be seen as de-humanising and exploitative to shop floor workers (Williams et al. 1992). Green (1999) concurs arguing assumptions made in Womack and Jones (1996b) are uncomfortably similar to those of Taylor (1911) suggesting lean uses increased management control legitimized as management through customer responsiveness; "*Muda is eliminated, Karoshi*[2] *is the price to be paid.*" According to Maccoby (1997) this new form of Taylorism is no different to the monotonous and iterative tasks repeated every 60–90 s in traditional mass production. Tangential to these concerns is the involvement of shop floor workers in improvement activities. Rinehart et al. (1997), during their study of a GM-Suzuki joint venture, found workers were encouraged to participate in developing improvements thus expecting them to design the very system that oppresses them. Other studies, this time at the Nissan plant in the UK, deemed as the most productive plant in Europe (Hines et al. 2004), argue Nissan's supposed regime of flexibility, quality and teamwork translates in practice to one of control, exploitation and surveillance (Turnbell 1988; Garrahan and Stewart 1992). One final critique of lean is presented by Cusumano (1994) who argues there are also consequences to the adoption of a lean approach. For example, traffic levels increase and in Japan this has led to roads becoming grid-locked as factories and retail stores want just-in-time deliveries.

Acknowledging the criticisms of lean, Hines et al. (2004) propose a framework to help better understand the application of lean and its relationship with other operational level tools. The early conceptual work of Womack et al.'s (1990) lean

[2]*Karoshi* is a Japanese word used to describe the sudden death or severe stress resulting from being over worked.

production paradigm is presented as a sub-system of lean thinking (Womack and Jones 1996b) supplemented by other concepts considering production capacity, quality, responsiveness of the manufacturing system, demand variability, availability of production resources and production control resources; all with the objective to eliminate waste. At a strategic level, lean thinking (Womack and Jones 1996b) sits alone and is relevant to all aspects of the framework with the goal of understanding value creation and customer value.

Reviewing the model presented by Hines et al. (2004), from a critical perspective it could be summarized as using heterogeneous concepts homogenized into an egocentric typology with the objective of overcoming previous critiques. Also, missing from the framework are details of its operability and how these disparate concepts interface. More importantly, there is no mention of, or any reference to, understanding the de-humanising effects and flexibility the concept has been so heavily criticised for. This leaves the framework open for further critique and suggests there is still room to improve the lean concept to where it set out to be in the first place, a transferable version of the Toyota Production System (Womack et al. 1990).

3 Developing a Value Improvement Model for Repetitive Processes

Barney (1991) presents a useful framework for understanding how sustained competitive advantage can be achieved arguing the exploitation of internal strengths must be matched to external environmental opportunities, whilst managing external threats and internal weaknesses. Focusing on the internal analysis perspective taking a Resource-Based View (RBV) of a firm (Wernerfelt 1984), Wilk and Fensterseifer (2003) argue competitive advantage can be realised through different amalgams of productive and strategic resources. Wernerfelt (1984) suggests resources are anything that could be thought of as a strength or weakness of a given firm, defining resources as '*tangible and intangible assets which are tied semi-permanently to the firm*'. Antecedent work by Penrose (1959) argues resources bundled together, render a service as an input to a production process and it is these bundles of resources—providing potential services—that are the source of uniqueness in each individual firm. Penrose (1959) also suggested unused productive services are a waste, that they are potentially free and therefore, if used profitably, can provide competitive advantage. Waste elimination is a key objective of the Lean Production concept (Womack et al. 1990) and further developments of the Lean framework provide a useful approach for realising competitive advantage through waste elimination (Womack and Jones 1994, 1996a, b, 2005a; Rother and Shook 1998; Jones and Womack 2003).

Adopting the RBV internal analysis (Wernerfelt 1984) with a view to exploit internal strengths (Barney 1991) focusing on the improvement of resource bundles (Penrose 1959) and waste elimination (Womack et al. 1990), this paper introduces

Fig. 2 DMAIC and PDCA knowledge accumulation cycle

the concept of a VIM for repetitive processes developed and tested within multiple action case studies in both service industry and manufacturing applications.

Developing the VIM for repetitive processes, Fig. 2 shows a proposed framework providing a structured approach to sustainable value improvement building on the Six Sigma DMAIC and Deming/Shewhart Plan→Do→Study/Check→Act (PDCA) cycles. Of interest to this discussion is the original Shewhart Cycle discussed by Deming (1986) where the four step PDCA cycle has a fifth step defined as "*Repeat step 1, with knowledge accumulated*" and a sixth step defined as "*Repeat Step 2, and onward*". This continuous knowledge accumulation cycle allows for better understanding of the process to be improved rather than being a one off improvement typically found in the linear and sequential Six Sigma DMAIC improvement process.

Figure 2 shows how the PDCA and DMAIC improvement can be structured to complement each other; DMAIC is added to the continuous cycle of PDCA and the PDCA cycle is enhanced by the framework provided by DMAIC.

The proposed value improvement cycle takes the following steps based around seven Ps[3] (Liker 2004): Purpose, Perspective, People, Plant, Product, Performance and Process:

[3]People, Plant, Product and Process are the 4Ps commonly used in manufacturing as a useful framework for understanding problems. There are many different versions of the 4Ps in the literature, for example Liker (2004) proposes the 4P model is based around: Philosophy, Process, People/Partners and Problem Solving.

1.	Define	Understand what the **Purpose** of the investigation is from the Business' **Perspective**? Quantify the change required perhaps using the Six Sigma project charter approach
2.	Plan	Understand how the resource bundles of **People** and **Plant** are aligned to deliver the customer needs detailed in the **Product** description
3.	Do	Run the repetitive **Process** to deliver the **Product**
4.	Check/ Measure	Understand the outcomes of the repetitive **Process** and measure **Performance**
5.	Analyse	Analyse the **Performance** comparing the actual outcomes against those specified by the **Product** quantifying examples of waste (Lean) and process variability (Six Sigma) against the customer **Perspective (Product)** and business **Perspective (Purpose)**
6.	Improve/Act	Change the **Process** inputs based on the outcome analysis
7.	Control	Put in place control mechanisms to ensure the **Process** changes are sustained
8.	Define 2	Start again revisiting the **Purpose & Perspective**

Also supporting the VIM framework is the systems thinking approach to describing a process by answering the following questions, 'who?', 'what?', 'why?', 'where?', 'when?' and 'how?' (Godfrey 2010). Developing this systems approach further, Blockley (2010) suggests all processes have attributes that are characterised by understanding the relations between these questions:

$$\mathrm{W}hy? = How?\,(What?\,Who?\,Where?\,\&When?)$$

Building on the link with DMAIC and PDCA presented in Fig. 2 and the eight steps of the proposed value improvement cycle, in Fig. 3 the Author presents an initial conceptual model useful for visualising the cycle. Reviewing the PDCA inputs to the model, the repetitive cycle is placed under Deming's 'Do' with inputs of People, Plant and Products under 'Plan'. A useful tool for mapping and understanding the scope of a repetitive process is the Supplier-Input-Process-Output-Customer SIPOC tool (Pyzdek 2003). More specifically, the SIPOC is used as a methodology to identify factors influencing the repetitive process which can be used to populate the VIM. Using the information from the SIPOC—with a specific understanding of the output(s) to the customer—the requirement from the process owner is detailed for the product being processed. Therefore this product requirement encompasses the voice of the customer and is the value statement for the particular VIM. From a Lean perspective this value statement can be used to identify what is value-adding (VA), non-value-adding (NVA) and necessary but non-value-adding (NNVA) (Hines and Rich 1997; Rother and Shook 1998; Hines et al. 2000; Jones and Womack 2003) later in the VIM cycle.

The outcomes of the repetitive process are shown under 'Check' with particular performance indicators used to facilitate the identification of gaps to the customer needs (Product). Finally the 'Act' is the point of change where the inputs to the repetitive process are adjusted in a change, improve loop and the repetitive cycle can be completed again.

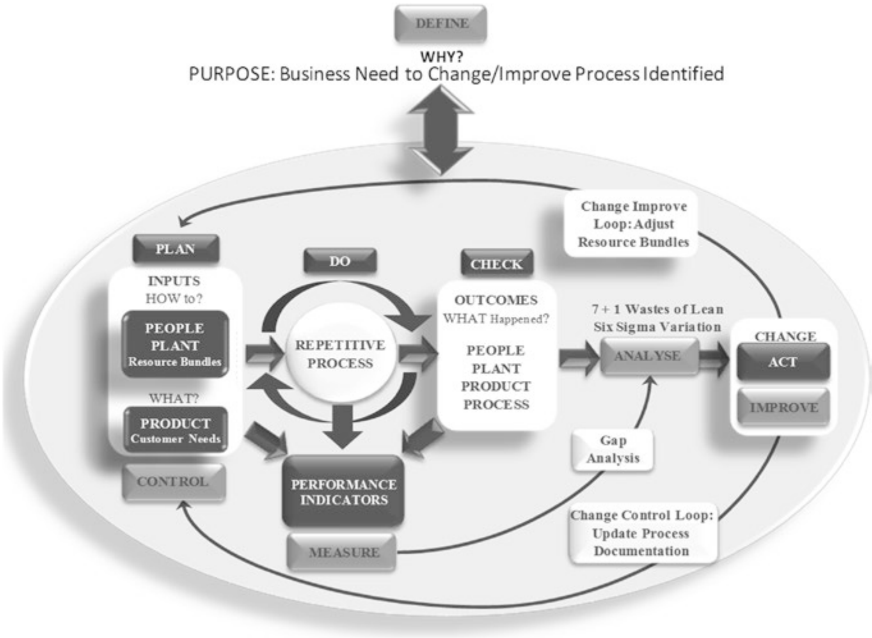

Fig. 3 Initial value improvement model framework

Complementing Deming's PDCA are the five steps of the six-sigma DMAIC process. The first step 'Define' is shown sitting outside of the repetitive process and is based around the purpose for the intervention or understanding of the repetitive process in question from a business perspective. Following the Plan, Do and Check stages is the 'Measure' step and measurement of a relevant performance indicator to understand how the process has performed so that the 'Analyse' step can be completed understanding the gap between the customer and business requirements using waste and variation analysis tools for the lean and six-sigma toolkits.

The 'Improve' step matches the 'Act' step and makes changes to the process inputs. The key contribution to the DMAIC process is the final step 'Control'. This is also complementary to the PDCA cycle as it is at this point the changes to the repetitive process can be controlled so that any changes made are robust and the inputs to the repetitive process do not go back to the format before the change was made.

Linking with antecedent research conducted by the Author (Gibbons 2008, 2009; Gibbons and Burgess 2010; Gibbons et al. 2012a), the initial value improvement framework presented in Fig. 3, in Fig. 4 the Author introduces the 1st working draft of a conceptual framework in the development of a value improvement model for repetitive processes including the placement of the individual

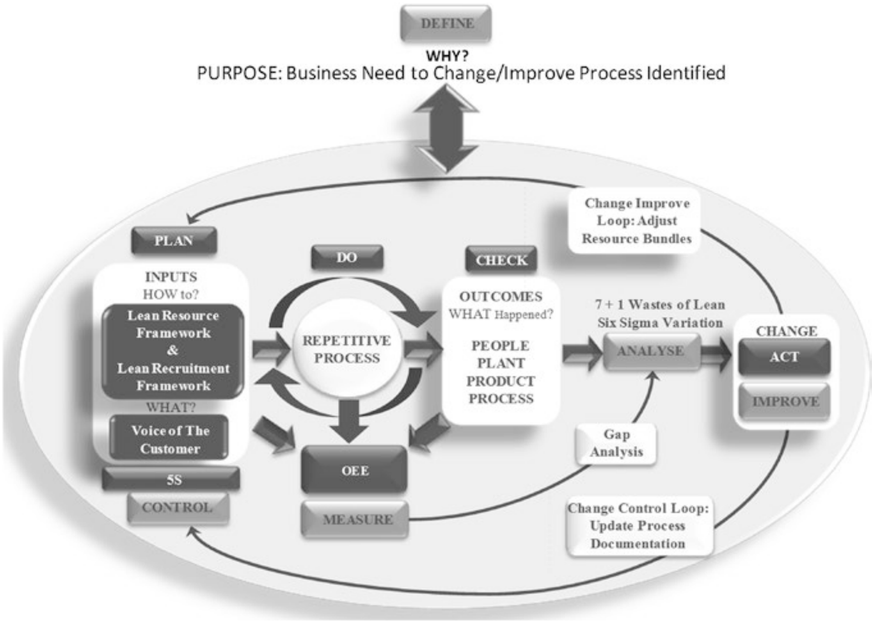

Fig. 4 Value improvement model for repetitive processes draft

concepts of: 5S, OEE, Lean Resource Framework and finally a Lean Recruitment Framework.

5S has been added to the model directly above the 'Control' stage and as has been argued in Gibbons (2008), the philosophy of 5S is seen as the platform to build any improvements upon, especially those direct inputs providing a service to the repetitive process. The important control documentation is the bespoke reference material—such as drawings, technical standards, standard operating procedures and common language compendiums—used at some point during the lifecycle of the repetitive process. From a Lean perspective the standardisation of the control documentation is classified as using a 5S approach which in itself can be measured to identify areas for improvement (Gibbons 2008). This standardised approach to processes reduces variation in the process and on its own can deliver quantifiable improvements to process outcomes (Gibbons 2006). For the VIM this is a critical element to both understanding the process and managing the direct process inputs themselves.

OEE has been added to the model as part of the 'Measure' stage and is shown as linked to the direct process inputs, repetitive process and outcomes. As has been argued in Gibbons and Burgess (2010), OEE can be used to provide an indication of lean six-sigma capability and also as a measure in the DMAIC process. From a Lean perspective OEE can be used in the manufacturing industry as a holistic measure of availability, performance and quality focusing on identifying the VA, NVA and NNVA elements of the process. For non-manufacturing industries bespoke measures can be used to understand how the process has performed focusing on the input requirements identified by the customer. Complimenting OEE, additional measures can be used to understand what happened specifically to the people and plant producing the product, understanding the 3Es, efficacy, efficiency and effectiveness of the repetitive process matched to the customer requirements. Developing useful definitions for the 3Es from antecedent work by Checkland and Scholes (1990) and Checkland (1999), efficacy can be defined simply as ‘does the repetitive process work?’, efficiency as ‘the output divided by the input, are we good at the repetitive process?’ and finally effectiveness as ‘is the repetitive process matching the longer term aim and are stakeholders satisfied?’

The lean resource and lean recruitment frameworks have been added to the model as part of the ‘Plan’ stage. As has been argued in Gibbons et al. (2012a), the lean resource mapping framework provides a useful tool for understanding how the resource bundles (people and plant) provide a service to the repetitive process. The matching of people, plant and process is a key element in the development of a value improvement model as is the identification of instances of the eighth waste introduced in Gibbons et al. (2012a) classified as polarisation. Complementing the lean resource mapping is the lean recruitment framework which can be used to understand the core competencies and capabilities of the people element of the repetitive process (Gibbons 2009).

The internal elements on the VIM focus on measuring/analysing an outcome based on a requirement and feeding back improvements and updating process controls. This could be classified as hard systems thinking (Checkland 1981) which was developed to solve real-world problems during and after the Second World War. Although proven to be very useful, hard systems thinking has received considerable criticism focusing on its limitations when understanding complexity, politics, plurality, beliefs and values (Jackson 2003). Looking to overcome these potential weaknesses the VIM also takes into account internal and external influencing factors taking a more holistic approach encompassing elements of soft systems thinking as introduced by Checkland (1981). This understanding of the internal and external influencing factors of a repetitive process as well as the ‘given’ direct inputs is seen as the key to successful business change and therefore supports the realisation of sustainable competitive advantage.

Building a new approach to using lean and six-sigma tools through the development of a value improvement model for repetitive processes and overcoming the criticisms of lean and six-sigma implementations where improvements are made in isolation without a full understanding of other processes, people and plant (McAdam and Lafferty 2004; Nonthaleerak and Hendry 2008; Näslund 2008), the Author presents Fig. 5 showing the VIM presented in Fig. 4 with two additional bands around the outside.

The first band—shown overlapping with the repetitive process—represents the internal influencing factors to the particular repetitive process. These influencing factors are the things which do not directly influence the process but have either a positive or negative impact on the repetitive process. For example, other processes

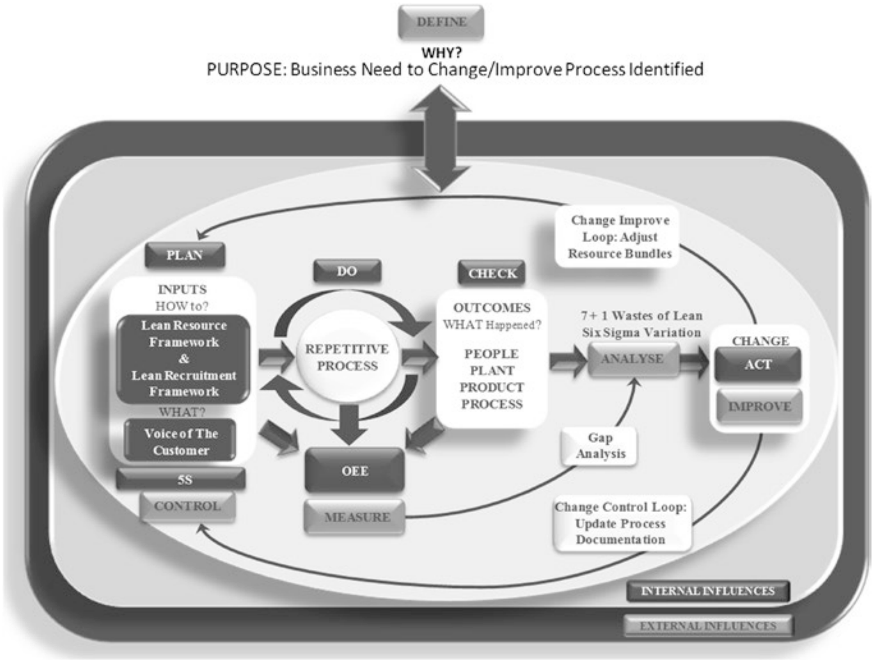

Fig. 5 Value improvement model for repetitive processes 1st draft

linked to the repetitive process must be understood and these would be included in the internal influencing factors. The internal influences area also contains those indirect elements which are more generic to the business environment such as local culture, leadership, business strategy, core competencies and are process inputs which can be changed and controlled but not as easily as the direct inputs.

The outer band represents the external environment influencing factors which similarly to the internal influencing factors can be either positive or negative. Examples of external influencing factors include legislation, climate (both business and weather) and industry regulations. The external factors are outside the control of the repetitive process and there is very little chance of directly changing or controlling them, although the process is influenced by them.

Finally, comparing the customer requirements to the actual outcomes, detailed analysis is completed to identify improvement opportunities to the repetitive process. Using Lean and Six Sigma analysis techniques process variation and waste can be identified and improvement plans developed. Once the improvements have been identified there are two critical change loops which must be completed to close the value improvement cycle so that the repetitive process can be run with refined inputs. The first is the change improve loop which is made to the direct inputs to the process, the resource bundles of people and/or plant. Typical changes will be based around removing, repairing, restoring or replacing the resource

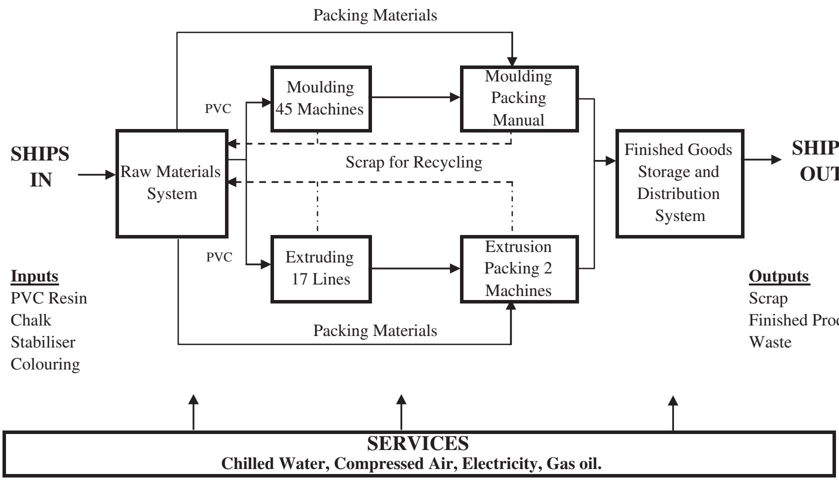

Fig. 6 Process flow diagram

bundles. In parallel to the change improve loop there must be a change control loop to ensure the change improvements to the resource bundles remain in place and that the process documentation and information is updated to reflect these changes.

4 Value Improvement Model Manufacturing Case Study

Operationalising the value improvement conceptual framework and testing the usefulness as a practitioner tool, the following case study presents an example of the VIM for the plastic pipe, extrusion manufacturing process. The case study was made at a large sized UK manufacturing company producing plastic plumbing and drainage products for both retail and construction civil engineering marketplaces. Figure 6 shows a simplified process flow diagram for the manufacturing operations used within the Company. The two main production processes employed utilise extruding and injection moulding technologies, with all PVC blended on site from raw materials.

A management review of existing key performance indicators (KPIs) identified current scrap levels in manufacturing were averaging above 12 % and in the last financial year this was estimated to have cost the business £1.4 million in replacement materials alone equating to over £7.6 million over the last 5 years (using available data). Further analysis identified one particular process (Orion[4]) had accounted for 15 % of the total scrap generated during the last financial year.

[4]The process name is a pseudonym.

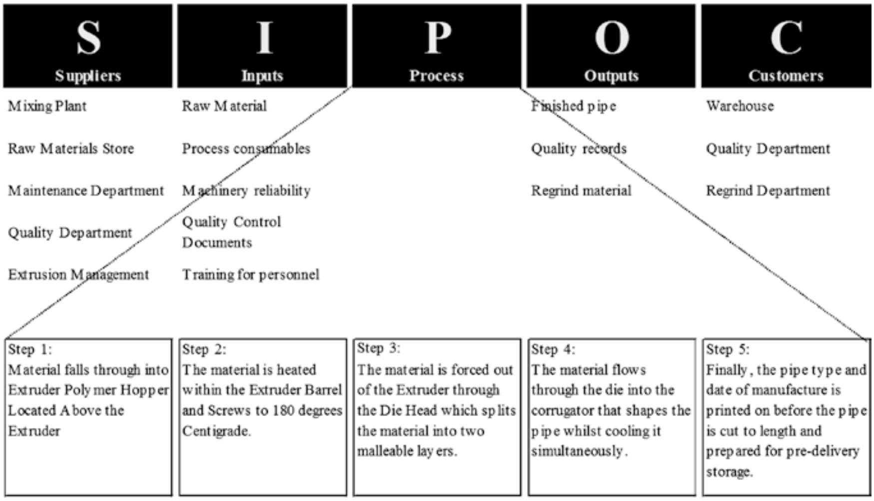

Fig. 7 Extrusion process SIPOC

An improvement project was established to identify the root cause of this problem and to put in place sustainable improvements at minimal total cost.

Figure 7 shows the Author's proposed SIPOC for this process setting the scope of the investigation and identifying the key customers, their requirement specified under outcomes and the suppliers and their inputs to the process summarised to the five main steps. Any other activities outside of these process steps are not included inside the scope of the improvement initiative. The Author feels this could be a critical failure in the six sigma methodology as improvements are based round activities within the scope of the SIPOC without fully understanding the process more holistically. The VIM development discussed in this paper seeks to overcome this 'silo' approach to process improvement.

In Fig. 8 the Author shows the VIM developed for the Orion extrusion repetitive process including the internal and external influencing factors. The resource bundles are represented by the Machine Setters and Extrusion Equipment and the Product is defined as a 300 mm diameter corrugated pipe. Overall Equipment Effectiveness (OEE) was used to capture more specific and objective data onto the Orion process and data was collected in collaboration with the process operators, over an initial six-week period.

Utilising the Lean Six-Sigma DMAIC approach, the data collected was analysed and the initial emphasis was made on improving the quality failure modes based around standardising and simplifying the activities carried out by the process setters and operators. Following a Kaizen (Imai 1986, 1997) improvement activity, data was collected for a further 6 week period and analysis demonstrated a significant improvement with the OEE rising from 34 to 62 % (see, Gibbons 2006). This first pass improvement was made on the basis of applying 5S principles to the equipment hardware and for standardising the setting duties developing standard operating procedures (SOPs).

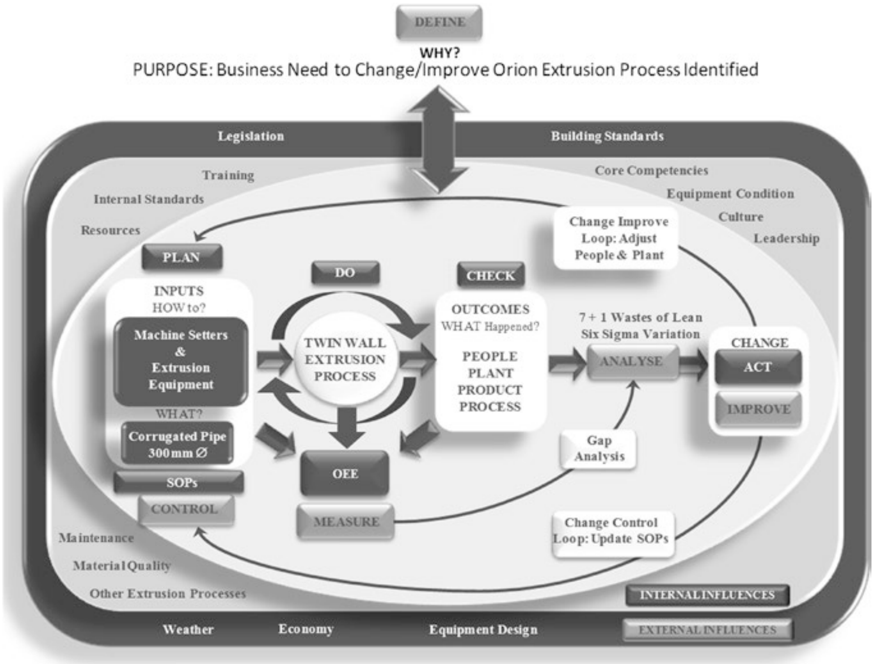

Fig. 8 Value improvement model for manufacturing process

One of the internally influencing factors of the model is shown as equipment condition which was found to be negatively influencing the repetitive process. Due to a lack of ability to complete customer orders on time the equipment was on a downward spiral of condition with no time allocated for maintenance activities. Maintenance is also shown as an internal influencing factor and should have a positive impact on the repetitive process.

With this in mind, during the Kaizen improvement event the equipment was given an overhaul as part of the 5S process improving the condition to a manageable level in the future. The lack of maintenance is linked to another internal influencing factor—leadership—where the production manager had adopted a 'fire-fighting'[5] approach and was running the whole of the extrusion department with a very short-term approach negatively influencing the repetitive process.

Although the improvements to the OEE for the Orion process were significant, an OEE of 62 % is a long way from the World Class levels of 85 % suggested by Robinson and Ginder (1995). Therefore looking to further improve the Orion process the OEE data must be further analysed to identify opportunities for

[5]Fire-fighting is a term used in industry to classify a management approach based around short-term thinking often ignoring longer-term consequences of decisions made.

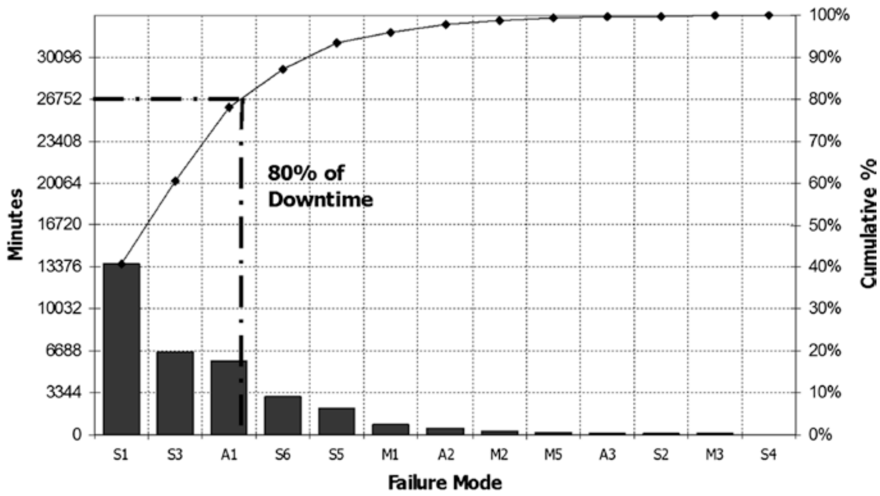

Fig. 9 OEE data availability failure mode pareto analysis

improvement. In Fig. 9 the Author shows the failure modes presented in order of magnitude. Added to the Pareto graph is a cumulative percentage line facilitating the inclusion of an 80 % failure mode block to identify where the focus of improvement should be made.

Inside the 80 % cumulative block of failure mode minutes are 3 of the failure mode categories accounting for nearly 20 % of the total failure mode categories and >26,000 min of downtime. Of these failure modes two non-related categories account for 38 %, S3 (die strip and clean)—which has been improved upon as part of the standardisation and simplification activities—and A1 (no programme).

More importantly, and responsible for 40 % of downtime within the availability element of the OEE calculation, failure mode S1 (waiting setter) represents 25 % of the total inefficiencies witnessed within the Orion process. Therefore the focus of the investigation is to identify the root causes for the 40 % downtime *waiting setter.*[6]

4.1 Problem Root-Cause Analysis

Imai (1997) suggests that a problem solving technique known as the '*5 whys?*' can help identify the real root cause of the problem. This technique is applied to the unavailability inefficiency identified: 'waiting setter':

[6]The term 'setter' refers to a skilled production technician capable of preparing a process for production.

Problem statement: Over a period of six weeks the Orion process was unavailable for production for 25 % of the time.

Why 1?

Q1. Why was the Orion process unavailable for 25 % of the time?
A1. There was no setter available to attend the process.

Why 2?

Q2. Why was there no setter available?
A2. There was no setter available for the following reasons[7]:

- Setter attending to other production processes within the factory due to the absence of other setters (planned and unplanned).
- Setter driving forklift for extrusion department due to absence of usual driver (unplanned).
- Orion process setter off sick or on holiday. No relief cover planned using other Orion setters and no other non-Orion setters capable of setting process.

Why 3?

Q3. Why was the setter attending other processes within the factory?
A3. There is a lack of skilled setters for some of the more complex processes (especially Orion) combined with limited flexibility and an imbalance of setter skills between products. When absences (planned and unplanned) occur production management prioritise setter deployment on a fire-fighting basis.

Why 4?

Q4. Why is there both a lack of skilled setters and low level of flexibility between product processes?
A4. The production strategy deployed focuses on achieving higher efficiencies delivered through economies of scale using dedicated personal specialising in individual product process setting skills. Complementing the lack of available setters is a zero overtime policy implemented as a result of a flexible working initiative. Poor management of the flexible working agreement means that when setters are absent no arrangements are made to cover their dedicated product process.

From the 5why analysis, the root cause of the waiting setter problem is identified as a consequence of a business strategy focused on delivering economy of scale efficiencies utilising inflexible processes and personnel combined with an

[7]At this point the investigation could be broken off into three separate streams to identify the root causes of each of the reasons listed. For brevity, only the first bullet point investigation will be presented. However, the full investigation identified a root cause linking all three of the reasons presented.

imbalance of setter skills. Complementing the rigid production strategy is a human resources strategy incorporating a zero-overtime policy as a result of a flexible working initiative.

In summary, the combination of an inflexible product/process skill base, general disparity of skills and a zero-overtime policy are seen as the cause of the waiting setter effect. Consequently, production managers are forced to fire-fight to meet customer deliveries using whatever resources are available.

4.2 *Lean Resource Mapping Framework Application*

Looking to overcome the problem with resource alignment to fulfil customer expectations through manufacture and delivery of products in a timely manner, the lean resource mapping framework introduced in Gibbons et al. (2012a) is used to understand how the resources (people and plant) are aligned to the products and process. Figure 10 is presented by the author as the operational level resource matrix for the main processes and functional activities used within the Company.

Reviewing the operational level resource matrix it is possible to see the relationships between processes (shown horizontally) and functional activities (shown vertically). For example, the maintenance function is vertically polarised to the process setting, quality control and production operating functions. In contrast, the quality control function is integrated with production operating. Also showing

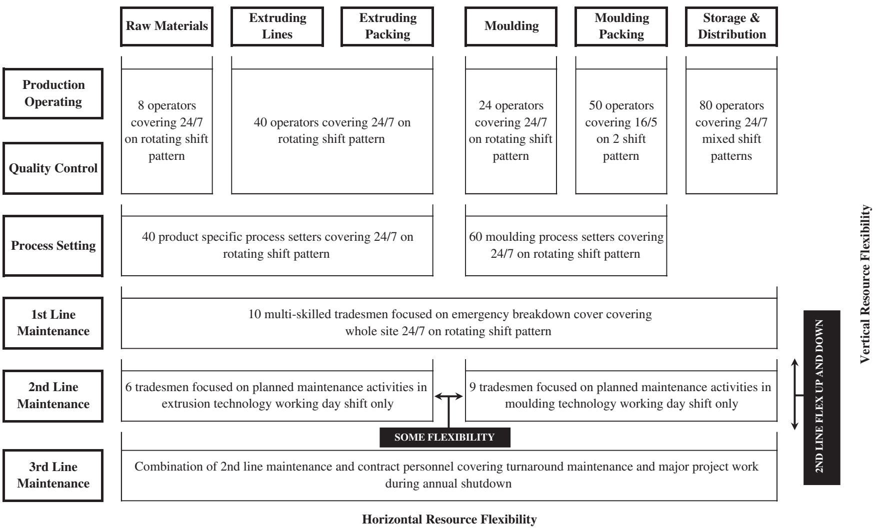

Fig. 10 Operational level resource matrix

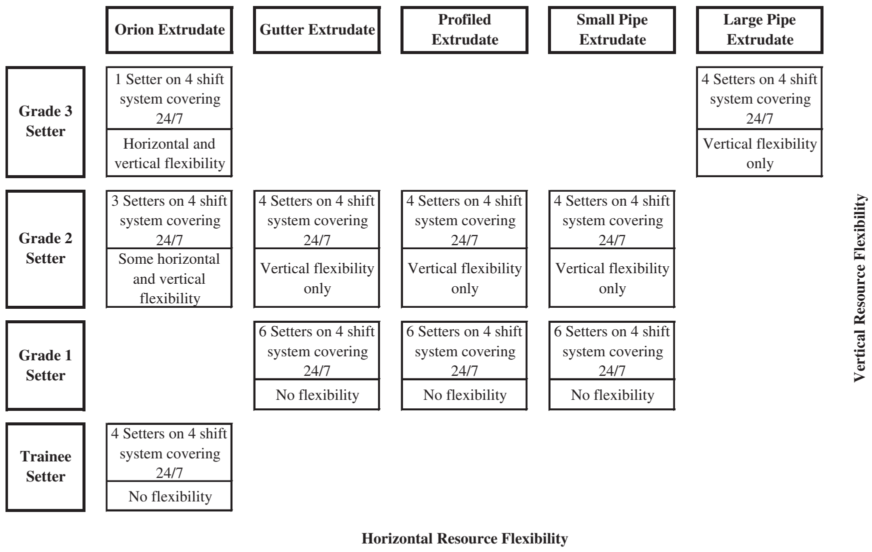

Fig. 11 Current state resource matrix

vertical flexibility, the maintenance function is split into its three main levels[8] (Kelly 2001) and shows how the 2nd line resources are flexible both up and down to cover 1st line and 3rd line maintenance activities.[9]

Reviewing the horizontal flexibility it can be seen that the 1st line maintenance resources are covering the whole factory utilising a 24/7 rotating shift pattern. The 2nd line maintenance resources are split between the two main processes, extruding and moulding as are the process setters. Additionally, the 2nd line maintenance resources show some flexibility horizontally between the two main processes.

To understand the problems identified within the Orion process the resource diagram must be taken to a lower level of functionality. In Fig. 11 the Author shows the current state resource matrix for the extrusion department with the five main product groups utilising extrusion processing techniques spread horizontally. Perpendicular to the product groups are the four levels of setter skills with the Grade 3 setters being the most skilled and experienced and the trainee setters being the least experienced.

Reviewing the resources allocated to the Orion product group it can be seen that there is only one grade 3 setter covering this area. As indicated, this one

[8]The maintenance function is usually split into 3 categories: 1st line maintenance covers corrective repairs and minor preventative online; 2nd line maintenance covers planned preventative, on or off line; and 3rd line maintenance covers major modifications offline (Kelly 2001).

[9]In an organisation practicing Total Productive Maintenance (TPM) you would expect to see 1st line maintenance activities, and some 2nd line activities, covered by maintainer/operators.

setter is also horizontally flexible covering all product ranges and vertically flexible covering lower level setter duties. This shows that of the 4 shift crews covering the Orion processes there is only one setter capable of performing the 'expert' troubleshooting and process setting duties on this product specific process line. Consequently, in the absence of a grade 3 setter on their shift, the three, grade 2 Orion setters are forced to be vertically flexible carrying out expert duties they are not capable of doing.

Another observation of the grade 3 setter horizontal plane is that within the large pipe product group there are four grade 3 setters who are horizontally polarised but flexible covering lower level duties. This means that highly skilled setters are carrying out duties that could be quite easily covered by lower level setters when they could be horizontally flexible using their expert setting skills to support other processes.

Overall there seems to be an imbalance in the dynamic matching of the workload between setters and product groups within the extrusion department. For example, there are cases of bad vertical flexibility, where setters are forced to carry out duties which they are either not qualified to do or too qualified to be doing. There is little horizontal flexibility between product groups and the few instances where it exists leave the setter stretched and the department vulnerable to problems (as has been identified in the problem solving 5 why root-cause analysis).

To overcome the imbalance of setter skills and product processing requirements a change in the resource structure must be made. In Fig. 12 the Author presents a

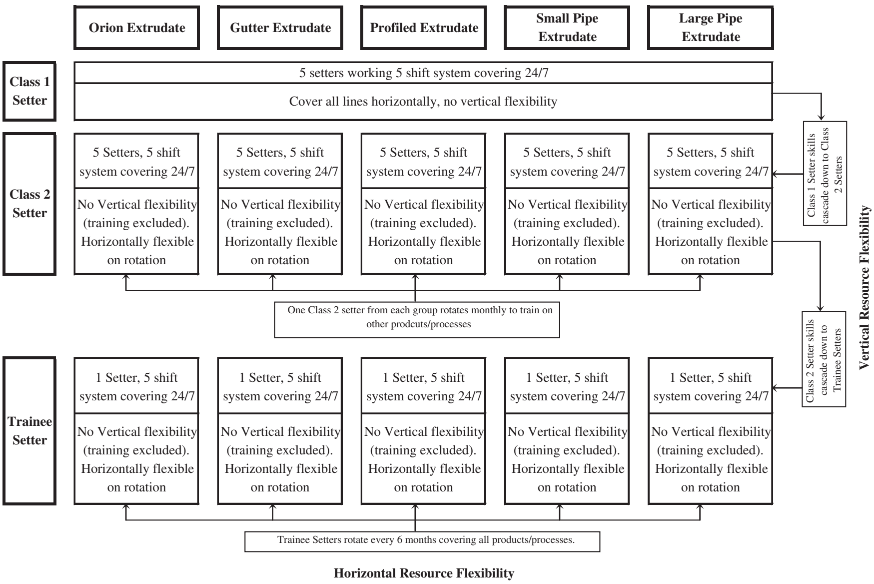

Fig. 12 Future state resource matrix

future state resource matrix taking into account the problems identified through the current state resource matrix.

Maximising appropriate flexibilities horizontally and vertically, the future state resource matrix is based on a workload incorporating three levels of setter functionability utilising a new 5 shift system to ensure there is always cover where required.[10] For example, the class 1 setter function is covered by five setters with one setter always on duty. The class 1 setters are horizontally flexible focused on utilising their high levels of skill and experience in all product groups with no vertical flexibility.

Reviewing the class 2 setters it can be seen that these are semi-permanently fixed horizontally to product groups with one setter in each group rotating monthly to gain the skills and knowledge to work within other product groups. The class 2 setters are only vertically flexible when being trained by the class 1 setters whose knowledge cascades down to them through fixed training plans with the objective of developing future class 1 setters.[11]

Finally, there is one trainee setter in each product group who is fixed horizontally for six months before rotating with all other trainee setters to move into another product group. As with class 2 setters, trainee setters are only vertically flexible when being trained, this time by the class 2 setters who cascade their knowledge down through fixed training plans with the objective of developing future class 2 setters.

4.3 Implementing the Lean Resource Matrix

Jones and Womack (2003) argue the realization of a future state map in one big leap is not ideal and therefore suggest the use of an ideal state map as the end goal utilising future state maps as incremental leaps. The development of the ideal state map can be broken down into manageable steps employing yearly value stream plans (Jones and Womack 2003) incorporating manageable segments of future state maps known as loops (Rother and Shook 1998).

Applying the VSM implementation techniques to the proposed framework seems logical and applicable. The future state resource matrix would become the ideal state resource matrix and an implementation plan using new future state resource matrixes and loops as stepping stones (Wernerfelt 1984) could be developed.

[10]The Company had previously operated a four shift system covering manufacturing operations, day and night, 24 h a day, seven days a week. The proposed 5 shift system uses an extra shift incorporating redundancy to utilise flexible working agreements.

[11]The lean resource matrix can also be used for succession planning also providing 'stand-by' redundancy in resource utilisation in case of an emergency or change to the system. This perhaps helps to overcome one of the criticisms of lean where resources are kept to a minimum leaving the overall system vulnerable. This also helps overcome one of the other criticisms of lean where flexibility is removed through waste elimination and a linear focus on process optimisation.

Facilitating the development of personnel, the lean recruitment framework introduced in (Gibbons 2009) could also be used to match the requirements of the different setter roles assessing the levels of the existing employees and developing training plans to fill any gaps.

5 Discussion

The VIM has been developed from the individual elements of research presented in antecedent research (Gibbons 2008; Gibbons and Burgess 2010; Gibbons et al. 2012a, b) a 1st draft conceptual model has been presented in Fig. 5. Operationalising and testing the usefulness of the value improvement model, a case study example was presented and a VIM was developed for a manufacturing extrusion repetitive process as shown in Fig. 8 (*m*-VIM).

A first pass improvement to the extrusion process applied the 5S principles to standardise the repetitive process which in itself improved the OEE level from 34 to 62 %. Looking to further improve the OEE level a review of the value improvement model identified how other processes were influencing the machine Setter availability.

Figure 13 shows the Author's (de-)value improvement model for the extrusion manufacturing process overlaid with the following comments:

- Other external extrusion processes are shown negatively influencing the machine setter availability.
- A consequence of this negative influence is a reduction in the OEE as the extrusion equipment is not operated when the Setters are not available.
- A consequence of the reduced OEE leads to the Leadership fire-fighting to match customer orders.
- A consequence of the fire-fighting leads to a reduction in planned maintenance as the extrusion equipment is not released from production.
- A consequence of the deterioration of the extrusion equipment leads to a reduction in the level of OEE as the availability efficiency element also reduces in parallel to the equipment condition.
- A consequence of this a 'de-value' cycle starts where the leadership continues to fire-fight and the equipment continues to deteriorate until a catastrophic failure causes a major intervention.

Overcoming the problems identified with the external extrusion processes influencing the setter availability, the lean resource mapping framework was applied taking into account the requirements of other processes. Operationalising the proposed resource alignment, the lean recruitment framework was also proposed as a means to evaluate the competency levels of the machine Setters, developing training plans to achieve the required levels of resource flexibility. The results of the manufacturing value improvement are summarised by the Author in Fig. 14. Linking OEE with a financial value, the estimate for each 1 % of OEE was

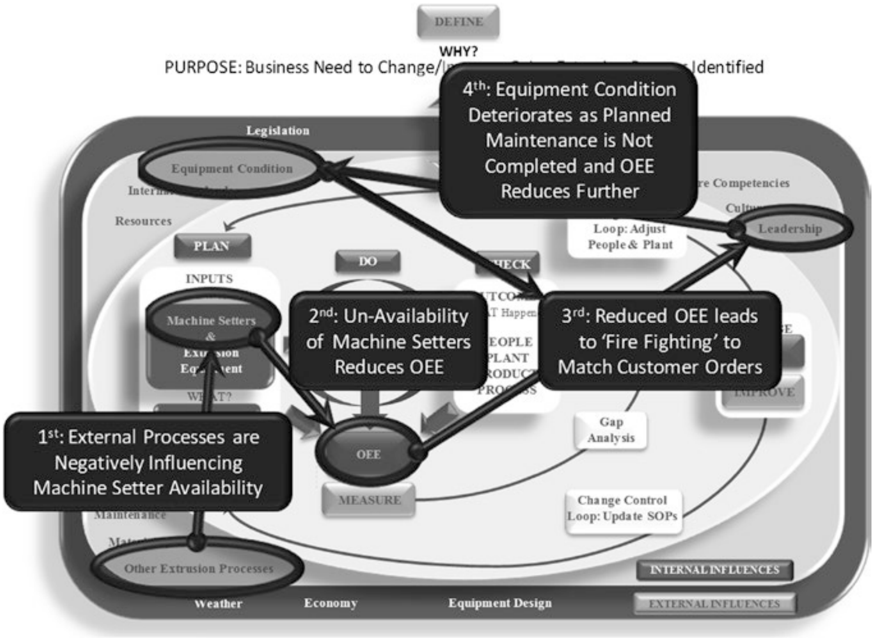

Fig. 13 Manufacturing de-value improvement model

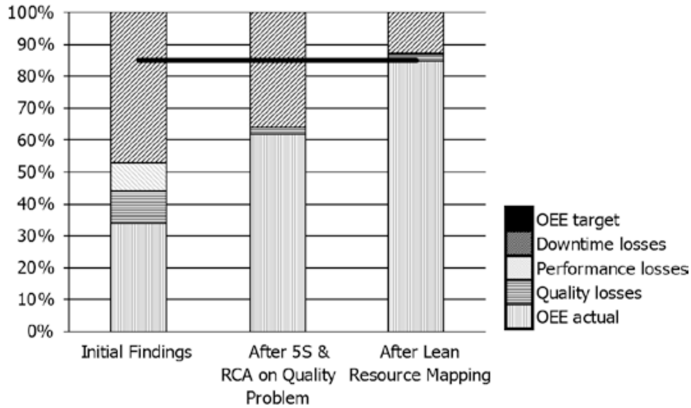

Fig. 14 OEE improvement results

approximately £18.5 k PA with savings in material, resources and reduced costs of re-manufacturing non-conforming products. In summary, the impact and value adding contribution for the manufacturing case study:

- OEE increased from 34 to 85 % giving a value improvement of £18.5 k × 51 % = £943 k PA.[12]

5.1 m-VIM Strengths

One of the underlying strengths of the VIM is the focus on repetitive processes rather than one-off activities. By focusing on repetitive processes, the VIM can be built around an accumulated knowledge of what has actually happened allowing improvement decisions to be based on the evidence of antecedent process performance. The feedback loops of the value improvement cycle also inform future investment decisions creating a continuous value improvement action cycle based on quantifiable evidence. Therefore, as the maturity in process knowledge accumulation increases through the VIM, so do quantifiable and justifiable opportunities for positive interventions for process improvement to be made. With a one-off process there is not necessarily the maturity and knowledge accumulation to create a value improvement cycle.

5.2 m-VIM Limitations

Although the VIM has been proven to be a useful methodology for understanding and process improvement, there are some limitations which the Author encountered during this case study application. Perhaps the most important limitation to understand relates to the adoption of the VIM. For example, the value improvement current and future state models can be developed and used to identify gaps, but on their own, will not translate the current to the required future state. For this to happen, management intervention is required. Therefore, the success of the VIM application is dependent on the engagement of the ‘actors’ within the repetitive process perhaps through understanding the existing culture of the organisation. For example, the leader of the repetitive process must positively promote the value improvement activity, proactively engaging with the other actors and demonstrating leadership through adoption of the Plan→Do→Check→Act approach.

[12]The assumption is made that there is a linear relationship with the OEE improvement % to £, however in reality this is probably not linear but for the sake of quantifying the value impact, the Author argues this approximation is acceptable so long as the Company accountants are happy to approve the financial benefits in OEE % saving (as was the case in this example).

Sponsorship of the value improvement initiative must also be at the Owner level. Equally important is the buy-in from the 'actors' providing a direct service to the repetitive process. Outside the scope of this paper, perhaps future research could look at the cultural aspects of the VIM and their influence on the success or failure of the repetitive process as either a positive or negative internal influence.

6 Conclusion

This paper has introduced the 1st draft of a value improvement model for repetitive processes and provided a case study example based around a manufacturing process showing how the individual concepts of 5S, OEE, Lean Resource Mapping and the Lean Recruitment Framework can be incorporated into an *m*-VIM for repetitive processes. Future research should look to further develop the VIM so that it can be used within service industry and other business environments. Also, future research should look to further develop the VIM, perhaps focusing on developing a self-perpetuating process improvement cycle translating a 'current state' VIM to a 'future state' VIM in individual, but interconnected and economically quantifiable steps.

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