Wider applications for Lean: An examination of the fundamental principles within public sector organisations

Introduction

Lean originated in the automotive sector and more specifically in the Toyota Motor Corporation (Shingo 1989; Monden 1998), thus the core principles and practices of lean have been explicitly designed for use in organisations engaged in high-volume, repetitive manufacturing environments (Liker 2004). The lean approach has then been adapted and adopted by a wide range of sectors, both in manufacturing and service, private and public and high to low volume (Holweg 2007). The hypothesis of this paper is that if lean is to be successfully applied beyond this conventional organisational context, then its fundamental principles will need to be reviewed and adapted to suit the specific needs of the host organisation.

The literature review outlines the evolution of lean from its automotive origins to wider sectors and in particular, service and public sector applications and presents a model of how lean principles and use of tools interacts with the operations of the organisation. Using this model the subject organisation, the Royal Air Force's Tornado Joint Integrated Project Team (JIPT), is examined and differences both in the application of tools and applicability of the lean principles are explored. Parallels are then identified between Tornado, other service sector, public sector, service and repair organisations and military organisations in their application of lean principles.

Literature review

The literature review outlines the evolution of lean from its automotive origins to wider sectors and in particular, service and public sector applications. It highlights the need to critically examine the relevance of the fundamental lean principles, to a service, public sector environment. Lean ideas have been extensively applied beyond their origins in the automotive industry evolving firstly to other manufacturing sectors and then into the service sector (Bowen and Youngdahl 1998; Hines, Holweg and Rich, 2004) and as part of this widening of lean, many public sector organisations have experimented with and adopted lean, to some extent (Radnor, 2010).

From its origins in the automotive sector, the attractions of lean have been brought to a far wider audience (Holweg, 2007) particularly since it has been codified into the five lean principles (Womack and Jones, 1990). These five principles are enacted through a series of commonly used tools such as kanbans, 5S and Visual Management (Bicheno 2004). Thus, a generic model of lean implementation, showing the interaction between its operational context, fundamental principles and application techniques, can be developed (Figure 1). The conventional lean environment has many facets but it is principally one of high stable volumes and moderate variety (Shingo, 1989 and Monden 1998) and this forms the top part of Figure 1. This operational context allows managers to apply lean principles (Womack and Jones 1996), to identify areas for improvement, and finally, having identified areas for improvement, tools and techniques that result in improvement can be applied, thus reinforcing the stability of the environment. (Murman 2002).

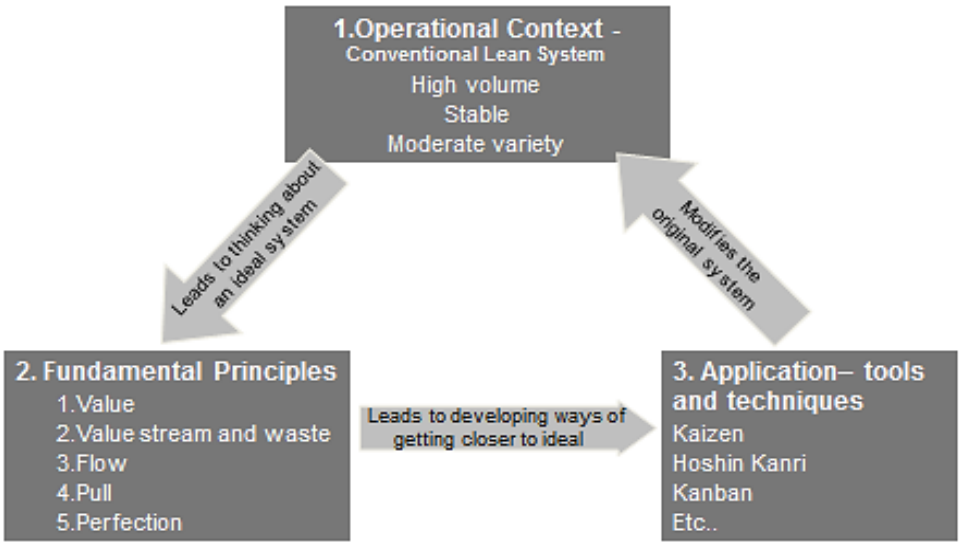

Figure 1: Lean thinking for conventional organisations (developed by the authors)

Through publications such as Womack and Jones (1996), Shingo, (1989) and Monden (1998), and extensive industrial application, lean ideas came to the attention of other sectors and were widely adopted, including sectors such as aerospace (Murman 2002), and construction (DTI 1998). Wider adoption of lean has meant that many of the ideas have become mainstream; however, this has also meant that the universality of lean has been questioned by authors such as Cooney (2002), Bartezzaghi (1999) and Hines, Holweg and Rich (2004). For example, Cooney (2002) evaluates cases in which lean has only been partially adopted and questions whether such approaches really are lean. Bartezzaghi suggests that some companies have begun to "*question the general validity of lean*

production" (p230) and also *"the definition lean production itself is vague and confused"* (p232).

Conversely, others such as Bane (2002), and Buzby et al. (2002), talk not only of the growing need for lean thinking, but the increasing application of lean in non-manufacturing sectors. Bane for example believes lean manufacturing to be a *"marvelously, universal improvement approach"* and that *"…non-manufacturing organizations can reap rewards from leading edge approaches if they look past the manufacturing-associated labels and utilize the underlying concepts."* (Bane, p.245)

Whilst much speculation and conjecture exists around the validity of lean and its transferability to service sectors, increasing evidence has emerged over the last twenty years, demonstrating clear business improvements within service based organizations, as a result of a lean thinking approach. For example, it has been argued that the ideas of lean production, as defined in manufacturing, are also applicable within product development and order-taking environments (Womack & Jones, 1996).

Specifically in the public sector there has been considerable reflection of the application of lean including: healthcare (Spear, 2005, Esain, Williams et al. 2008 and Radnor 2010); military (Agripino *et al*., 2002 and National Audit Office 2007) and higher education (Comm and Mathaisel, 2005, Emiliani, 2004). The actual application of lean has been mixed, Radnor et al.(2006) provides a good overview for the public sector. So lean has evolved from its origins within automotive manufacturing through to public service. However, the problem exists that although lean has been applied in a wide range of settings the fundamental thinking on which lean ideas were originally based have not been updated and adapted accordingly. This point was partially raised by Hines et al. (2004) who acknowledge that lean has evolved on the basis of the five principles, but its application has gone well beyond the use of a set of shop floor tools. This criticism was also raised by Radnor, Holweg and Waring (2012) who questioned the underlying assumptions for using lean in a healthcare context, and more generally its wider public sector application.

In parallel the application of private sector ideas to the public sector principally, with a view to increasing efficiency, is well documented in the New Public Management literature, whereby public sector managers have been encouraged to embrace approaches from the private sector, including areas such as lean (Radnor et al 2006). However, the general applicability of New Public Management has been challenged by authors such as Boyne (2002) who argues there are four possible main areas of difference between public and private sector organisations, namely: organisational environment; organisational goals,

organisational structures, and managerial value. It is these types of differences that may need to be taken into account when attempting to apply lean in public service organisations.

This study then addresses the need to re-evaluate lean by reviewing whether its fundamental principles and standard tools and techniques are appropriate when applied in a public service environment. More specifically, this study critically reviews the suitability of lean when applied in a novel public sector context, namely, the maintenance of the Tornado fighter aircraft, within the British Royal Air Force.

Structure of Tornado Joint Integrated Project Team (JIPT) [i]

At the time of researching this case, two derivatives of the Tornado aircraft were operated by the RAF (F3 and GR4), and these were based at four RAF sites in the UK. The F3 at RAF Leeming in North Yorkshire and RAF Leuchars in Scotland, whilst the GR4 is based at RAF Marham in Norfolk and RAF Lossiemouth in Scotland. These Main Operating Bases all fell under the responsibility of 1 Group, Headquarters RAF Strike Command, who were responsible for all strike attack and offensive support aircraft. Tornado logistic support was managed through a Joint Integrated Project Team (JIPT) based at the site at RAF Wyton (see Figure 2).

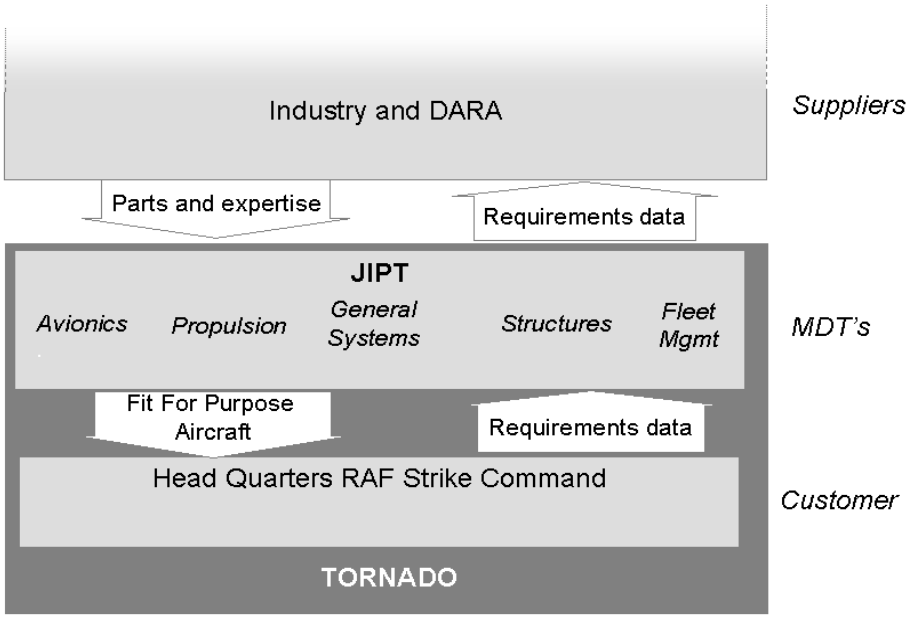

Figure 2: Tornado JIPT structure

The JIPT was the focus organisation for this research as it provides supply and engineering support to the whole Tornado fleet. From 2005, it took responsibility for the in-

depth maintenance carried out at each of the Tornado Main Operating Bases. This allows the JIPT to provide consistent strategic and output based direction across the whole of the support chain. This responsibility, to maintain and develop the Tornado as the RAF's *"all weather attack aircraft"* (Royal Air Force 2013) until it is retired from service, was managed in partnership with the Prime System Integrators, namely BAE Systems (airframe) and Rolls Royce (RB199 engines).

The JIPT consisted of a number of multi-disciplinary teams (MDT's) such as avionics and engines, as well as infrastructural elements such as finance, commercial, etc. The primary objective of the JIPT, in collaboration with industrial partners Rolls Royce Defence Aerospace, BAE Systems and Defence Aviation Repair Agency (DARA), was to provide the customer (Headquarters RAF Strike Command) with available, capable and safe aircraft.

Against this backdrop, the maintenance of Tornados by the JIPT and its partners was considered to be an appropriate focus for this case study, for the following reasons:

1. The Tornado JIPT had decided to apply lean to support the maintenance regime for all Tornado aircraft;
2. The authors were provided with good access, to the JIPT, over a period of nearly four years, both at an operational and strategic level,
3. It became evident, through networking events, that the results of this study would have a wider resonance, as lean in Tornado JIPT shared notable similarities with other military lean implementations within in the Royal Air Force (Apache, Hawk and Harrier, DLO News 2005) the Royal Navy and Army, and other public services such as the NHS and Universities.

Research Strategy and Methods

The purpose of this paper is to explore the implementation of lean within the public sector and specifically within the context of the Tornado JIPT, looking particularly at differences in context, to investigate how these might affect which principles, tools and techniques are applicable and which are redundant, or require modification. Thus the three elements in the model developed in Figure 1, namely operational context, fundamental principles and application techniques are examined within the context of a public service environment. The funding for this was provided by the JIPT who were seeking the expertise of the researchers in reviewing the lean activities in the Royal Air Force.

To do this, lean activities within the Royal Air Force were critically reviewed; these activities took place over an extended period of three and half years. More specifically, this research had two key focal points: a review of a variety of operational level rapid improvement activities (RIA's); and the development of a set of new performance measures for the JIPT. The following two sections review the purpose and research methods adopted for each of these areas of research.

Research Method for the Review of Tornado Rapid Improvement Activities

RIA's, also known as Kaizen events, often form the more '*hands-on*' activities within lean implementation and these were conducted at an operational base for Tornado.

The review of the RIA's was chosen for this paper because most of the lean principles and many of the tools common in lean implementation were encompassed within the RIA's. The review of operational level RIA's was commissioned by the Tornado management team because they wanted to understand the effectiveness of different approaches to RIA to develop their own '*one best way*', to conduct future improvement activities. Ultimately, the authors visited four distinct areas of operational activity, assessed the method of the improvement activity, documented it and then returned to the improvement team to validate the findings. The method of assessment for each RIA involved an interview with the internal change agent and their team, where available. Then the researcher took a tour of the area which often included informal interviews with personnel who worked in the area. These two parts of the assessment process took particular account of:

1. Operational performance measures
2. The improvement approach – usually documented as a flow diagram
3. The tools such as 5S etc. utilised
4. The improvements made
5. Follow-up by the consultants/ support team
6. Suggestions by the improvement team for the activity
7. Suggestions by the team for the wider improvement activity
8. Learning made by the people in the area
9. Level of adoption of the lean approach
10. The level of sustainability

The first seven assessment areas were primarily based upon the interviews and documentary evidence whilst the final three were judgements made by the researcher largely based on direct questions but also supported by the area tour with the informal interviews and

observations. Each visit was conducted over a day and then the findings validated by a follow-up meeting whereby the change agent could comment and correct any inaccuracies. Each of these reviews produced an agreed report and quotes in the results section of this paper are taken from these reports, thus the reports are the principle source of the research for this paper.

Research Method for Performance Measures Activities

The performance measurement activities were principally focused around developing appropriate performance measures for Tornado JIPT. These were conducted over a period of three years at different levels within the JIPT but examined particularly the operational measures for the MDT's. This was achieved using a series of workshops, led by the authors, for each MDT. The workshops took an MDT measures team through the development of operational measures for the purpose of improving performance. In addition the authors also conducted a review of the higher level weekly performance measures for the whole JIPT. As such this part of the research was more akin to action research than the assessment of the RIA's. Evidence from the workshops such as reports, presentations, photographs and contemporaneous notes from meetings were used for this research. The development of performance measures was selected for this paper because it accessed the concept of 'value' and also included some of the more administrative areas of the JIPT not yet reached by RIA's, and addressed those areas likely to be more affected by some of the features more prevalent in public service organisations, as identified by Boyne (2002).

Research Results

This section outlines a summary of the Rapid Improvement Activities and the Performance Measurement workshops. Differences between the Tornado JIPT and conventional lean organisations are then highlighted. The main results are an analysis of the application of lean within the Tornado activities.

Summary of RIA activities

The Rapid Improvement Activities (RIA's) took place at a main operational base from where Tornado aircraft flew and were serviced. Areas 1 and 2 took place in large areas equivalent to a whole hanger where many people worked. This meant for both of these activities only a small group could participate in the improvement activity.

Area 1 had seven tracks, where each track serviced one aircraft. The initial focus was on one track where the adoption of lean ideas was good and the improvement team and their manager were pleased with progress. Some ideas such as the re-organisation of low cost consumable items to be locally available were spread across the whole area but larger changes such as re-orientating the aircraft within the track had only been implemented within the initial track.

Area 2 used the MOD's own developing team of lean consultants, who took a less formal lean approach. They undertook considerable process mapping and achieved a high level of consensus about what should be done. They identified 74 problems to be addressed that were wide ranging and many had been well known for some time – and so this activity did not conform to a formal lean agenda. This was also reflected in the 5S approach where the team used some elements of 5S but did not conduct a formal 5S implementation.

	Purpose	**Area of focus**	**Team**	**Tools used**	**Duration**
Area 1	Improve flow and reduce through put time	Hangar – whole aircraft servicing	External consultants sponsored by supplier and 7 people from area	5S, Visual management, Change layout for improved flow	11 weeks
Area 2	Free resources (people, space and equipment) to take on additional work	Large functional area – similar to a hangar	MOD consultants and 15 people from area	Process mapping, 5S, re-laying out to improve flow	10 week diagnostic and plan and 9 month implementation
Area 3	Cost saving identified in end to end study	Small functional area	External consultants and 6 people from area	5S, SOP, VM Pull system	5 week diagnostic and plan 19 week implementation
Area 4		Small functional area	External consultants and all personnel in area	5S, SOP, VM Pull system	5 week diagnostic and plan 19 week implementation
Development of performance measures	Develop usable performance measures for MDT's	Across the JIPT focusing on MDT's	Teams of about eight people for each of the 4 MDT's	Communications boards, some aspects of policy deployment	Each MDT took about six months and the total time for all the MDT's was eighteen months

Table 1: Summary of lean activities

Areas 3 and 4 were both conducted in a similar way by the same group of external consultants. The remit for both these activities was to meet stretching cost savings specified by a high level study called "End to End" (NAO 2007). Both the area 3 & 4 team took a formal lean approach implementing a wide range of lean tools shown in Table 1.

Summary of Tornado Performance Measures

The development of performance measures was an activity in which all three of the authors participated, the whole process took nearly four years and went from top level policy deployment and strategy setting, down to performance measures at an operational level. The principle activities were a series of workshops with each of the MDT's. The purpose of these workshops was to develop a suite of performance measures that highlighted areas for improvement and action for the MDT. This would allow the MDT to co-ordinate improvement activity and highlight areas where effort should be focused in order to ensure they were fulfilling their function within the JIPT and their wider military role.

Much of the discussion evolved around the role of the MDT and how it would know whether it was performing well and this inevitably led on to discussion of 'value' for the MDT and the Tornado JIPT. The two most successful MDTs took different routes, but both ensured that the MDTs leaders' views were well represented and also incorporated other more technically detailed viewpoints. The first approach was where the MDT leader was present at all meetings and ensured customer and supplier processes were present too. The result was a practical well-understood range of performance measures that are being used as part of decision making in the MDT. The second approach utilised the two MDT's deputies who had clear vision of what was required, who discussed it with a larger group and then it was quickly implemented. The other MDTs had a lesser degree of success, this was mainly due to the process being delegated to a technical person who did not have the strategic view required to make decisions on what was important to the MDT. Nevertheless work was on-going to get all the MDT's to the best standard possible. Some of the MDT's translated their measures onto communications boards

Differences between Tornado JIPT and Conventional Lean Organisations

Having examined the lean practices of the Tornado JIPT in detail, and over a lengthy period of time, it was possible to critically evaluate the extent to which they matched the conventional view of lean, as portrayed in Figure 1. The aim, therefore, of the remainder of

this section is to establish how the Tornado context differs from a conventional lean Toyota type context, before examining the extent to which lean principles and tools still apply, in a public sector service context. The first stage of the research strategy entailed a review of the differences between the conventional lean operational context and the Tornado JIPT operational context, Figure 3.

1.	Military hierarchical culture
2.	Service and repair – not assembly
3.	Two state demand pattern
4.	Complex extended enterprise
5.	Non-growth

Figure 3: Differences between JIPT and conventional lean operational context

The first of these differences is the complex culture of the organisation which, due to its military nature, is inherently hierarchical. This is also strongly influenced by government policy and adopts a risk avoidance approach, as is common for public sector organisations (Boyne 2002). In addition, there are issues associated with the hierarchical structure which might also be seen to inhibit change, such as the typical two year tour of duty for personnel. This has been identified as an issue for lean implementation sustainability by Cullen et al. (2005) and from interaction with military personnel attending lean courses run by the researchers.

The second major difference is the nature of the operation which, being service and repair, rather than assembly, is designed to deal with low volumes. This is highlighted in all the areas 1 to 4 which have to cope with unpredictable inputs due to the incidence of unexpected repairs and breakages.

The third major difference is the need to cope with two states, peace time state which is largely predictable, based around training schedules and below capacity, and a combat or 'surge' state which is essentially unpredictable (based on combat activity) but likely to be near, at, or above capacity (Godsell *et al*, 2006). The fourth further major difference is the complex enterprise nature of the process, as shown in Figure 2, whereby servicing and maintaining the aircraft is shared between a number of military and civil organisations in such a way that staff from different organisations are often co-located at either the RAF bases

or supplier manufacturing or repair facilities. The role of the Tornado JIPT has been to manage and control this highly complex extended enterprise. This type of complexity is common is public sector organisations as highlighted by Boyne (2002). The final and possibly most significant difference is that this is not a growth environment and is explicitly identified as a shrinking one. The number of Tornado platforms in service with the RAF will be progressively reduced over the next 20 years as they are replaced by Typhoon. As a result, excess resources liberated by efficiency changes are most unlikely to be able to be easily redeployed within Tornado and there are likely to be more complex human and capital resource issues than in a conventional, commercial lean environment.

Because the operational context of the Tornado JIPT is so very different to the conventional high volume, low variability environment in which lean is typically applied, the principles and tools of lean need to be adapted to this context, as described in the following section.

Analysis of the application of Lean Principles and Tools within JIPT.

The purpose of this section is to examine the extent to which the fundamental principles and tools and techniques apply to the lean activities undertaken at the JIPT. This addresses, boxes 2 and 3 from Figure 1, highlighting any changes required for a non-conventional lean context. Thus this section presents a review of the data gathered as part of the review within each of the RIA areas, as well as in the performance measures work as shown in Table 2.

Starting with area 1, the application of the five lean principles was most affected by the size and complexity of the area, which meant that the team chose to initially change only one of the seven tracks. The area manager expressed concerns about having one track in seven run in a different way, and suggested that: *"perhaps using 5S everywhere first"* might have been a better approach. Having two systems co-existing meant that a '*value stream*' was not fully established for the area, and so the '*flow*' and '*pull*' principles could be only partly established. However, this mixed approach to implementation is not uncommon in the aerospace sector (Cullen et al. 2005). The personnel in the area embraced the idea of waste reduction within the limits of the two co-existing systems, and started to apply 5S beyond the initial first track to the whole area and also to reduce waste through re-organizing low-cost consumable items to within the area, and managed by a pull system.

Table 2: Review of lean principles and tools within different activities

		Area 1	Area 2	Area 3	Area 4	Development of performance measures
Fundamental principles	**Value**	Increased visibility of pre-existing measures	Using same model as MDTs to develop performance measures but after RIA	Increased visibility of pre-existing measures – aspiration for comm's board	Developed communications board but not derived from own MDT	On-going work to encapsulate value.
	VS and Waste	Cannot establish VS and hence push to pull without radical break. Small areas of pull and flow	Undergoing radical break but after RIA	Only part of VS changed to pull	Only part of VS changed to pull	Development of measures to highlight waste, flow and pull although there is no consensus that these should be used
	Flow			Improved through use of tools but not as coherent as area 4	Established pull and flow in area but needed work further with suppliers and customers	
	Pull					
	Perfection	All initiatives encountered some issues in this area, but degree of success was strongly affected by senior manager's approach. In some cases this hindered the consensual process; in other cases it was greatly enhanced. A recurring issue was the absence of the senior manager and so it was difficult to achieve their buy-in which limited some initiatives.				
Tools and Techniques used		Focused on lean tools – 5S, spaghetti mapping, relay out to improve flow pre-kitting	Some lean tools - 5S, spaghetti mapping, relay out to improve flow and simulation	Focused on lean tools – 5S, visual management, flow and pull system		Policy deployment/ communications boards workshops

In the long term there will be a need to make a complete break from push to pull right across the whole hangar to allow a pulse line to be implemented (a pulse line is a form of modified pull system suitable for servicing aircraft DLO News 2005). In a pulse line the tracks would become interdependent and the complexity of such a change represents a risk. The question for this area is how can the foundations for such a change be best laid? The question of value was largely neglected and pre-existing concepts of how the area should perform were employed, although these were made more visible.

Area 2 also had the challenge of a large area and they tackled this by extensive value stream mapping then moving to use of simulation tools. However, within the time frame of the RIA they did not take the radical break required to establish a pull system. They did establish a stronger value stream by implementing smaller improvements identified as part of the mapping activity, and through this process also reduced waste in the area. However, implementation of lean tools was not that formal and the team took a pragmatic approach and

applied a wide range of lean tools where it was felt they could be used. This resulted in some lean tools, such as Visual Management, having been applied in most places but not in a particularly rigorous manner. More specifically, a formal report concluded that: "*too many tools"* were being applied with a "*lack of focus*", which meant that change over analysis was "*not done formally*". The on-going efforts by the personnel who work in the area mean that some parts of the area have implemented additional tools such as waste elimination, but once more its uptake was patchy.

Although the initial results in this area were perhaps the most impressive, with high levels of buy-in and understanding, the longer term result was more variable as the lean message has been watered down by the informality of implementation with a "*hit list still on-going*". However, this work has proved useful as a learning opportunity in trying out a variety of tools and has had a high level of acceptance from the workforce, possibly due to its less radical nature. The complexity of the process and the leap of faith required for a pull system meant that perhaps this route has laid foundations for the move to a pull system, which was planned to be implemented.

In terms of encapsulating *value* in area 2, a similar route was taken to that of area 1, as part of the RIA studied, value was not particularly mentioned. However, the subsequent work as part of the performance measures activities was adopted and the area closely aligned their measures with those of the relevant MDT.

Turning now to areas 3 and 4, these were the smallest, which meant that it was possible to move to a '*pull*' system within the timescales examined and achieve a good result in the change process. However, each of these areas exists within a larger supply chain, employing a more traditional push system. Technicians, within area 4, stated they encountered problems in getting components and modules at the rate demanded by their pull systems and because of lack of visibility in the supply chain, exemplified by the supplier being described as "*someone in the IPT"*, there is little opportunity to address these problems. Clearly extension of the internal work to the wider supply chain would be required. Area 3 did not progress as far as area 4 and so implemented some tools and techniques, but was not able to achieve such a cohesive approach within the area. In terms of the '*value*' principle, area 3 made some progress, but did not get to implementing a communications board and fully considering value from its customers' point of view. To some extent the "end to end" document stated what was required in terms of value from areas 3 and 4 but the management of area 3 found this excluded their views, stating *"Plan fully formed before we got our hands*

on it – could have learnt more by having a go too", i.e. the management of area 3 to have been able to influence what they could contribute in terms of value.

Area 4 was also the first area to implement a communications board and, as part of this initiative, it developed measures such as "*modules available*" (to their customer) and turnaround time. Consequently, it can be concluded that they were starting to adopt the *value principle.* At the time, however, the relevant MDT had not developed its own measures and so the value stream in which area 4 resides did not have an explicit top down statement or measure of *value.* This led personnel working in this area, to take a best guess at what would be important about their work to the MDT.

For the performance measures development process at the MDT level, the approach taken by the MDT leader greatly affected the outcome for their measures and subsequent communications board where they were displayed. Where the MDT leader was present or their deputies were available, fuller discussions were possible about how the MDT contributes value and the teams were able to start to engage with measures that encapsulated lean principles, such as measures to highlight waste and emphasise flow. The differences in make-up of the MDT measures teams also affected whether there was an intention to keep the measures up to date, both in terms of their value but also of their design, i.e. there was a fuller commitment to continuously improve the design of the measures and this addresses to some extent lean principle of *perfection*. Thus the MDT team make-up affected both the actual measures developed and how well they addressed the needs of the JIPT and thus engaged with lean ideas, but also how well those measures were maintained and developed subsequently.

Comparing the implementation of the RIA in all the areas, areas 1 and 2 had similar challenges in terms of size and complexity and so putting into place clear value streams. The work conducted in area 2 seemed to lay the best foundations for future work and the radical break to a pull system. The smaller size of areas 3 and 4 allowed more progress in this area although this then highlighted issues where localised pull conflicted with push systems in the wider supply chain.

Many tools and techniques have been used within the Tornado environment including policy deployment, 5S, visual management, etc. (Table 1). These have been applied with no particular need to modify. Any problems with implementation have been associated with getting the right people to the meetings, resources to carry out actions and so on, however, these are the types of issues that might be encountered in any organisation and are not

peculiar to Tornado. So the issue of the ability to apply lean tools in this environment does not appear to be a problem as the tools seem to be robust in their applicability.

Discussion of Lean Principles in Tornado JIPT

The aim of this section is to critically evaluate the extent to which each of the five lean principles could be applied, in its conventional form, within the Tornado JIPT. At the end of the discussion of each principle a proposition is made relating to its use in either the public sector or military.

Considering *value*, the concept of internal customers and thinking about what they value was in its early stages within the RAF and the systems to integrate this in operational practices were limited. As part of the work on development of performance measure there was discussion about who was the customer and from the JIPT's view this was Headquarters RAF Strike Command (the area of the RAF responsible for flying aircraft). Thus the immediate customer for the JIPT is clear but they also have a wider remit to a final customer and this then raises the question, who is Headquarters RAF Strike Command's customer?: this was a point under internal debate, and generally it was perceived to be the British Government or the Defence Management Board (the MOD's Board of Directors chaired by the Secretary of State for Defence). One may argue that, at a further level of abstraction, it is therefore the UK tax payer. As such, moves were taken to encapsulate *value* as perceived by Headquarters RAF Strike Command and there was on-going work in policy deployment between the JIPT and Headquarters RAF Strike Command, also reflected in internal performance measurements within the JIPT. This ambiguity of who is the customer is a major issue for public sector environments and is identified as common problem by Boyne (2002) who hypothesises that public sector managers are required to pursue a larger number of goals (from different stakeholders) and that these goals can be vaguely defined. Thus the value proposition is "The concept of value holds true in the public sector but needs to be considered broadly to include the wide variety of stakeholders and what they value."

The next lean principle is *identify the value stream and eliminate waste*. This is in some ways relatively straight forward in that there was only one product and the primary task was maintaining a pool of functioning and appropriately equipped aircraft. There were some additional requirements that were specified as part of Headquarters RAF Strike Command's customer - the British Government - in that there had to be accountability in terms of

governance. As there was only one product, the Tornado aircraft (although there were variants), but with very high complexity it could be considered to be constituted from smaller products that can be divided into Value Streams (VS), (Rother and Shook 1998). Thus the JIPT was divided into simpler groups; Avionics, Structures, Engines, General Systems and Fleet Management and each team control a value stream (Figure 2). Each of these groups was termed a MDT (Multi-Disciplinary Team) who can then focus on waste elimination with their team. The product structure within each team varied greatly and this affects the waste elimination approach taken.

Within a VS there is also a need to ensure that there is an ability to meet 'surge' demands as well as peace time demands and therefore the design of the value stream needs to be able to cope with both states (Godsell *et al*, 2006). Designing a VS for two possible states can lead to waste in either or both states.

In addition the VS also needed to be able to cope with the inherent variability that ensues because of the service and repair environment. There was unpredictability because components that were checked as part of their servicing regime can have unexpected problems such as cracks or excessive wear. These types of unexpected problems that occur outside of the standard servicing regime Tornado call 'arisings'. The MDT managers were seeking to reduce the problem by investigating the cause of arisings and so make them part of the predictable and therefore manageable servicing regime. In this sense, they were trying to turn 'strangers' (one-off hard to predict) into 'repeaters' (more regular and predictable) in order to reduce complexity and hence allow for reduced cost and higher in-service levels (Hines and Samuel, 2006).

This problem of unpredictability as an input is reflected in other lean service research. It is identified by Kiff (2000) who explores the application of lean in automotive dealers in the context of services vehicles. He identifies the misdiagnosis of repairs leading to parts not available to complete work, as a waste. This also has analogies in the healthcare sector where the unpredictability of inputs – in this case patients – is a recurring theme. It is particularly acute in emergency departments where patients arrive with the full range of medical problems, and sorting and prioritising patients is a key process. Ben-Tovim et al. (2007) outline how changing from a purely triage based prioritising process to one that also included lean ideas of waste reduction had an impact that was immediate *"with a discernable lessening of chaos in the department" (*p13).

The motivation for waste removal in a non-growth environment can be an issue for many organisations seeking to pursue a lean ideal, as many lean transformations result in

personnel reduction. In a growth situation these excess people can be redeployed for new business, whereas personnel in non-growth organisations inevitably become concerned about their job security and so participation in lean events becomes unappealing. Tornado JIPT does not have any growth (item 5 in Figure 3) but is part of much larger organisations (RAF and civil service) where people can be, and are, posted outside of the JIPT. However, change in any format is a worry for people and there will be changes to personnel structures. The issue of non-growth and waste elimination for suppliers is more complex because they know they are bidding for a smaller pool of work. However, there is also the motivation for future projects within the RAF and the partnered contracts cover a 10 year period, rather than the annual contracts previously issued by the JIPT. Motivation for suppliers is also an issue for implementing changes associated with improving flow and pull. Thus the value stream proposition is that "These concepts remain valid for public service but additional variation can cause waste where the customer provides a less predictable input into the value stream." This proposition also has an overlap with flow discussed below.

The next fundamental principle is *Flow*. Each of the MDT's is responsible for managing flow within their product group. As such the main barrier to flow for all MDT's is location of the elements of the value stream. These elements are often distributed widely in remote parts of the UK, principally because security, not logistics, was a primary consideration in their original siting. To improve flow, managers would want to resite these elements, but change to the location of military and defence organisations is particularly sensitive because of political concern about defence jobs, as voiced by Amicus[1] (2004). *'We need a UK defence procurement policy that works in tandem with our suppliers so these vital and high earning jobs can be safeguarded and the military can be supplied with the high quality apparatus they need.'*, so managers within MDT's have additional restraints on their decision making as compared to a commercial environment, also highlighted previously by Boyne (2002) as part of his hypotheses on the environment of public sector managers. The proposition for flow is encapsulated in the previous proposition for value streams.

Pull, the next fundamental principle, looks at how the demand signal for products, components and services are managed within a value stream. Demand in the service and repair environment of the JIPT generally tends to default to push rather than pull, because as a product becomes defective or requires a service, it enters the service or repair route and works its way through the process to emerge as scrapped or repaired some time later. This is

[1] Manufacturing, technical and skilled persons' union

complicated because what would at first appear predictable is in fact not, in that regular services can often have an unpredictable element of 'arisings'. So a typical route for a component is: removal from use on the aircraft and entering a service bay where it will usually join a queue; some diagnostics will then be performed and a decision is made as to whether it should be repaired or scrapped. If the component can be repaired it will be repaired if parts are available, returned to the pool of available equipment and returned to service when required.

Whether this repair route is organised as push or pull depends on the monitoring and control system. In its current state of push, the focus is on pushing through parts to the repair bay when they have been removed from the aircraft. To convert the service and repair loop to a pull-like system requires focusing on maintaining a sufficient pool of spares parts as a decoupling point (Hoekstra and Romme 1992). This concept was adapted for reverse logistics (or repair supply chains) by Banomyong, Veerakachen and Supatn (2004). Aircraft requiring spares would pull from the decoupling point. To achieve this type of change from push to pull requires considerable input from suppliers of spares and Tornado need to ensure that external agents are motivated to do this despite a non-growth situation. However this approach may be too focused on the idea of pulling, when what is required is a focus on customer needs. This leads into the ambiguity of the pull principle in the service sector, which is really one of definition, the broader idea of pull in service is considered to be providing a service, as and when required by the customer, in which case then the wording of 'pull' may be a misnomer. For many services, such as patients in A&E or equipment requiring maintenance (as in car servicing or Tornado modules), arriving at the start of process is the signal to start work, so this does not 'pull' the process from the final end as is the case for tangible goods in the conventional lean sense. As Bicheno (2008) states *"'Pull' in service means short-term response to the customer rate of demand"* (p30). Thus the proposition for pull is, "The underlying ideas of pull are appropriate for the public sector but for the purposes of clarity it should be renamed 'demand readiness'".

Perfection, the final principle, is about revisiting and improving what you have done. Most commonly this is embodied in the form of Continuous Improvement (CI) and associated Rapid Improvement Activities (RIA's). Many organisations regard CI as discrete, focused activities, but it is embedded CI processes that lead to fully sustainable CI (Bateman 2001). In some ways the military services have strengths here in that following formal processes (exemplified by Plan, Do, Check, Act for CI, Deming, 1994) is embedded in their

culture. However, the way that CI is usually implemented in a private sector manufacturing environment is by consensual discussion and this approach does not sit well with the hierarchical nature inherent in military life. This problem with CI in military organisations is also raised by Kange and Apte (2007) who in the context of Lean Six Sigma identify the traditional strict hierarchy of military life as a barrier to improvement activities, along with the frequent rotation of officers to different jobs, also an issue at Tornado. Thus the proposition for perfection relates only to military organisations "Where the strong hierarchical structure can inhibit the conventional CI approach. Steps to reduce the influence of the command structure in CI activities needs to be taken to allow freer flow of ideas."

This discussion leads the authors to three propositions relating to the use of the lean principles of value, waste, flow and pull in the public sector, and one for perfection only relating to military organisations:

Value proposition

The concept of value holds true in the public sector but needs to be considered broadly to include the wide variety of stakeholders and what they value.

Value Stream, Waste and Flow Proposition

These concepts remain valid for public service but additional variation can cause waste where the customer provides a less predictable input into the value stream.

Pull proposition

The underlying ideas of pull are appropriate for the public sector but for the purposes of clarity it should be renamed "demand readiness".

Proposition for Perfection

In military organisations the strong hierarchical structure can inhibit the conventional CI approach. Steps to reduce the influence of the command structure in CI activities needs to be taken to allow freer flow of ideas.

Conclusion and Insights for future development of Lean in the service sector

The approach of identifying differences between the Tornado JIPT's conceptualisation of lean, and its conventional application has highlighted some important insights: some of these are particular to military organisations, whilst others may be applicable to other types of public sector organisations.

This research has found the primary difference between conventional lean and public sector and many service organisations involved in service and repair, is adapting the idea of *pull*. Thinking in narrow terms of pulling demand does not operate to the customers benefit in a service environment, where the signal to work is an input to the process. In this case the system should be ready to operate when customer demand occurs. This fits with the original idea behind *pull* because it meets the needs of the customer, but better suits a service environment. So the *pull* concept should be renamed to "demand readiness" in a public service environment to avoid practitioners trying to unnecessarily develop inappropriate *pull* systems. This proposal at first appears a radical shift from the original *pull* principle, but actually fits well with its origins of demand in terms of meeting customers needs.

When considering *value*, waste removal and flow, the issues of implementing change in a public service environment are highlighted (as identified by Boyne (2002)) including multiple stakeholders, which affects ideas of *value*, and also inhibits changes to the design of the value stream. In parallel, for Tornado, within the consideration of removal of waste in the value stream, an issue that occurs across service and repair activities in both public and private sector alike, is that of unexpected inputs. Unlike conventional lean where suppliers can be audited and inputs can be controlled, the customer supplies or is the input to the process and so there is less predictability over the work to be done. Tornado and other similar environments have taken steps to address this but it is an additional requirement to conventional lean.

Specific to military organisations were the issues of how to cope with the inherent hierarchy whilst engaging in Rapid Improvement Activities and Continuous Improvement. These types of activities within a lean environment generally require a consensual, democratic approach rather than the military chain of command approach. The final difference that military has to face is the issue of peace and non-peace time demand levels and it is embedded in their primary purpose that they should be able operate at both levels; this means that any values stream designs have to operate at two demand states.

References

Amicus. 2004. http://www.amicustheunion.org/main.asp?page=867. In address to MPs.

Agripino, M., Cathcart, T. and Mathaisel, D., 2002. A Lean Sustainment Model for Military Systems. Acquisition Review Quarterly, 9, Fall, 275-296. ISSN: 1087-3112.

Bartezzaghi, E., 1999. The evolution of production models: is a new paradigm emerging? International Journal of Production & Operations Management, 19(2), 229-250. ISSN: 0144-3577.

Bane, R., 2002. Leading Edge Quality Approaches In Non-Manufacturing Organisations. In: Proceedings of ASQ Annual Quality Congress, Denver, CO., May, 245.

Bateman N., 2001. SMMT Industry Forum. Sustainability: a guide to Process Improvement. Lean Enterprise Research Centre, Cardiff University. ISBN: 0-9537982-2-4.

Banomyong, R., Veerakachen, V. and Supatn, N., 2004. Leagility in reverse logistics process: a case study of electronic appliance manufacturer. In: 9th Logistics Research Network (LRN) Conference 2004, Dublin, Ireland, 8-10 September 2004, 36-42. ISBN 1-904564-10-0.

Ben-Tovim, D., Bassham J., Bolch D., Martin M., Dougherty M. and Szwarcbord M., 2007. Lean thinking across a hospital: redesigning care at the Flinders Medical Centre. Australian Health Review 31(1), 10 - 15.

Bicheno, J., 2004. The New Lean Toolbox. Buckingham: Picsie Books. ISBN: 978-0954124410.

Bicheno, J., 2008. The Lean Toolbox for Service Systems. Buckingham: Picsie Books. ISBN: 978-0954124441.

Bowen D and Youngdahl, W., 1998. "Lean" service: in defense of a production-line approach". International Journal of Service Industry Management, Vol. 9, Issue: 3, 207 – 225.

Boyne, G.A., 2002. Public and Private Management: What's the difference? Journal of Management Studies. 39(1), 97-122. DOI: 10.1111/1467-6486.00284

Buzby, C.M., Gerstenfeld, A., Voss E.L. and Zeng A.Z., 2002. Using lean principles to streamline the quotation process: a case study. Industrial Management & Data Systems, 102(9), 513-520. ISSN: 0263-5577.

Comm, C.L. and Mathaisel, D.F.X., 2005. A Case Study in Applying Lean Sustainability Concepts to Universities. International Journal of Sustainability in Higher Education, 6 (2), 134-146. DOI: 10.1108/14676370510589855.

Cooney, R., 2002. Is "Lean" a universal production system? International Journal of Production & Operations Management, 22(10), 1130-1147. ISSN: 0144-3577.

Cullen, P.A, Hickman, R., Keast, J. and Valadez, M., 2005. The Application Of Lean Principles To In-Service Support: A Comparison Between Construction and The Aerospace Defence Sectors. Lean Construction Journal, 2(1), 87-104. ISSN: 1555-1369.

Deming, W.E., 1994. Out of the Crisis. 2nd ed. Cambridge Mass.: MIT. ISBN: 0 911379 01 0

DLO News. 2005. How Logistics have been transformed at RAF Cottesmore. http://www.mod.uk/linked_files/dlo/DLO_News_ISSUE_25_section2.pdf

DTI. 1998. Rethinking Construction. URN 03/951.

Emiliani, M. L., 2004. Improving Business School Courses by Applying Lean Principles and Practices. Quality Assurance in Education, 12(4), 175-187. ISSN: 0968-4883. DOI: 10.1108/09684880410561596.

Esain, A., Williams S, and Massey L., 2005. Combining Planned and Emergent Change in a Healthcare Lean Transformation. Public Money and Management 28(1), 21-26. DOI:10.1111/j.1467-9302.2008.00614.x

Fillingham, D. 2007. Can lean save lives?. Leadership in Health Services, *20*(4), 231-241.

Kang K. and Apte U. 2007 Lean Six Sigma Implementation for Military Logistics to Improve Readiness, 4th Annual acquisition research symposium, Thursday Sessions, May 16-17. URL ADA493547.

Kiff, J., 2000, The lean dealership – a vision for the future:"from hunting to farming". Marketing Intelligence and Planning 18(3), 112-126. 0263-4501

Godsell, J., Harrison, A., Emberson, C. and Storey, J., 2006. Customer Responsive Supply Chain Strategy: An Unnatural Act? International Journal of Logistics Research & Applications, 9(1), 47-56. DOI: 10.1080/13675560500534664.

Hines, P., Holweg, M. and Rich, N., 2004. Learning to Evolve: A Review of Contemporary Lean Thinking. International Journal of Production & Operations Management, 24(10), 994-1011. DOI: 10.1108/01443570410558049.

Hines, P. and Samuel, D., 2006. "The development of supply chain relationships: a multi lens approach". Working Paper, Cardiff Business School, Cardiff.

Hoekstra, S. and Romme, J., 1992. Integral logistics structures: developing customer oriented goods flow. London: McGraw-Hill. ISBN: 978-0831130374.

Holweg M, 2007. The genealogy of lean production. Journal of Operations Management 25(2), 420-437.

Liker J. 2004. The Toyota Way—14 Management Principles from the World's Greatest Manufacturer. McGraw-Hill ISBN 0-07-139231-9

Monden, Y., 1998. Toyota Production System: An integrated Approach to Just-In Time. 3rd ed. Engineering & Management Press. ISBN: 9780412839306.

Murman E.M., 2002. Lean enterprise value: insights from MIT's lean aerospace initiative. Palgrave Macmillan. ISBN: 978-0333976975.

NAO – National Audit Office. 2007. Transforming Logistics Support for fast jets. No. 0825 2006–07. London: The Stationery Office. ISBN 9780102947304.

Radnor, Z., Walley, P., Stephens A. and Bucci G., 2006. Evaluation of the Lean Approach to Business Management and its Use in the Public Sector. Scottish Executive Social Research: Edinburgh. ISBN: ISBN 0 7559 6056 4.

Radnor, Z., 2010. Review of Business Improvement Methodologies in Public Services. London: Advanced Institute of Management Research (AIM). ISBN: 978-1-906087-28-9.

Radnor Z., Holweg M, and Waring J (2012), Lean in healthcare: The unfilled promise? Social Science and Medicine, 74,3, Feb. 2012, 364-371 ISSN 0277-9536

Rother, M. and Shook, J., 1998. Learning To See: Value Stream Mapping to Add Value and Eliminate Muda. Brookline, Massachusetts: The Lean Enterprise Institute. ISBN: 978-0966784305.

Royal Air Force Website: last accessed 28.8.13
http://www.raf.mod.uk/equipment/tornado.cfm

Shingo, S. and Dillon, A.P., 1989. A study of the Toyota production system from an industrial engineering viewpoint. Portland, Oregon: Productivity Press. ISBN: 978-0915299171.

Spear, S. J., 2005. Fixing Health Care from the Inside, Today. Harvard Business Review, 83(9), 78-91.

Womack, J. Jones, D and Roos, D. 1990 The Machine That Changed The World. NY: Rawson Associates.

Womack, J. and Jones, D., 1996. Lean Thinking. London: Simon & Schuster. ISBN: 978-0-7432-3164-0.

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