Beyond theory: An examination of Lean New Product Introduction practices in the UK

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Abstract

Interest is growing around the application of Lean techniques to New Product Introduction (NPI). Although a relatively emergent topic compared to the application of Lean within the factory, since 2000 there has been an exponential rise in the literature on this subject. However, much of this work focuses on describing and extolling the virtues of the 'Toyota approach' to design. Therefore, by way of a stock take for the UK, our research has set out to understand how well Lean product design practices have been adopted by leading manufacturers. This has been achieved by carrying out in-depth case studies with three carefully selected manufacturers of complex engineered products. This paper describes these studies, the detailed results and subsequent findings, and concludes that both the awareness and adoption of practices is generally embryonic and far removed from the theory advocated in the literature.

1. Introduction

Manufacturing industry remains a vital part of the UK economy, employing approximately 3.5 million people across a diverse range of companies. There is a wealth of initiatives targeted at sustaining the competitiveness of UK companies and, within manufacturing operations, the most prominent and successful of these is the application of Lean. The term 'Lean manufacturing' can be traced back to John Krafcik [1] and the International Motor Vehicle Programme (IMVP). Most people see the genesis of Lean principles as the Toyota Production System, however, the origins of a Lean style of production are apparent in the work of Henry Ford and earlier (Ford, 1922 [2]; Ford, 1926 [3]). Ford developed many techniques that today would be associated with Lean, including single-piece-material-flow and Kaizen. The following quotation is taken from Ford in the 1920s and is just one example of his obsession with reducing 'waste' in production.

"Every extra motion, every trivial waste of time on the part of any workman must be eliminated. It is the solution to this problem of "waste motion" both with men and machines, which to a very large degree makes it possible for Ford to put on the market such a high grade car at such an extremely low price"

The work of Ford influenced Toyota. Taiichi Ohno, a Toyota plant manager and practitioner, developed a number of tools to ensure the principles of Lean were adopted. As Hines et al [4] note, the process of Lean manufacturing remained in the Far East and Japan for two decades and only began to filter out to other countries during the 1970s when Toyota, Nissan and Kawasaki began to use Western suppliers for parts. They imparted their knowledge to develop their supply chains and so passed on their working practices. However, it still took many years for Lean practices to be adopted by western companies and it was not until 'The Machine That Changed The World' [1] was published that Western manufacturers really began to develop Lean practices.

Lean principles are usually associated with to the 'operations' of a manufacturing enterprise, such as processes of material supply, component production, and delivery of products and services to the customer. However, authors such as Womack and Jones [5] see that 'Lean thinking' can also be applied to great effect outside manufacturing operations although examples of this, such as applications in service-based enterprises, remain relatively rare. Nevertheless, there is little doubt that the application of

Lean principles beyond the shop floor represents a significant opportunity for improvements in competitiveness. One area of growing interest is Lean New Product Introduction (NPI). Over the past six years the number of articles on this topic have grown exponentially (see Baines et al [6]) and, although still relatively few, they are sufficient to articulate a basic set of practices for a company wishing to implement Lean in the design office. These practices include, for example, a set-based approach to design, a key leadership role of the Chief Engineer, and specific methods of standardisation in information management. However, much of the existing knowledge base on Lean NPI is based on articulating the practices that Toyota has found to be successful. Little is known about the extent to which these practices are being adopted by UK based manufacturers and so it is difficult to define what further research is necessary on this topic.

The question therefore arises as to how advanced are UK manufacturers with regard to the implementation of Lean in New Product Introduction? Of particular interest are those companies that can be thought of as leaders in design and can be expected to be advanced in the adoption of new practices. Likewise, investigating those manufacturers who deal with relatively complex engineered products is likely to be more revealing of the challenges that may exist to implementing Lean NPI. This paper therefore describes research based on detailed case studies of three UK based manufacturers. The findings from these studies generally reveal that practice significantly lags theory. They indicate that the automotive sector is leading in the application of Lean NPI, Aerospace is following, with more general engineering being slowest to adopt these techniques. Indeed, in some instances Lean NPI may be lagging by as much as 10 - 15 years. Although the results of any case-based research can only be considered as generally indicative, there is little to suggest that our results are unrepresentative. Indeed, we are confident in our findings and in our overall conclusion presented at the end of this paper, in that UK manufacturers still have some way to go in their journey towards Lean NPI.

The paper begins by describing the research design for this study and in particular justifying the case study methodology and selection of companies. A short description is then given of each of the three companies studied along with a brief insight to their current Lean activities. The cases are then analysed and the key findings drawn.

2. Research methodology

2.1 Case study design

This study has focussed on gaining an in-depth and reliable understanding of the actual practices of UK manufacturers. A popular approach taken by researchers in studying such practices is to rely on questionnaire based survey work. However, while competent survey methods may be applied by the researchers, busy practitioners rarely treat these data collection methods with the necessary precision needed to give reliable indications of actual practices. Often such techniques have to rely on the opinions, perceptions and judgments of one or two junior people within a factory. Hence, even when the statistical analysis is reliable the results may not be. This was of particular concern in this study as the phenomenon of Lean NPI is emergent and not yet well understood. A more robust approach is to visit a selection of companies, carefully chosen to be a representative sample, and to thoroughly explore evidence of actual practices. Although resource intensive, it was decided that such a case study approach was most useful in this instance.

Our choice of case study companies was carefully considered. In favouring in-depth studies, where our team may need to visit several times, the range of companies was necessarily small. The companies chosen were producers of complex engineered products as these represent key industrial sectors in the UK (e.g. aerospace, power generation, transport, etc). Three companies were subsequently decided upon; the first being a leader in aerospace, the second in automotive, and the third in agricultural and construction machinery.

The case study data collection protocol has been largely based on the seminal work of Yin [7]. First, a series of research questions have been formed to guide our investigation. These questions have been distilled from our systematic review of existing literature [6]. From these a data collection protocol was then formed. This specified for each question where, and with whom, evidence might be found within a case. This was then translated into an Interview Pro-forma for the research team to use as part of semi-structured interviews with personnel within the companies. The selected companies were then contacted, the purpose of the study outlined, and then arrangements made for the research team to visit. Prior to the visits the research team familiarised themselves with the products and markets of each company. Each study then consisted of a series of interviews with personnel who could act as expert witnesses as to how the company was dealing with Lean NPI. The data from these interviews was captured as case reports for each company. These were then checked with the companies for accuracy and then used as the basis for cross analysis to generate the findings for this paper.

Finally, in order to gain access to each of the three companies, we were obliged to ensure that potentially sensitive details of their processes would not be released. Therefore, we have chosen not to disclose the company names, as this gives us greater freedom to discuss our results and findings. However, we have given a short resume of each company (section 3) as of June – December 2006 when these studies were carried out.

2.2 Formation of research questions

This section describes the formation of a series of research questions that were used as the basis of the Interview Pro-forma used by the research team. As outlined above, this is based on an in-depth literature review on Lean NPI [6] and so, for brevity, this section only gives a synopsis of the key literature.

The first apparent issue is concerned with how Lean is defined in practice. In the 1980s Lean was associated with a reduction in waste in the factory, moving onto quality, cost and delivery during the 1990s before the focus shifted to customer value after 2000 [4]. This is reflected in the design literature. For example Haque [8] argues that engineers need to move from a production focus, in which the primary aim is waste reduction, to one of identifying and enhancing value. Furthermore, irrespective of context, the underlying key to maximising the success of Lean has been the adoption of an organisation-wide culture across all areas in the business. For example, the 'Lean Enterprise Value' publication from MIT's Lean Aerospace Initiative (see McNeel [9]) supports the view that the entire enterprise must undergo a Lean transformation for the impact of Lean to be significant. A truly successful application of Lean principles to any process will, more often than not, require fundamental changes in systems, practices and behaviour throughout an organisation. This leads us to our first question;

Question 1: *“What definition does the Company attach to ‘Lean’, and is it seen as a set of tools or a more fundamental transition?”*

There are a wide variety of examples where Lean has been applied to product design, engineering and development in such fields as software [10, 11], construction [12] and aerospace [13, 14] and other industries. In addition, case studies do indicate that the application of Lean to NPI is feasible and capable of delivering benefits for large and small companies [15]. However, the extent to which Lean is being applied is relatively unknown. This gives rise to the question;

Question 2: *“Is the Company adopting Lean principles in the design office and NPI processes?”*

Within manufacturing the first principle of Lean is to ‘specify value’ [5]. Lean is about creating more value for customers by eliminating activities that are considered wasteful. However, when applying these principles to NPI it is widely recognised that waste is much more difficult to identify than in a manufacturing environment. In manufacturing, for example, waste is seen as excess inventory or Work-In-Progress (WIP). However, in NPI the WIP inventory is generally in the form of information. The value of this information can be to increase certainty and so reduce risk. Clearly value in the NPI process needs to be precisely defined as it is not necessarily the same as value in production operations. This leads to the question;

Question 3: *‘How does the Company define ‘value’ in the NPI process?”*

Producing the right information, in the right place and at the right time, creates value in the product development process [16]. However, some iteration in the process can be essential for the creation of value [17] so, too, is rational risk-taking [18]. Indeed there is a lack of clarity in the literature not only about how value is created (question 3) but also as to where value is created in the design office. We therefore posed the question;

Question 4: *“Where and when does the Company consider ‘value’ to be created in the NPI process?”*

The literature [19, 20] suggests that a Toyota style set-based approach is key to Lean NPI. Set-based design imposes agreed constraints across different functions to ensure that a final sub-system solution, chosen from a set of alternatives from a particular function (such as body, power train, engine management etc), will work with convergent solutions from all other functions. During the design process, as each alternative is evaluated, trade-offs are made, weaker solutions are eliminated and new ones are created by combining components in new ways. This approach is seen as superior to the alternative point-based design process which fails to effectively reuse information/designs and is prone to significant ‘rework’ costs. This prompts the question;

Question 5: “*Does the Company take a ‘set-based’ or ‘point’ based approach in the NPI process?”*

In the literature there is consensus that the key to a successful product design process is the strong leadership of an expert Chief Engineer (CE) who, has total project responsibility and, is supported by experienced functional engineers [8, 20 & 21]. Success does not require the CE to have control over all the engineering resources but, rather, is driven by targets and deadlines and always willing to step back and reflect on the range of design options available. The allocation of a project manager to administer the programme on behalf of the CE is common practice. We therefore ask;

Question 6: *"How does the Company manage NPI programmes and who has the ultimate responsibility for delivery?"*

The generation, use and re-use of knowledge/information is identified in the literature as key to a successful adoption of Lean in NPI [19]. Reinertsen [18] captures this with the phrase "The work product of product development is information". The challenge is in ensuring that the information is structured in such a way as to make it communicable between systems. Haque and James-Moore [15] suggest that systems for controlling documents, central databases, knowledge-based systems, project management systems, CAD/CAM/CAE/PDM systems and web-based data sharing and communication tools can all be used to facilitate Lean. However, the form that such systems should take is not yet clear. We looked to test this with the question;

Question 7: *"Does the Company have a formal and integrated management system for the capture and distribution of NPI knowledge / information?"*

Studies of product development processes claim some resource utilisation rates of over 95% [18]. When combined with variability, in both project duration and work content, this creates the perfect conditions for long queues. This is equivalent to the causes of excess inventory within production. Unlike their manufacturing counterparts, however, product developers appear to do little to measure or manage these queues. This gives rise to the question;

Question 8: *"How does the Company manage work flow in NPI and is this compatible with the principles of Lean?"*

3. The Case Study Companies

Three leading UK based manufacturers were asked the eight questions by the research team. This section provides a short summary of these companies. Pseudonyms have been used to protect the company identities and so enable a fuller description of their practices in section 4.

3.1 Aero Ltd

The company is a provider of power systems. They design, manufacture and support a comprehensive range of products and services in a range of market sectors. Their product development process has seven stages, Innovation (0) to End of Life Disposal (6). There are 5, 10 and 20 year technology "Vision" acquisition horizons to feed new product development requirements. The NPI processes at the company currently take 30 months to complete but are targeted to be reduced to 18 months.

3.2 Auto Ltd.

The company is a major player in the automotive sector. There are three technical centres undertaking product development in Japan, USA and Europe. The case study was carried out at the European design centre which feeds products into manufacturing plants in Northern Spain and England. The vehicle design work undertaken at the centre is for the vehicle upper body. Cultures at the technical centres are different in the three regions, although a company wide approach to product development is achieved by developing working methodologies and guidelines.

3.3 Excavator Ltd.

The company is one of the larger manufacturers of construction and agricultural machinery. Operating Worldwide and employing over 6000 people. Its range of more than 250 products places significant pressure on the NPI process. The company is currently experiencing an increase in annual growth rate from the developing world, particularly in India where it has operated for many years. For over 10 years the company has operated with autonomous business units undertaking manufacturing and product design, supported and steered by executives at a Group level with responsibilities for Manufacturing and Product Development.

4. Analysis and key findings

The findings given in this section have been established by comparing the data gathered at each of the case studies. Here, we are mindful that although our cases have been carefully chosen as representative samples, our results are only strictly true of the three companies studied. Hence, although we are confident that they are indicative of many UK manufacturing companies, we have been careful to phrase our findings appropriately.

4.1 How Lean is defined

Responses from Aero and Excavator were brief and consistent. In both cases Lean was largely seen as being concerned with waste reduction. Furthermore, and somewhat consistent with this more traditional view, Lean was thought of as a set of tools mainly for use within manufacturing. Auto has a more sophisticated view. While they saw Lean as embracing a set of tools, guidelines, etc., they also acknowledged a more cultural aspect to the definition. They recognised Lean as a philosophy, associated with value and continuous improvement, that can be applied organisation wide and across both the manufacturing and design process. We have captured these differences as:

Finding 1: "Within Auto, Lean is defined as a philosophy associated with value creation, whereas Aero and Excavator largely see Lean as a tool set for waste reduction."

4.2 When Lean is being adopted in the design office

All three cases described how Lean principles were actively being applied within their manufacturing operations. Similarly, all three organisations saw this as being key to their ongoing competitiveness, with formalised corporate wide approaches being used. Furthermore, in the case of Auto this approach is "rolled out" to their first tier suppliers. Aero perceives that both the company and associated sector are just starting to explore and adopt some Lean NPI. Excavator sees this as a new and emerging topic for themselves and the sector as a whole. Auto is more advanced and is applying lean principles to design.

They see their main competitors to be in a similar state, but that adoption in their wider sector is slower and somewhat fragmented. They also comment that some companies simply see Lean NPI, confusingly, as the direct application of shop floor techniques to the design office. Therefore:

Finding 2: "In the application of Lean NPI, Auto is most advanced; Aero is exploring and adopting some techniques, whereas Excavator is only now becoming aware of the approach."

4.3 How value is defined in NPI

Our third question sought to understand how the company defined 'value' as this is fundamental to the application of Lean NPI. We found this question needed some further explanation in all cases. However, Auto was again more advanced. They responded that "qualified objectives in the product development programme need to be identified before value can be defined". Furthermore, they believed that these should be related to customer requirements. For Aero, traditional techniques such as 'earned value' are currently used. Their approach is to first educate designers to better understand the importance of information flow and then to associate this with 'earned value'. This approach is somewhat similar to a focus on flow and WIP when implementing Lean on the shop floor. Finally, Excavator think of adding value for the customer when introducing new products, using concepts such as cost roll-up, cost down or value analysis. We have captured this in our finding:

Finding 3: "Understanding what constitutes value in NPI is complex. Auto clearly defined value relative to the customer; Aero associated value with improvements in efficiency, while Excavator has a more fragmented interpretation of value."

4.4 Where and when value is created in the NPI process

As highlighted in finding 3, above, only Auto articulated a definition of value that is consistent with the concept of Lean NPI. Therefore, it was only meaningful to explore question 4 with this company alone. For Auto, value is thought to be created in the design process where customer requirements are met at programme gates. Therefore, we have summarised this as:

Finding 4: "When value is thought of in terms of satisfying customer requirements, it is considered to be created at the point in the NPI process where these are met."

4.5 Set-based versus point-based NPI

At Auto a simultaneous engineering approach is used where 'concept sheets' establish product specifications which are firmed up as the project progresses. An initiative, FastD (Find A way to STreamline Design) has been implemented as a right first time design approach aimed at significantly reducing design changes in development. Aero however takes a point based design approach though the merits of a set-based approach are being considered. One reason for this is that problems currently arise because functional areas and suppliers do not lay out the "what's possible" boundaries at the product definition phase. This gives rise to design conflict at later stages and rework costs (as suggested by McManus [19]). This underlines the advantages in the Toyota concurrent set-based design approach in which all functions agree design constraints at the programme outset and then work independently towards a final solution that fits within the overall product system. Excavator also adopts a 'point based' approach, although this is also under review as part of their concurrent engineering process which has been in place for some time. Here, the set-based design concepts were not widely understood. Therefore, this is summarised as:

Finding 5: "Auto applies a set-based approach to NPI. Aero is aware of set based design but has no consensus on implementation. Excavator applies a point-based process and is unaware of the alternative as practiced by Toyota."

4.6 Who manages and takes responsibility for NPI programmes

In Auto product design programmes are driven through a project management office working to defined and detailed schedules with specific gateways and milestones. The Chief Vehicle Engineer (CVE) has responsibility for a single vehicle platform development and possibly a range of variants. All design and test functions report to the CVE on status against the programme schedule. The CVE, together with Product Directors (usually engineering based people), decide any design trade offs.

Alternatively, Aero are piloting the use of techniques such as network simulation as a tool to understand dependencies but are using a more traditional approach to programme management. Here, the budget/programme management responsibilities of the Chief Engineer versus the Project Executive, is currently a subject of debate.

Within Excavator the NPI process is controlled and managed in a similar way to Auto using a gateway key milestone events process. There are set rules for milestone reviews, which all functions attending must adhere to. These include product performance criteria and financial status. The final responsibility for programme success lies with the business unit managing director. However, specific project managers are appointed who are responsible for the programme coordination and cross functional activities. Usually the project manager is an engineer. Therefore, we have summarised these three situations as:

Finding 6: "In Auto the CE takes not only a technical responsibility but also plays a role in defining customer targets and ensuring overall profitability and marketability, whereas in Aero and Excavator the CE role is mainly one of technical responsibility."

4.7 How information is managed

Auto use an integrated management system for capture and distribution of information, which is continuously under development. Global portals and web e-rooms facilitate open access for engineers. Electronic based knowledge depositories are under development. Detailed standards are in place for reporting information, which is similar to the Toyota 'A3 sheet' reports [22].

Aero uses structured methods for Requirement Flow Down, Design Definition and Design Review Information. In addition there are formal 'Lessons Learned Logs' to capture useful information including "what didn't work" (a key element in the Toyota methodology). The company has an open knowledge sharing culture facilitated by a Knowledge Management Group and includes 'communities of practice' sharing relevant information via e-mail and internet 'chat rooms'.

Excavator has not yet adopted a formal knowledge management system for the recording and distribution of knowledge in the NPI process, whereas in Auto and Aero they have well defined and controlled knowledge management systems in place which show significant similarities to each other. Their approaches align well with the views of Mounteney [23] on the sharing of design and manufacturing information across the new product introduction process, as being a knowledge management issue. Therefore;

Finding 7: "Throughout their organisations both Aero and Auto apply the standardisation of knowledge / information management processes that are supportive of Lean NPI; such a system does not exist in Excavator".

4.8 How workflow is managed

Auto appears to manage through detailed master project schedules into which individual processes are mapped and progress managed through design reviews and gateways. However, their FastD initiative was introduced and has achieved significant reductions in waste caused by negative design iteration.

In Aero there are multiple plans at component and sub-system level with people allocated responsibility to manage them. However, efficient integration of these plans into a single workflow is often lacking with integration being managed through meetings and development testing. Currently multiple sources of incomplete design information can arrive at the same time and long iterative 'feedback' loops are common. This can result in the failure to use useful design information. Like Auto a formal series of design reviews and gateway processes do exist.

In Excavator workflow is driven by project management. Some assessment of lead times is carried out for different work packages that are required as inputs to gate events. Bottlenecks occur as a result of the timing of external product launch windows, which generate requirements for the simultaneous use of common functions (e.g. service, technical publications, tests). This is consistent with Oppenheim's [21] view that product developers apparently fail to measure or manage queues which are always likely to occur with product development where high resource capacity utilisation and work content variability are common.

Finding 8: "Auto has designed workflow to avoid queues and bottlenecks, whereas Aero and Excavator are more embryonic in their understanding of these issues"

5. Conclusions

Our findings show an intriguing picture of Lean NPI (see Table 1). Auto is by far the most advanced, with Lean seen as a philosophy associated with value creation, and has actively applied these techniques in the design office. Value is defined relative to the customer, a set based approach is applied, and the Chief Engineer (CE) is wholly responsible for the NPI programme. Throughout the organisation knowledge / information management processes are applied that are supportive of Lean NPI, and similarly workflow is designed to avoid queues and bottlenecks. Aero lags behind significantly, yet has made some advances towards Lean NPI. For example, Aero sees Lean largely as a tool set for waste reduction and is starting to explore some techniques. Value is largely associated with efficiency and the CE has a technical role. However, set-based approaches are being investigated and knowledge / information sharing processes are in place. Finally, Excavator lags behind both Aero and Auto.

The question now arises as to whether these findings are a fair representation of UK manufacturing. As previously mentioned, the companies were very carefully chosen and at no point in our studies did we become doubtful of this choice. Therefore, we feel that our results are probably indicative of the adoption of practices within the UK. Namely, the automotive sector is leading in the application of Lean NPI, Aerospace is following, with more general engineering being slowest to adopt these techniques. In our experience this is somewhat similar to the pattern followed with the adoption of shop-floor Lean, though lagging behind significantly. Taking the observation of Hines et al [4], that there was a change in emphasis of shop-floor Lean, from waste to value sometime around the mid 1990s, then currently Lean NPI may be lagging by as much as 10 – 15 years. However, adoption of Lean NPI may rapidly accelerate because, for example, our understanding of Lean fundamentals are now relatively sophisticated.

Future research could aid the application of Lean NPI by industry. Our thoughts are that work is still needed to consolidate our understanding of Lean NPI, with issues still arising in perceptions of value, knowledge and information management. Indeed, shop floor Lean accelerated once concise ‘agendas’ were defined [24]. Other than this, the largest challenge is in facilitating and sustaining organisational change. Something many manufacturers still struggle with. Our feeling is that bringing about a philosophical change in the values and attitudes of designers and engineers will probably be the largest single issue facing the successful exploitation of Lean NPI.

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Table 1 Case Study Questions and Associated Key Findings

Question	Key Finding
What definition does the Company attach to 'Lean', and is it seen as a set of tools or a more fundamental transition?	Within Auto, Lean is defined as a philosophy associated with value creation, whereas Aero and Excavator largely see Lean as a tool set for waste reduction.
Is the Company adopting Lean principles in the design office / NPI processes?	In the application of Lean NPI, Auto is most advanced; Aero is exploring and adopting some techniques, whereas Excavator is only now becoming aware of the approach.
How does the Company define 'value' in the NPI process?	Understanding what constitutes value in NPI is complex. Auto clearly defined value relative to the customer; Aero associated value with improvements in efficiency, while Excavator has a more fragmented interpretation of value.
Where and when does the Company consider 'value' to be created in the NPI process?	When value is thought of in terms of satisfying customer requirements, it is considered to be created at the point in the NPI process where these are met.
Does the Company take a 'set-based' or 'point' based approach in the NPI process?	Auto applies a set-based approach to NPI, Aero is striving to adopt this approach, and Excavator applies a point-based process and is unaware of the alternative as practiced by Toyota.
How does the Company manage NPI programmes and who has the ultimate responsibility for delivery?	In Auto the CE is wholly responsible for the NPI programme; whereas in Aero and Excavator the CE role is mainly one of technical responsibility.
Does the Company have a formal and integrated management system for the capture and distribution of NPI knowledge / information?	Throughout their organisations both Aero and Auto apply the standardisation of knowledge / information management processes that are supportive of Lean NPI; such a system does not exist in Excavator.
How does the Company manage work flow in NPI and is this compatible with the principles of Lean?	Auto has designed workflow to avoid queues and bottlenecks, whereas Aero and Excavator are more embryonic in their understanding of these issues.