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Lean Product Development: Nothing new under the sun?

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Abstract

The concept of Lean Product Development has attracted the attention of many scholars, since its inception in the 1990s derived from practices at Toyota Motor Company. Keys to this approach to new product development are a few methods derived from Lean Production as well as longer established practices, such as Concurrent Engineering. That makes one wonder whether Lean Product Development is a new practice, a new method or an encapsulation of already existing methods at the time; that quest about the roots and the tenets of Lean Product Development, also in comparison to other methods for new product development, is the onus of this paper. That journey takes this propositional paper not only to the roots of Lean Product Development and the context of its era of conception, but also to what this concepts adds to other extant methods for new product development. Particularly, that comparison draws out that other methods are trying to achieve the same objectives: creation of products and services with value to the customer, reduction of time-to-market and efficient use of resources. That allows managers for new product (and service) development to choose from a wider pallet of methods and approaches to enhance performance of R&D and to connect better to manufacturing (incl. supply chains). Inevitably, this has implications for research. Hence, this paper sets out a research agenda based on the deliberations and gaps that have been uncovered in the discourse.

Keywords:Lean Product development; New Product Development; Lean Thinking

1. Introduction

Traditionally, lean thinking is associated with manufacturing. After its conception for manufacturing [6, 7], there are an increasing number of attempts to transfer its principles, tools and techniques to other processes, such as New Product Development (NPD) [1: 1539, 2: 3, 3: 3, 4: 2798]; this attempt for NPD is often designated as lean product development. The emergence of lean product development, should be set off against other approaches to processes, methods and management for NPD that appear in the literature. In that context, some works, such as [5: 1, 8: 83, 9: 24, 10: 10285, 70, 71: 3], have already identified the existence of a wide array of approaches: sequential phasing for new product development, product platforms, concurrent engineering, waterfall models, stage-gate models, spiral development, capability maturity model, design for six sigma (DFSS), product lifecycle management (PLM) and lean product development. Hence, lean product development is one of the approaches currently being adopted by organisations attempting to maximise value, increase quality, shorten lead times, increase efficiency of resources and lower costs for NPD; lean product development tries to achieve these objectives by its focus on eliminating waste [2: 3, 11: 29, 12: 193, 13: 2]. However, for some researchers lean product development is not easy and simply implementing some of its techniques and methods, but they claim that lean is a way of thinking and should be adopted

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throughout the whole company. Furthermore, it has been mentioned by MacCormack et al. [15: 34] that companies must make substantial efforts to ensure that their NPD approaches are better aligned with their business needs. Thus, it seems clear that NPD needs to be fully integrated with strategic management, which applies to lean product development, too. That makes it a more difficult task to discern the benefits of lean product development as a singular approach. In this context, although various studies on NPD have been conducted [1: 1542], it appears that the mere conversion of principles taken from lean manufacturing to NPD settings does not necessarily equate to an effective lean NPD; it is sufficient to mention that numerous companies face difficulties in carrying lean product development out appropriately [11: 29]. In this paper, we aim to shed some light on this controversy of the principles and the scope of lean product development versus its benefits.

In addition to addressing this argument, another reason for this paper is that lean product development is still considered a relatively new approach to NPD and therefore it still lacks a systematic comparison with other approaches for NPD [9: 34]. Furthermore, Hoppmann et al. [2: 13] assert that there are no empirical studies about the implementation of lean product development, apart from those about Toyota's decades-long evolution of NPD. That stance is supported by Johansson and Sundin [16: 119], who found that the literature has offered fairly poor evidence regarding the industrial applicability of lean product development. The lack of evidence implies that is necessary to conduct a study comparing lean product development with other approaches to NPD. Once this is done, it will be possible to answer the question what lean product development brings to the table that other approaches do not. Therefore, this propositional paper scrutinises the tenets of lean product development and contributes to the debate on its added value for NPD relative to other approaches, concepts and methods.

2. Examining the Basic Tenets of Lean Product Development

Crucial to understanding the contribution of lean product development as an approach to the processes and management of new product development is to know what it is about. To that purpose this section explores the relevant features of lean product development before moving on to discussing its principles. The final subsection pays attention to its tools and methods.

2.1. Relevant characteristic of Lean Product Development

Most of all, lean product development should be taken as an approach to NPD. Processes of NPD cover capturing customers' needs and technological developments to generating instructions for supply, production, assembly, distribution logistics, use and recycling (see Figure 1 - Dekkers et al. [45: 321] for that generic process). Such processes should ensure that new product and the belonging processes match with the resources and structures of supply chains, manufacturing and business models, incl. considerations for sustainability [17, 18]. New product development should be placed in the context of (corporate and) competitive strategies with time-to-market, including product launch and commercialisation, being dominant. Lean product development [1, 2, 11, 12, 13] aims to achieve this by reducing waste. In addition, Nepal et al. [19], assert that the objective of a lean management structure is ensuring alignment, ownership, teamwork, communications and visibility across the NPD processes. That indicates that lean product development might be associated with different objectives presented by different authors. Therefore, a discussion about this approach derived from lean thinking is needed to clarify what is really new and if all the tenets are applicable to NPD.

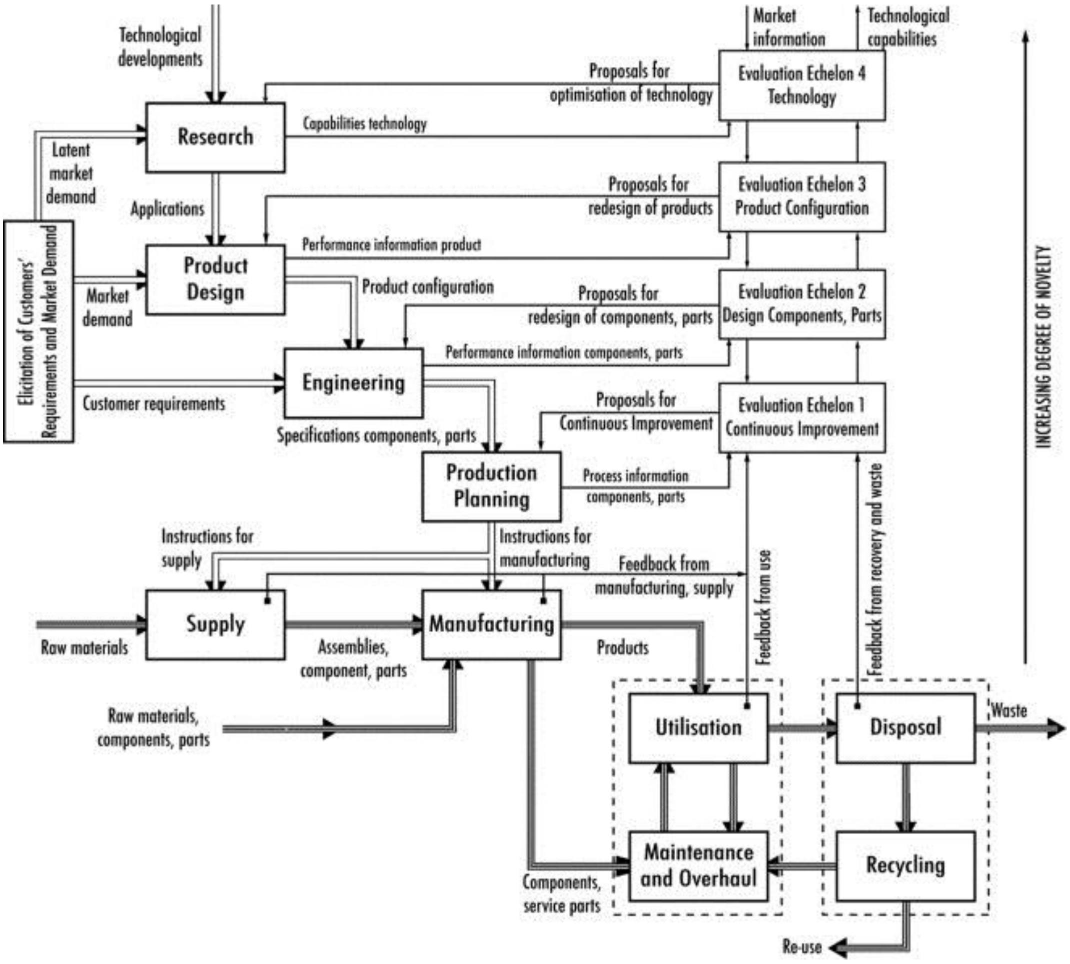

Figure 1- Generic Reference Model for Engineering, Manufacturing and Deployment Processes. Source: Dekkers et al. [45]

If we equate Toyota's approach to product development as lean product development, according to Ward et al. [20], 'set-based concurrent engineering' is a central concept. Calling it also the second Toyota paradox, they describe how this principle of subsequent evaluation of design alternatives and elimination of less preferable ones leads to an effective and efficient process for product development. They assert that Toyota's approach enables reliable and efficient communication, allows better management of parallel development activities and teams, enhances organisational learning and leads to optimal designs. Five years later, Raudberget [46: 685] writes that the evidence until that date seems to be limited to the original case of Toyota. He adds then his own four case studies implying that the cost of products is reduced but the lead-time for development and the use of resources increased [ibid.: 691–2]; he also reports that the companies ponder implementing it for successive products. Whereas there is scarce evidence for set-based concurrent engineering, Pugh's [47] controlled convergence method is seen as a basic tool for designers and engineers (though his thought is preceded by that of Abernathy and Rosenbloom [67], albeit not very clearly stated). It is Pugh's method [48], later published in 1991, that set-based concurrent engineering mimics. Others, among them Ulrich and Eppinger [49] and Wheelwright and Clark [50], have adopted this approach, too. Though advocated as unique by Ward et al. [20], in later paper they link it to the method of Pugh without mentioning that Toyota's approach is no different. Subsequent studies (e.g. Khan et al. [51]) are extending this framework of set-based concurrent engineering, though not referring to Pugh [47] or similar works.

Thus it can be concluded that set-based concurrent engineering is not a unique feature, even though (recent) works on lean product development [26, 68, 69] are ignoring its heritage.

In addition to the heavily cited paper by Ward et al. [20] about set-based concurrent engineering, one of the most cited papers about lean product development, the one by Karlsson and Åhlström [14], addresses the implementation of lean product development in a case study. They explain that lean product development comprises of numerous interrelated techniques and methods, including supplier involvement, cross-functional teams, concurrent engineering, integration (as opposed to coordination) of various functional aspects of each project, the use of a heavyweight team structure and the strategic vision and objectives for each development project. However, an in-depth study of cases by Boer and During [39] reveals similar aspects as being crucial to the success of project for new products (and process innovation). All these aspects, except supplier involvement, also feature in papers about project management. For example, in early 1990's, Pinto and Pinto [56: 200] and Henke et al. [57] assert that an important key to successfully developing new programs (and product) is the degree of cross-functional cooperation. Furthermore, around the same time period, Clark and Wheelwright [58: 9-10] and Brown and Eisenhardt [59: 359] support that heavyweight team leaders offer improved communication, strong identification and commitment to project, and a focus on cross-functional problem solving. Moreover, the integration of various functional aspects of each project is discussed by Project Management Institute [60: 39]. Curiously, Karlsson and Åhlström [14] have not addressed waste, which is considered a core principle of lean product development; that differs from other propositional writings, such as [21, 22, 23]. Furthermore, the study by Karlsson and Åhlström has not analysed the principles, tools and metrics that some relate to lean product development, which can be found in other studies, for example [23, 24, 25]. It should also be noted that the paper by Karlsson and Åhlström does not mention set-based concurrent engineering at all. Therefore, the two most cited papers – Ward et al. [20] about set-based concurrent engineering and Karlsson and Åhlström [14] – are incomplete and do not do justice to the heritage beyond lean product development.

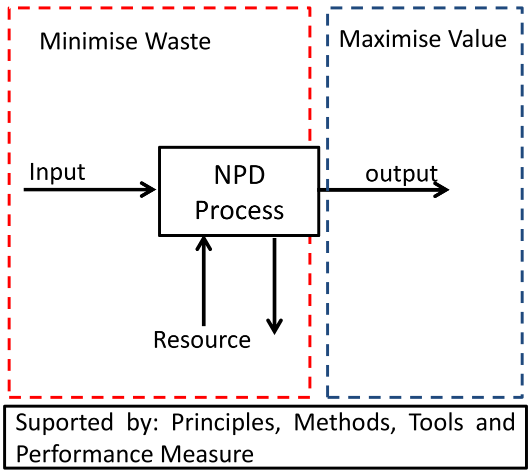

Figure 2- Waste and Value in NPD. Source: Adapted to [1,2]

Over the course of time, extensions have been proposed to the original concept of lean product development [31]. Cases in point are the studies by Al-Ashaab et al. [26] and Carleysmith et al. [27] that include set-based concurrent engineering, product lifecycle management and Design for Six Sigma (DFSS) in their approaches. From a practical point of view, other approaches, particularly the tools they offer, could be integrated without contradicting the core objective of lean – to provide value to customers [28: 997] and to eliminate waste [29: 15-16] (see Figure 2). Obviously, all these additions over the years by other researchers, such as [27, 55], have moved the approach of lean product development away from its initial focus on eliminating waste and adding value. For example, Pillai et al. [55] propose using lean six sigma for reducing the cost of development and improving the profitability of the project; however these researchers have not analysed waste as recommended in lean thinking. In this context, it is not yet possible to state that the lean product development is a new approach, even with its extensions; perhaps, it is only a philosophy of constant quest to eliminate waste and adding value applied to new product development, something we need to explore now.

2.2. Principles of Lean Product Development

That philosophy appears in the original writing by Womack and Jones [31: 28], when they state that lean thinking has five principles: value, value stream, flow, pull production and perfection. The thought is that these five principles do apply to lean product development, too, in some way. According to León and Farris [11: 43], there is agreement that lean thinking must be translated to fit the specific context of NPD; however, implementing only a few of its principles is not enough for achieving lean product development, according to Pernstål, Feldt and Gorschek [4]. Based on lean thinking, this is true because the implementation of a few principles will not result in the elimination of all waste within the context of NPD. Therefore, León and Farris [11: 43] claim that the few critical principles that best describe the application of lean thinking to NPD have not been reached, yet. Some have expanded the number of principles; a case in point is the paper by Liker and Morgan [25:10-15], who present 13 principles that underpin lean product development. It should be noted that these principles do not differ from those highlighted by Womack and Jones [31], but should be seen as a more detailed explanation. Thus, these, more recent writings do not shed light on the fundamental principles of lean product development.

Let us examine these five principles by first looking at the concept of value. Some works, for example [13, 23], instigate that the philosophy of lean product development has a strong focus on capturing the voice of the customer and on defining and maximising the perceived value by the customer. However, it is possible to find research in the late 1960's – early 1970's using the voice of the customer to increase the value of the product. For example, there are precedents with Quality Function Deployment (QFD) and a Scandinavian approach called Participatory Design. Both approaches involve customers in NPD [53:88, 54:464]. Often claimed as central to creating value, the analysis of value dates back to efforts at General Electric during the Second World War. Hence, it can be concluded that the principle of creating value for the customer dates back beyond the conception of lean product development.

The second principle of lean thinking is the optimisation of the value stream. This principle is mostly associated with the tool for Value Stream Mapping (VSM). According to Dal Forno et al. [61: 779], this is an important facet of lean thinking and is used for identifying value-adding activities and activities that are considered wasteful for materials and the flow of information and people. Furthermore, the deployment of VSM should lead to highlighting potential areas for improvement, while additional tools are used to conduct analysis [35: 205]. However, it is difficult applying VSM to the analysis of NPD processes due to the difficulties in defining what value is [11: 44]. Moreover, having a closer look at it, the depiction and its methods are merely an adoption of the ASME Process Mapping Standard, dating back to the 1920s. Again, this was developed for manufacturing rather than developed for new product development. In that context, it is worth to mention that new product development processes have an iterative nature; early decisions are later revisited and perhaps changed due to progressive insight about product specifications and technological capabilities [72, 73, 74]. None of the literature on lean product development (and it is extensive) has examined this argument. Akin the concept of value for the customer, the mapping of processes and its analysis roots in approaches known before the concept of lean product development came to light; moreover, these principles derived from manufacturing are declared to be valid without argumentation about the iterative character of new product development.

The latter flaw also surfaces for the third principle of lean thinking that is often mentioned in the context of lean product development, which is ‘flow’. This principle assumes that new product development and manufacturing are sufficiently isomorph from the perspective of control and process improvement. Contrastingly, Hinckeldeyn et al. [62: 3] and Salgado et al. [3: 4] have reasoned that NPD processes have more in common with job-shops than production lines. Contrastingly, Hadque and James-Moore [23:8] assert that to facilitate the principles of flow and pull production, several tools for information systems are used in organisations. The same authors [ibid: 6] assert that if information is ‘pulled’ it will be swifter available to the entity requiring it and, thus, it will compress the lead time for NPD, while noting that this is dependent on the degree of novelty. This notion is supported by Hinckeldeyn et al. [62: 1] who contend that the application of production management principles to engineering processes is related to the degree of novelty that is inherent to engineering projects in companies. None of the other literature on lean product development has questioned the validity of and the contingencies for transferring principles from manufacturing to new product development; this should be considered a prominent deficit. This discussion brings to the fore that the principle of flow together with the related fourth principle – pull production – carries little relevance to new product development as it stands, albeit that perhaps the degree of novelty is a determinant.

The final principle of lean thinking is the elimination of waste. To apply this principle seven sources of waste in the context of lean production are described by Shingo [66]. For lean product development Bauch [21] has suggested three additional sources of waste, see Table 1. More examples of the categorisation for sources of waste during product development processes can be found in Bauch [21] and Oppenheim [22]. However, it could be doubted whether these classifications are trivial and often unnecessary because of the degree of novelty as determinant. For instance, according to Baines et al. [1:1544], Work-In-Progress and excess inventory in NPD is generally in the form of information; the parallel is drawn with storing information. The stance is that waste should be minimised or if possible eliminated during NPD [13]. In practice, it will be difficult to assign a financial value to information, separate that a distinction between technical information and information for control might be helpful (see concepts of Applied Systems Theory). Moreover, how does one assess that unnecessary data are stored; only such can be determined at hindsight than by foresight. That becomes even more apparent when considering Stevens’ and Burley’s [43:16] finding that, on average, 3000 raw ideas are required to successfully commercialise one new industrial product. That underlines that uncertainties remain until the last moment and that subjectivity is inherent to NPD. Particularly for radical product innovation, a new specification for a particular product may not be a simple task, which could be simply eliminated or decreased in lead time. For reducing waste during NPD, one could fall back to striving for perfection (a.k.a. the zero-defects approach); Dombrowski and Zahn [32:1919, 63:13] affirm that is possible to find errors in all working process and, in fact, this occurs, also during product development. The same authors recommend as tools for lean product developments the Kano-Model, Quality Function Deployment, the Target Definition Matrix and Design for Assembly to minimise errors. The Kano-Model was developed during the 1980s by Professor Noriaki Kano and classifies customer preferences into five categories [64: 92, 65: 1129]. QFD [54, 75, 76] and Design for Assembly [77, 78] emerged during the same period. Specifically, Design for Assembly (DFA) should be seen as part of the paradigm that design and product engineering should not be disconnected from other functions, which became shortly after known as Design for X [79]. Furthermore, Design for Manufacturing and Assembly (DFMA) has been applied as an activity considered as lean too. The focus of work done with DFMA is on the development of products to simplify the assembly and manufacturing [36] in particular for products with manual assembly. This is nonetheless a way of eliminating waste and adding value. This discussion according to Bralla [44] began before 1995, with the first published article related to lean thinking for NPD. Thus, some of the concepts linked to lean product development emanated from both academics and practitioners searching for better fits between new product development and downstream functions during the 1980s and 1990s. Therefore, the search for ‘perfection’ builds on concepts that developed simultaneously but separate from lean product development, while sharing the same objectives.

The Table 1 - Relationship between wastes from product development process and manufacturing

No	Waste	Manufacturing	Product development
1	Waiting	Material and operation parts. Maintenance. Tools. Operators. Queue for further operations.	Available human or machine capacity. Information waiting for people. Waiting for data, answers, requirements, specifications, test results, approvals, decisions, review sections, signatures.
2	Transport	Excessive movement of pieces, materials, pieces and products. Storage movement Insertion or withdraw of material/product/piece.	Excessive data trade. Back and forth of tasks or of interrupted tasks. Inefficient communication.
3	Unnecessary movement	Operators’ minimum movements (reach, bend, force).	Remote places. Information search. Direct access lack.
4	Inadequate processes	Over-dimensioning of process, machines and equipment. Unnecessary accuracy of product or process, not meeting the client’s real needs.	Unnecessary precision and details. Unnecessary features and processes. Inadequate competence use. Inappropriate use of tools and methods. Excessive accuracy. Excessive transactions.
5	Inventory	Excessive raw-material storage, semi-finished products compared to the client’s demands. Waiting lines. Storage among operations.	Excessive data storage. Unnecessary prototype and equipment tests. Waiting lines in a critical path.
6	Over production	To produce more than the client’s orders. To produce before the client’s order.	Low synchronism of solicited time and capacity. Low synchronism of considered content. Excessive information dissemination. Task redundancy.
7	Defects	Components, materials, sub-assembling or products that do not have required quality. Production internal defects. Supplying defects.	Information with deficient quality. Wrong database and information. Poor tests and verifications.
8	Reinvention	Not applicable.	Project poor reuse. Knowledge poor reuse.
9	Lack of discipline	Not applicable.	Not well done objectives and goals. Badly defined roles, responsibilities and rights. Badly elaborated rules. Poor dependency definition among activities. Insufficient predisposition to cooperate. Incompetence or poor training.
10	IT resource limitations	Not applicable.	Poor compatibility. Poor capacity. Low capacity.

Source: [3,4]

2.3. Tools and Methods

To achieve the goals mentioned (add value and eliminate waste) a large number of tools and methods are included in lean product development. According to Carleysmith et al. [27], tools for lean product development are used to reduce waste associated with routine tasks, such as in laboratories, thus allowing more time for creative work. Furthermore, the literature, e.g. [13, 23, 33], has presented an extensive number of different tools and techniques to be used as part of the lean product development. Table 2 presents an overview. The applicability of the tools is assumed regardless of sector and competitive position, which leads to not considering the impact of concepts such as Order Entry Points (a.k.a. Order Decoupling Points). For the latter, Dekkers [81] makes a case showing the impact of it on management and control of product design and engineering processes. Moreover, the degree of novelty might have an impact on the suitability of tools and techniques, a strand of literature on lean product development missing thus far. Therefore, further research needs to be undertaken to identify what extent tools are applicable for which degree of novelty, which sectors and which business models.

Table 2 – Tools for Lean Product Development in literature

Tool Category	Tools
Customer focused tools	Customer representation Front loading Quality function deployment (QFD) Set-based concurrent engineering (SBCE) Set-based design Trade-off curve
Knowledge sharing tools	A3 documentation Cross functional teams Go see Obeya room
Visual management tools	5S A3 documentation Andon Obeya room Value Stream Mapping (VSM) Visual Management Visual Control Graphics
Efficiency tools	5S Cross functional teams Front loading Just in time Kaizen Kanban/ Heijunka Set-based concurrent engineering (SBCE) Staged freezing Standardization Takt Time Trade-off curve Value Stream Mapping (VSM) DFMA Empowerment; Zero defect; Poka yoke tools; Setup reduction Total productive maintenance (TPM)

Source: Adapted from [13, 25, 34,35,62]

A closer examination of Table 2 reveals that some of the concepts have been discussed before and some not. From those that have been discussed, most of them are not unique to lean product development neither do they originate in this approach. For example, according to Liker and Morgan [25:13] the tool for lean product development defined as Obeya room is a “big room” that enhances cross-functional integration and provides better communication, however a war room has been discussed by Project Management Institute [60: 100]. Moreover, the same analysis could be made for the discussions related to empowerment in early 1990’s [108]. The other techniques are mostly related to manufacturing (e.g. Just in Time, Takt Time, TPM). Furthermore, most tools are related to principles for manufacturing management and it is not necessary to re-iterate that the application of these to NPD depends primarily on the degree of novelty of products and processes [62:1]. Moreover, the application of these tools and methods needs to be embedded in a structured engineering process to be useful in a company [ibid.:1]. Yet, by using methods and tools for lean thinking, effectiveness and efficiency in NPD can be enhanced and therefore support companies in achieving improvements in their overall performance.

2.4. Performance measurement

Effectively managing and measuring the performance of NPD is widely seen as a means of ensuring business survival through reduced time-to-market, increased quality and reduced cost [37:147]. According to Loch et al. [87: 4], performance measurement systems is an important driver of output performance and thus it determine at which cost and how fast new products of what performance and quality can be introduced. The performance measurement systems are valid for the process of product development, because the organisation can be viewed as a set of processes, akin the thoughts about organisational routines (Nelson and Winter [91]) and the application of systems theories (Checkland, [107]; Dekkers [30]). Remarkably, some authors, such as Costa et al. [24:376], suggest that global indicators for companies or general indicators of NPD are specific for lean product development. Examples of these indicators are the total cost of projects, the number of patents and employee satisfaction. These performance indicators also appear as part of generic performance measurement systems [88, 92] and as part of performance measurement for innovation management [89, 90]. Therefore, the mere use of indicators does not make a company lean neither does it imply lean product development.

3. Is Lean Product Development the only way?

So far, the concept of lean product development, whatever it covers according to specific authors, has been rooted in preceding approaches and other concepts; perhaps something more can be derived from its implementation and use. In this respect, many works, for example [1, 2, 11, 14, 25, 38], cite as characteristics for the lean approach to new product development: the need for a heavyweight project manager [2:7, 14:285], the need for parallel activities [1:1545, 14:289, 19:59], the use of multidisciplinary teams and the collaboration and integration between departments to reduce the lead time of product development [14:283, 19:62, 25:13]. However, the question arises whether these features for lean product development are really confined to this approach. These features cannot be considered specific for the approach of lean product development since other concepts for product development, such as concurrent engineering [84, 85] and stage-gate processes (Cooper, [86]), have been related to the same characteristics, for example [9:38-39, 39:89, 40:362]. For those that are interested, concurrent engineering appeared first as simultaneous engineering [85:1883]. To support this notion, Meybodi [40:373] shows in a statistical study that similarities exist between principles for lean manufacturing and concurrent engineering for a majority of factors. However, it does not account for the characteristics of new product development, being iterative as discussed in Subsection 2.2 and therefore being more similar to a job-shop than a production line or manufacturing cells. One of the flaws in his work is then that the two-way communication is identical (for manufacturing one way is the primary process and the other way it is control information[1], whereas for new product development the two-way is about product specifications). Separate from works that are flawed in reasoning, both the implementation and use of lean product development falls back on determinants for success that are not exclusive, perhaps not even to new product development, and deploys concepts, such as concurrent engineering and stage-gate models, that came about independently.

For the perspective of standardisation and simplification in NPD [23], the same applies. In that respect, Baines et al. [1:1546] assert that the standardisation of knowledge and information management for the adoption of lean product development has yet to be defined. If we look at companies that use total quality management for all processes, this might bring about the need for standardisation and simplification. Logically, this notion might only apply when the degree of novelty for NPS is relatively low. Some authors, such as Hines et al. [28: 1007], view total quality management as a related technique to lean thinking in NPD, but do not seem to be aware that total quality management was practised well before lean production. In addition to total quality management with its drive for standardisation and simplification, some authors (e.g. Liker and Morgan [33: 16]) present modular design as an associated method to lean thinking in NPD. Although modular design might facilitate lean product development, its relevance to product development and manufacturing appears already in the work of Bikker and van der Heyden [82] and Kamarkar and Kubat [52]. Modularity often links to product families consisting of standardised assemblies, components and parts (Dekkers et al. [45: 322]); there is a strong relationship with product platforms (Utterback [83]). Modular design, product platforms and standardisation are means to an end for NPD and might facilitate lean product development but are not exclusive to it.

When lean product development is compared with other recent approaches (Rozenfeld et al. [9:33]), e.g. Design for Six Sigma, the Capability Maturity Model and product life-cycle management, it can be seen that these are complementary. For example, the focus of Design for Six Sigma is optimisation of design solutions mainly by using statistical tools, which can be used in the lean approach, but with the focus of waste elimination or value aggregation. Similar to PLM, lean thinking seeks the integration of all stages across the product life cycle, including production and organisational learning [98:882]. In addition, the Capability Maturity Model was developed in the late 1980s by the Software Engineering Institute and it is organised into five maturity levels [93:21, 94:246]. Nevertheless, when analysing the maturity levels it emerges that some of the principles are similar to lean product development and were created with the same objective during the 1980s and 1990s. However, the union of these approaches brings the idea of increasing the range of tools used in direction to solve problems of the NPD, which are also not new. Thus, we can consider that the lean applied to product development is an evolution of the previous NPD approaches with the inclusion of the lean thinking principles applied to waste elimination and value in NPD. However, that does not make the concept of lean product development neither unique nor new.

4. Some Final Thoughts

After looking at the principles, methods and tools of lean product development, also in relation to other approaches available, the question arises: based on the preceding critical review, what makes lean product development stand apart? In its original conception, dating back to Womack's and Jones'

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[1] Note the similarity in distinguishing primary processes and control mechanisms in Applied Systems Theory.

work [31], the foremost added value of lean product development is its focus on searching for value and eliminating waste. Over the course of time, authors have added other methods, tools and principles, increasing its scope but also causing confusion about the delineation of lean product development relative to other approaches. The shifting content and differing interpretations of scope do not allow systematic evaluation of its tenets, thus not meeting the criterion of falsifiability of constructs (see Bacharach, [95: 503]) across studies. Even studies themselves have not included the notion of falsifiability, e.g. [35, 51, 063], not in the least the original study by Womack and Jones [31]. Neither does such divergent adoption of the concept of lean product development lead to what theoretical question will be addressed, akin Sutton' and Staw's [96: 373] remark. Therefore, our first recommendation is that if studies are undertaken on lean product development, they should clearly identify its principles and its delineation from other approaches; authors doing so should also be clarifying why they have expanded on the original conception rather than including additional tools and methods.

Rather, based on these extensions that are put forward with poor or none reasoning, one cannot come to another conclusion than that lean product development in its original conception is simply inadequate. If the two main principles of eliminating waste and searching value for customers would suffice, no extensions and additions need to be proposed. Thus, the mere fact that numerous authors have included other approaches indicates the inadequacy of lean product development as an integral approach. Then it shares the same fate as product life-cycle management, product platforms, stage-gate models, etc.; all describe aspects of new product development but never its entirety. Antagonistic to our stance about lean product development that means that the extensions can be useful for managing new product development better, albeit that it means further confusion what lean product development is standing for (perhaps even leading to more papers in the future confused about conceptualisation).

4.1. Implications for Practice

All this discussion has implications for how new product development should be managed. NPD should be considered in a broader context that includes the corporate strategy for product development and marketing, incl. business models, competitive strategy, human resources [99, 100, 101, 102] and process performance. In addition, there are many alternative approaches (e.g. sustainable new product development [104], Design for X [79]) and methods and tools (e.g. Focus group, QFD, DOE, FMEA [103]). So, both arguments allow managers for new product (and service) development to select from a wider pallet of methods and approaches to enhance performance of R&D and to connect better to manufacturing (incl. supply chains). How lean thinking during new product development benefits overall performance in comparison to other approach remains elusive. Therefore, managers will have to rely on their intuition and experience for setting out appropriate approaches to new product development and how lean product development needs to be complemented to arrive at an integral approach.

Nevertheless, the 'lesson' from applying lean thinking to new product development is that of organisational learning. Thus, actions to reduce or eliminate waste and add value during the NPD process should be part of a continuous improvement process. Such thinking has strong parallels with organisational learning, for example, Adams et al. [97], Adams and Lamont [105] and Hoe [106]. Hence, the frameworks for lean product development proposed in the literature might assist companies in producing an environment adequate to increase their NPD performance.

4.2. Implications for Research

This positive connotation comes along with some profound limitations that have been highlighted during this review. The first one is the degree of novelty. The concept of lean product development has not been adequately placed on the dichotomy of incremental versus radical innovation. Particularly, its reliance on the elimination of waste implies that it only applies to recurrent processes, which can only be found through standardisation and simplification. It is incremental innovation in which this is possible and it rules out the use of lean thinking for radical innovation. The same applies to value creation for customers, albeit possibly to a lesser extent. The second limitation is the reasoning for the feasibility of lean thinking for product development. Most writings assume that new product development is similar to the recurrent processes of manufacturing, particularly production lines. We have already demonstrated that new product development resembles more a job-shop than line production (see Section 2.2). The question is then how to extent lean thinking to a job-shop environment. Such a quest should also go beyond over-simplification and incorrect comparisons; Meybodi's work [40] is a case in point. These two limitations need to be accounted for, which is poorly accounted for by the retrieved papers.

Taking these two limitations into account, further research is necessary on comparing lean product development with other approaches. Thus, future research to demonstrate the relationships between lean product development and, for example, product platforms, modular design, capability maturity model for NPD may well provide results that show how much is the degree of similarities between lean product development and these approaches as analysed by Meybodi's work [40] about concurrent engineering method. Furthermore, more research is necessary to analyse the applicability of production management principles to engineering management as researched by Hinckeldeyn et al. [62]. Since performance measurement applies to NPD irrespective of approach, this research will make it possible to verify the tenets of lean product development.

Further research is also necessary because of the limited scope of research methods. Most of retrieves papers are case studies, and in addition they are mostly descriptive. That does not necessarily lead to insight. Particularly, in these case studies the falsifiability of lean product development is not taken into account. That means that it is difficult to discern the tenets of lean product development versus those cases where it is absent (akin the call for maximum variation case studies by Flyvbjerg [109: 230]. Because of the limited scope of the 'original limited scope' of lean product development it will be even more difficult to distinguish its effects as part of an integral approach for NPD, where also other approaches, methods and tools contribute to overall performance. Multiple methods are necessary to assert the contribution of lean product development, following Weick's [110] arguments, albeit that all studies need to contribute collectively to convincing evidence.

Putting it all together, so far, the concept of lean product development brings little to the table beyond common sense and concepts that already existed at its time of conception and concepts that came about later. In that sense, lean product development is an amalgamation of tools and methods that is neither unique nor complete. Whereas it might have some advantages to bring together more methods and tools than those related to the principles of elimination of waste and searching for value for customers, that should not be presented as lean product development. For these reasons, it becomes necessary that researchers into lean product development demonstrate knowledge about its origins and present appropriately the heritage of all frameworks they use (it would be helpful if editors and reviewers would stimulate this 'literature sensitivity' as minimal professional knowledge).

4.3. Closing Remark

This brings us back to the starting point of this paper: why do academics present lean product development as something new or different? Is it a matter of management fashions, as Abrahamson and Fairchild [41] contend? Or is it simply that academics have to 'sell' themselves to practitioners, as Micklethwait and Wooldridge [42] assert? It is for the reader to decide. However, it is clear from our writing that there is nothing new under the sun for lean product development!

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