INTERNATIONAL CONFERENCE ON ENGINEERING DESIGN, ICED11
15-18AUGUST2011,TECHNICAL UNIVERSITY OF DENMARK

LEAN PRODUCT DEVELOPMENT: HYPE OR SUSTAINABLE NEW PARADIGM?

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ABSTRACT

The idea of lean product development (LPD), with Toyota used as the main case in point of demonstrating its abilities, has gained attention among managerial levels of companies dealing with product development. Allegedly the main gains of LPD are a high rate of successful projects in terms of cost and quality along with shorter lead times as well as fewer overruns in time and budget [1, 2]. This paper investigates the LPD concept in comparison with established models in the current product development paradigm in order to map out the main differences. It also compares LPD to the way product development is carried out in practice on the example of two European automotive companies. The results show that the main differences, among others, can be found first in the way knowledge is honored and managed, and second in how and when decisions are made along the process. From the discussion of the results, conclusions are drawn for potential improvements to traditional product development models.

Keywords: Lean product development, design methodology, VDI 2221, product development paradigm

1 INTRODUCTION

The term “lean” in lean product development originates from the paradigm of lean manufacturing [2] which has revolutionized the management of manufacturing by defining seven types of waste whose elimination continuously improves the manufacturing processes. “Lean” in this understanding has been steadily gaining attention for twenty years, now. A focus on identifying value adding activities and eliminating wasteful activities has ever since been the hallmark of “lean” [3].

The term “lean product development” (LPD) saw the dawn of light under that name already in the mid-1990s [4] but has only gained attention in the recent years, both in industry and academia. It claims to be a new paradigm in the area of product development and relies heavily on the case of Toyota as a demonstration of its abilities. Several investigations propose an interpretation of why Toyota is successful at product development: One main difference between lean product development and traditional (also referred to as “western”) product development is identified to be the focus on knowledge in the lean paradigm. This focus on knowledge is reflected in how product development is organized and executed and in which processes, methods and tools are applied and how.

The published works within the area of lean product development are mostly books written by a handful of authors with insight into Toyota’s product development system. In addition, cases from a few other companies [1, 5] have been reported, also in the form of books. Some academic initiatives in the form of, e.g., the Lean Advancement Initiative at MIT have performed research into the area mainly related to value stream mapping in product development [6].

Since the area claims to be a new paradigm the focus of this paper is to compare lean product development to models and theories commonly found in the established area of product development. The aim is to investigate whether lean product development contains elements that complement the existing product development models or if it can be considered to constitute a completely new paradigm. Thus the research questions posed in this paper are:

- *Which are the major differences between the area of lean product development and traditional product development frameworks?*
- *What conclusions can be drawn for potential improvements of the traditional frameworks?*

The research approach analyses publications on Lean Product Development, first. Second, it compares the results with traditional approaches from academia and industry – the former based on a literature study, the latter on the authors' experiences at leading automotive manufacturers. Third, the findings from this comparison are discussed and conclusions are drawn. Accordingly, the rest of the paper is structured as follows: Section 2 looks in more detail behind the ideas of lean product development. Section 3 explains and defines what we refer to when we talk about traditional product development. Section 4 makes a comparison following the process steps of traditional methods and with regards to major underlying concepts. Section 5 provides the discussion and finally section 6 concludes the paper with a revisit to the research questions and a future outlook.

2 LEAN PRODUCT DEVELOPMENT

The cornerstone of any lean system is its focus on "waste reduction" which is also the main focus of lean product development. Based on a distinction of value adding, non-value adding but necessary and non-value adding activities, the latter group is defined as waste. Two categories of waste can be identified in the published literature. We will label one of them "operational wastes", which are mainly elaborated by Morgan and Liker [2], and the other "strategic wastes", which are elaborated by Ward [4] and subsequently by Kennedy et.al. [1]. These two categories are based on the somewhat different approaches adopted by the respective authors where Morgan and Liker adopt a more descriptive approach of the Toyota product development system. Ward and Kennedy go a step further with a prescriptive approach and define a framework for lean product development that takes its empirical base from Toyota to a more general and conceptual level.

2.1 Operational waste

Morgan and Liker take the seven kinds of waste from lean manufacturing and transfer them to the product development process to identify similar kinds of waste. The following seven wastes are identified (based on manufacturing wastes in bold):

- **Overproducing**: unsynchronized concurrent tasks
- **Waiting**: Waiting for decisions, information distribution
- **Conveyance**: Hand-offs/excessive information distribution
- **Processing**: redundant tasks, reinvention, process variation, lack of standardization
- **Inventory**: batching, system overutilization
- **Motion**: long travel distances, redundant meetings, superficial reviews
- **Correction**: external quality enforcement, correction and rework.

It could be argued that most of these wastes are addressed in the traditional product development paradigm with a multitude of methods and tools for information management, project management, process modeling, knowledge based engineering, virtual teams and virtual product development. Morgan and Liker refer to the specific mix of management and engineering methods along with an organizational setup applied in Toyota to cater for the reduction of these wastes in their product development system. From a more philosophical point of view the perspective on the product development process adopted by Morgan and Liker is that the process can be considered as a manufacturing process with no tangential deliverables, a "product development factory".

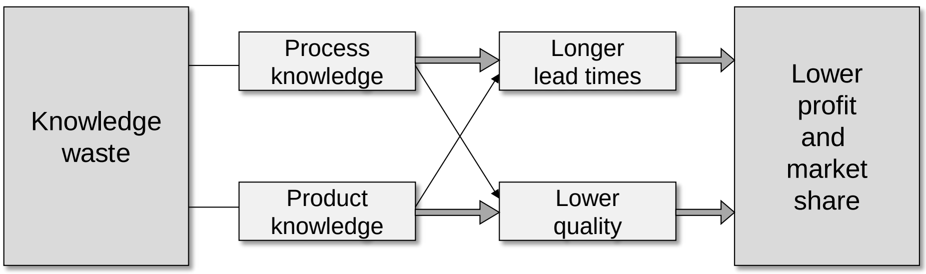

Figure 1: Knowledge waste and effects on product development metrics adapted from Ward

A similar point of view is adopted in the area of value stream mapping in product development which can be applied to the parts of the design process that are rather mature and therefore predictable with a defined flow of activities among which some are more “value adding” and some are less according to predefined measures. Methods and tools for this type of optimization can be found in e.g. [6, 7, 8].

2.2 Strategic waste

Ward and Kennedy have chosen to define only one type of waste, which is essentially concretized into all other types of waste within product development, and that is waste of knowledge. The idea of knowledge waste stems from the notion of product development as a knowledge intensive task which produces knowledge as much as it produces designs and information about the designs. Waste of knowledge is concretized into waste of product knowledge and waste of process knowledge. According to figure 1 loss of process knowledge leads mainly to longer lead times because any insight about how to improve the process by those who execute it that is not harvested (i.e. wasted) will mean that an opportunity to cut lead times is lost. In the same way any insight on how to improve the product solution will affect the product’s quality both in terms of build quality and solution quality.

2.3 Product Value Stream and Knowledge Value Stream

In their framework Ward and Kennedy define two value streams in product development, schematically depicted in figure 2. The product value stream (PVS) can be considered to be what is traditionally labeled as the “product development process” in most companies starting from a specification and ending with a completely defined product, ready for production.

The knowledge value stream (KVS) passes across projects and caters for a management and build-up of knowledge. There are methods for managing it in and between projects. Most of the methods used in KVS, such as trade-off diagrams or engineering checklists, are also aligned with the processes in the PVS to support the everyday activities as well as strategic capture and reuse of product and process knowledge. This is the major reason for why this is considered as “lean” since having a strategy and methods for capturing and reusing knowledge lowers the risk of repeating mistakes, thus saving time and making the product value stream more efficient and more effective.

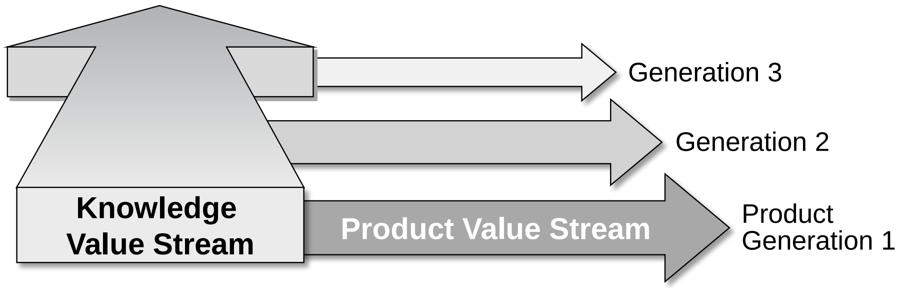

Figure 2: Knowledge Value Stream and Product Value Stream

At Toyota, the interaction between the two value streams is addressed through the role of a chief engineer, as depicted in figure 3. Prior to any product development project there is a knowledge gap between what is known until that point in time, and what needs to be known before there is enough certainty for a product development project to be successful. The chief engineer enters the scene and acquires the voice of the customer in order to scope down in detail which technical challenges the product development project has. This can be done because there is a knowledge base related to each part of the product where it is stated how far conceptual solutions can be stretched and still work. This information is coded into trade-off diagrams from previous projects. The knowledge base is compared to the challenges to clarify which parts of the product need new solutions and which can be carried over (at a conceptual level) and “stretched” in relevant parameters to achieve the characteristics needed in the new product.

This approach advocates a modularized product, since consequences and effects of changes in one module can be kept under control via known interfaces and more easily planned for in a new project. Once the chief engineer’s “concept paper” for the new product is approved the product development project is started and all of the detail designs are performed with certainty that they will work. In this phase the number of people is largely increased and the work is more standardized in order to make this phase as efficient as possible.

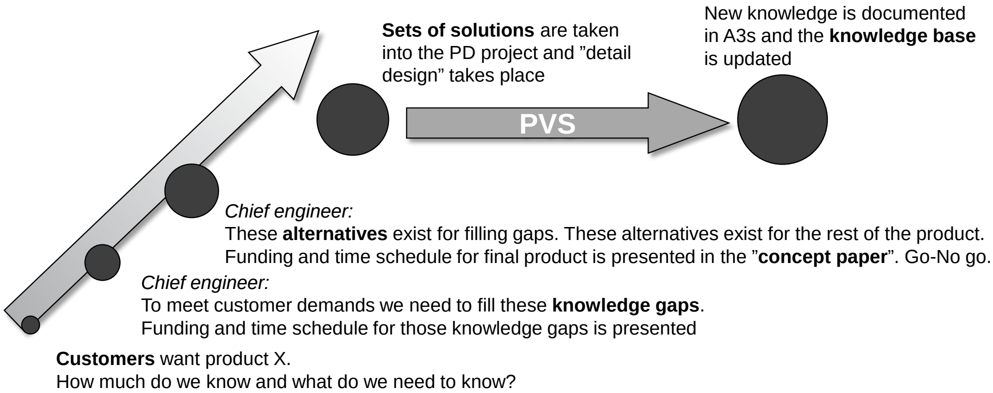

Figure 3: Closing the knowledge gap in the interface between KVS and PVS

3 TRADITIONAL PRODUCT DEVELOPMENT

When we talk about traditional product development we mean well established models for the development process from both academia and industry. In academia, on the one side, a wide variety of process models exist, with most of them having been derived from basic problem solving concepts then adapted and expanded to the scope of product development [14]. On the other side, industry has developed own process models from experience, trying to put into an order and to standardize the different development steps with main focus on development efficiency.

Against this background, it will be interesting to see how lean product development compares to both sides as it on the one hand widely originates from the analysis of established industrial processes and on the other hand has been abstracted to a more academic product development model, as such.

In the following, examples for both sides of product development processes will be described in comparison to the lean product development concept described in chapter 2. With "knowledge" being the core message of lean product development, this will be given special attention in the comparison.

3.1 Academic

In academia, a wide range of models exist for the process of product development. The majority of them describe more or less comparable step-by-step process flows from the initial idea generation to a fully documented design. Each of these steps is supported by a variety of methods and partially tools.

For this paper, three models were chosen based on them claiming to be application-oriented models and representing internationally acknowledged standards in education and research. These are the models of VDI 2221 [9] on the one side and Ulrich/Eppinger [10] and Ullman [11] on the other side. They will be looked at in detail as a representation for the entirety existing. The former results form an attempt by the Association of German Engineers (VDI) to generalize the ideas of other existing models with special regard to applicability in practice. Worked out under the direction of Beitz, it comes close to the widely recognized methodology of Pahl and Beitz [12]. The latter both add more international perspectives and offer development toolsets also designed for practical application. Thereby, both Central-European systematic "school culture" and Anglo-American problem-oriented "shop culture" approaches to engineering methodology [13] are considered in this paper.

VDI 2221

VDI 2221 is a core guide line of the Association of German Engineers (VDI) and splits up in several sub guidelines from product planning (VDI 2220) to detailed conception (VDI 2222) and design (VDI 2223). It was established in 1985 in an attempt to deliver a harmonization from different methodologies around with special emphasis on applicability for practical engineering.

The middle column of figure 4 shows the process steps of VDI 2221. With product planning as an input special emphasis is put on the early, creative phases of the design process. Early and detailed requirement specification builds the process input to be also controlled throughout the process. Then, before getting physical, an abstract functional modeling phase sets the ground for determining the solution concept, which then, in the later phases, is materialized into geometric modules and documented for further realization. According to this flow, testing would be not part but a follow-up step of the design process. The only result of the design process is the documentation of the product to be realized.

The process flow of VDI 2221 is designed to support mainly from-scratch new developments. Engineering adaptations or changes are not covered explicitly; they may be realized by skipping some of the earlier process steps. The process is also designed to be executed undistributedly by a single designer or organizational design unit. The process steps are in a strict sequential order, however feedback loops are proposed between all steps and their respective predecessors.

Some important underlying concepts can be identified. First, there is a formalized switch between a concrete requirement (step 1) to an abstract functional (steps 2-3) and back to a concrete realization phase (steps 3-7). Second, the process can be divided in a top-down problem breakdown phase (steps 1-3) and a bottom up system realization phase (steps 3-7).

Analyzing VDI 2221 regarding the understanding of and emphasis on knowledge delivers just fragmentary results. Knowledge is explicitly mentioned just once and in the sense of the provision of design rules in the context of the embodiment design phase (step 5). Implicitly knowledge is also the basis for solution catalogues proposed to be used in the solution finding phase (step 3). Creation of such rules or catalogues is covered by a separate process not part of the design process itself. Thus knowledge seems to be understood just in a sense of knowledge provision and usage, not in the sense of (formalized) knowledge creation and reuse.

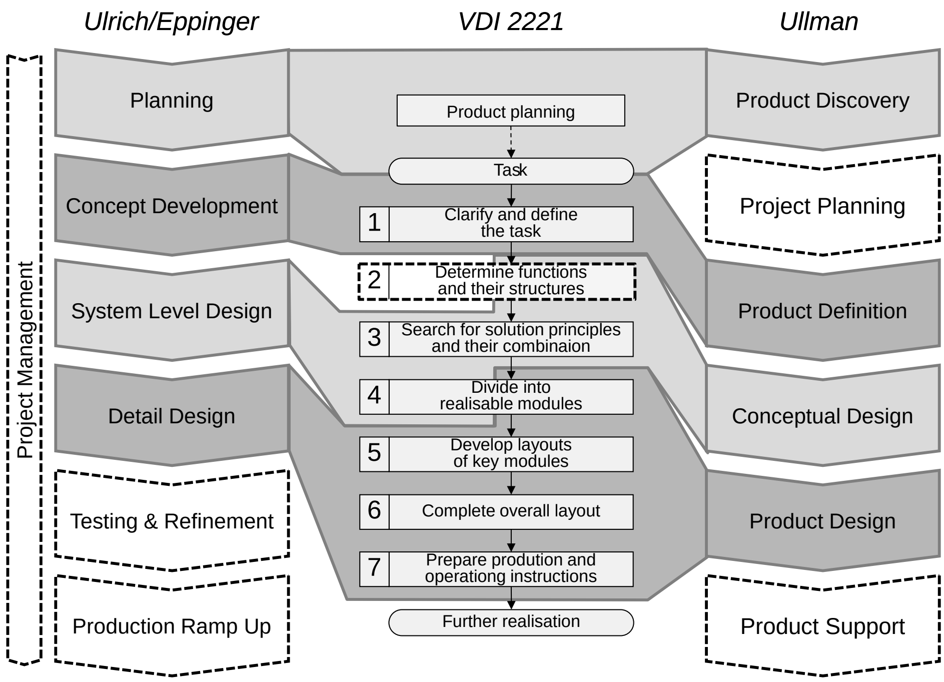

Figure 4: Process flows of VDI 2221, Ulrich/Eppinger and Ullman in comparison

Ulrich and Eppinger

Ulrich and Eppinger propose the process flow shown on the left side of figure 4. They claim to provide a methodology balancing aspects from both theory and practice by emphasizing applicable methods throughout the process. The comparison to VDI 2221 shows on the one hand a broader understanding of product development – the process includes both testing/refinement and production ramp up phases. On the other hand the abstract functional modeling step of VDI 2221 is omitted. This as well as the inclusion of project management indicates the problem-oriented application focus of the model.

Similar to VDI 2221, Ulrich and Eppinger mainly support new product development projects, engineering adaptations or changes are not explicitly covered. The sequentiality of the process appears to be more loosely, the character of the methodology is more one of a method toolbox than one of a strict process model. Also in Ulrich and Eppinger, knowledge is mainly understood just in the sense of a design input somehow available to be applied.

Ullman

The right column of figure 4 compares Ullman's process model to VDI 2221. Similar to Ulrich and Eppinger, he provides an application-oriented approach to product development, with also a similar scope.

Compared to VDI 2221 and Ulrich/Eppinger however, Ullman's understanding of knowledge is broader. Besides the aspect of knowledge application he sees knowledge creation as a key characteristic for progress in the design process, see figure 5, with frontloading it being desirable to accelerate the process. Knowledge in this context is understood as knowledge about both the design problem and its solution, making design freedom decline with each amount of new knowledge created.

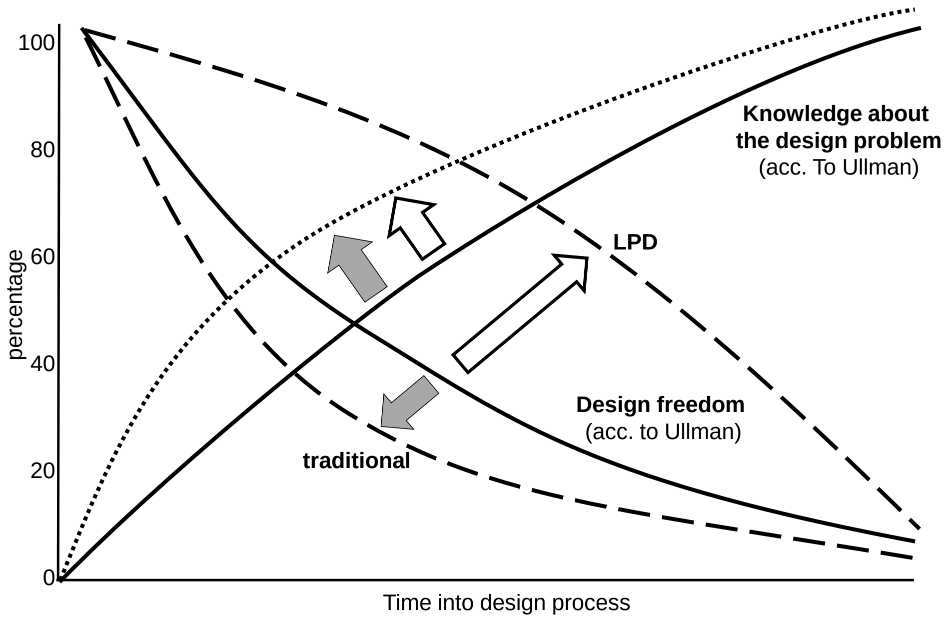

Figure 5: Knowledge creation and design freedom acc. to [Ullman] and improved as intended by traditional and LPD models

Although all three models described intend to focus on practical applicability, none of them has managed to be transferred or implemented in its entirety to a wide application base. Investigations looking for reasons (e.g. [14, 15]) identify, among others, too much rigidity and sequentiality in process flows, too much generalization across product types and industries and a predominance of instructional methodology over hands-on engineering as main points of critique. Thus the following chapter will take a brief look at applied product development processes from industry.

3.2 Industrial

As pointed out above, one major criticism to academic product development models is their high level of generalization. This being said it is comprehensible that industrial companies develop individual best-fitting product development systems, themselves, mainly based on best practices and own experiences. Descriptions of industrial product development models can therefore only be singular views, which may however give general insights in practical requirements to methodology. Against this background, a brief description of traditional European car development will be given in the following, derived from experiences at leading German and Swedish automotive manufacturers. The restriction to a European view follows the understanding that lean development ideas have not seriously entered those processes, yet. Industrial processes in the context of this paper are therefore to be understood as traditional western – e.g. European – industrial processes.

Automotive development projects generally follow quite strict process plans, which, on a macroscopic level, reflect the general process steps of VDI 2221 as described above. Their main intention is to ensure product development efficiency in terms of time and quality through the execution of quality gate milestones, see e.g. [16] for a more detailed description of as-is processes and relevant process trends. In a highly distributed environment project management is a main aspect of these models. In contrast to VDI 2221, prototyping and testing are main components of these models, with the former sequentiality making more and more room for virtual, concurrent and fully integrated testing steps.

As the majority of product development projects large parts of automotive development projects are more of an adaptive than of a new development character. This is often taken into account by splitting new pre-development processes from adaptive series development processes. The industrial practice of incremental development is also reflected in the rise of the separate and largely empirical and descriptive academic field of engineering change management which seeks to develop solutions to support it through dedicated processes, methods and IT support [17, 18].

Even looking in detail at the industrial process models for product development, knowledge generation does not play a significant role as such. Knowledge based engineering tools may be applied in single process steps and their respective methods, often for automation purposes. Systematic knowledge capture and reuse through dedicated knowledge management initiatives however happens, if at all, outside of the main product development processes, e.g. through separate improvement or IT projects. Instead, the staffing of product development projects is seen as critical as it is assumed that the involvement of individuals with experience automatically caters for a systematic reuse of their knowledge. Dixon [19] notes that the assumption that experience equals knowledge is largely false. In order to create usable knowledge experienced individuals need to go through a cycle of knowledge creation based on their experience; otherwise they risk repeating mistakes. Exercises dedicated to such knowledge creation are however seldom allowed sufficient time in industrial practice.

4 COMPARISON BETWEEN LEAN AND TRADITIONAL CONCEPTS

In this section, lean product development aspects are compared with the traditional approaches from academia and industry. First, this is done in respect to the main process steps of the frameworks described in figure 4. Based on this comparison, general conceptual characteristics of the different approaches are identified and discussed in detail. Focus is kept on topics in which traditional and lean approaches differ; where applicable, also differences between traditional academic and traditional industrial concepts are pointed out.

4.1 Comparison of process steps

Requirements management

LPD demands strong personal responsibility for each individual to know the “voice of the customer” which is significantly amplified through the chief engineer. Requirements are collected and successively detailed along the process through decisions based on explicit knowledge at the project milestones.

Traditional frameworks show a strong belief that a well-designed process can relief designers from personal responsibility of knowing customer and lifecycle requirements. Instead, through specifications, the communications of requirements are almost in a contractual manner. A “freeze” of requirements is advocated as early as possible through the focusing on early decisions, thereby however accepting later revisions.

Abstraction and functional modeling

In **LPD**, functional modeling is not defined as such but applied as an enabler together with modularization for defining and addressing limited knowledge gaps in different product sub-systems. Customer and market segments accentuate functions and properties which in turn guide the identification of which sub-systems that need to be innovated in a certain project.

In **traditional academic** models, functional modeling is an important part of “school culture” approaches (e.g., VDI 2221) but not in the more problem-oriented approaches, such as Ulrich/Eppinger and Ullman. The increasing importance of cross-domain (e.g. mechatronic) product trends brings functional modeling to the front in **traditional industrial** processes.

Conceptual design

LPD encourages sets of solutions early and keeps them alive as long as possible. Concepts are eliminated only when explicit knowledge exists (from e.g. testing) that they are unfeasible in relation to requirements. If no alternative concepts are feasible, the previous and proven fallback solutions are preferred.

Traditional models encourage conceptual sets of solutions early in the process. Then, decisions for elimination or succession of options are done fast and with limited knowledge about the solutions and their limitations and abilities.

Detail design

In **LPD**, detail design is performed with high confidence that the chosen conceptual solutions will work in the desired intervals.

In **traditional** models, detail design is performed to a certain level to be able to test the concept. Detailed adaptations and redesign is performed until converging on a design that sufficiently fulfills the requirements. If this fails, an alteration of the requirements is done instead.

Testing

LPD follows a “test then design” order. Testing generates explicit knowledge used for concept selection and is also used to verify and validate detailed design. It is an integrated component of the design process.

Traditional industrial processes “design then test”. Testing is done to verify (or guide the adaptation of) one specific design early before its release to manufacturing. However, the growing significance of modeling and simulation techniques begins to change this approach towards a more “simulate then design” work order. **Traditional academic** processes also “design then test”, but in a more sequential order. In VDI 2221, testing is not even part of, but subsequent, to the core development process.

Based on this process step oriented comparison the following underlying concepts can be identified as fundamental distinguishers of Lean Product Development to traditional frameworks.

4.2 Knowledge management

LPD shows a strong belief in people and testing which both are seen as “knowledge generators”. The codification of knowledge is standardized through, e.g., trade-off diagrams and engineering checklists which are used to support transparent decision making, as noted above. Knowledge is a significant core outcome – a deliverable – of the process. It is at least as important as the product, itself, see figure 3. Knowledge produced but not made reusable is considered waste.

Traditional industrial models do not recognize knowledge as a deliverable in the same way and consequently its management is implicit. Knowledgeable individuals are recognized but they may consider their knowledge to be a personal belonging used for personal gains. The managerial layers view knowledge as a commodity that can be codified, or even transferred from external sources, with the ultimate goal of process automation. These conflicting views make it hard to establish practices for managing knowledge as it is neither considered to be in the responsibility of the product development process, itself, nor of the acting individuals. This renders continuous product and process development a farfetched goal and even seeing knowledge management as time-consuming and wasteful.

As mentioned for the industrial ones, also in **traditional academic** models knowledge is not mentioned as a deliverable but merely recognized as an enabler. Knowledge may be provided to the product development process. New knowledge may develop throughout the process as a kind of by-product, if and how it may be recycled is however not within the responsibility of the process, itself.

4.3 Decision making

In **LPD**, decision making is delayed as much as possible and knowledge build-up is frontloaded as much as possible to enable well-informed decisions based on explicit knowledge, see figure 6. Concept related decisions are taken with highest possible certainty. In LPD, deciding means more the step-by-step elimination of less feasible alternatives instead of directly deciding for a supposed-to-be best one, thereby keeping design freedom as open as possible and continuing knowledge build-up for a wider range of solution alternatives (sets); see figure 5.

Traditional models focus on taking many decisions early to “land” on a certain concept and allow time for the hard to predict iteration of detailed design, testing and refinement until the solution meets

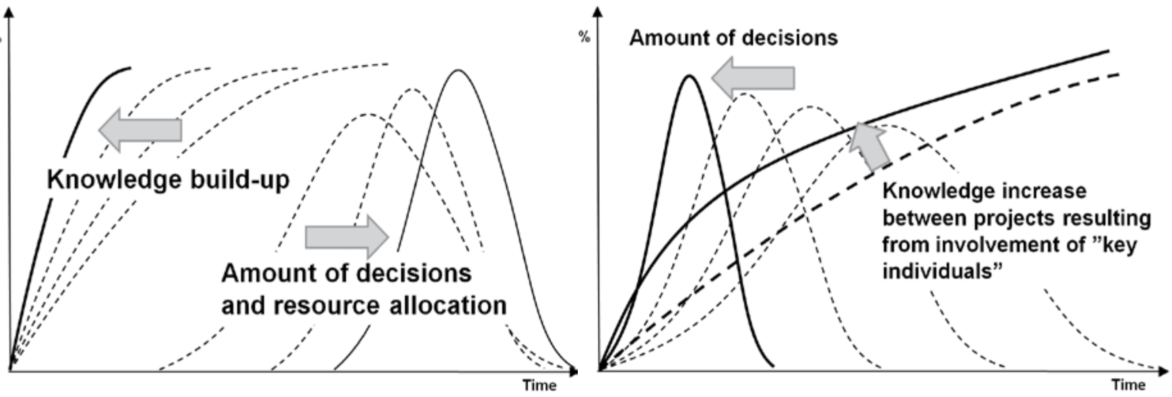

Figure 6 – left: LPD interpretation of frontloading = frontloading knowledge build-up; right: traditional interpretation of frontloading = frontloading amount of decisions

the requirements. Decisions are based on uncertainty but taken to meet project milestones in the product development process.

4.4 Innovation

In **LPD**, the notions of ‘innovation’ and ‘performance’ are managed separately through the two interconnected value streams (KVS and PVS). Innovation is about developing new solutions and knowledge about them, without focus on lead times, by addressing identified knowledge gaps. Performance is about making the process of detail design and industrialization of conceptually sound solutions which are known to work, with focus on lead times. The split implies dedicated organizational and managerial approaches for both streams. Although separated, the two value streams are populated with the same individuals to secure an effective transfer of knowledge and technology.
In **traditional academic** models, innovation is done as an integrated part of each product development project. The team is supposed to both innovate and perform simultaneously (innovation under time pressure) which leads to longer lead times if not successful. **Traditional industrial** processes have partially begun to move towards a separation of pre-development and series development processes, often concretized in the form of platform or module strategies.

4.5 Product improvement

LPD enables continuous product improvement by capturing knowledge in, e.g., trade-off diagrams or engineering checklists. The availability of a documented “knowledge baseline” enables a more precise engineering change management.
Traditional industrial models perform product improvements either through engineering change requests or through new development projects executed “from scratch” without a documented knowledge baseline. Involvement of “key people” is assumed to cater for an implicit knowledge reuse.
Traditional academic models reflect mainly new product development, while the academic branch of engineering change management is mainly descriptive and reflects industrial practice.

4.6 Process improvement

LPD also manages process knowledge explicitly, mainly through engineering checklists. Process improvements at a micro level are within the responsibility of each designer.
Traditional industrial models often initiate process improvements at a macro level from an IT perspective, e.g. through the introduction of new IT tools, or performed by someone external to the design process, e.g. a process owner or consultant. This reflects a top-down oriented ownership of the design process as a managerial instrument to control operations as opposed to a bottom-up oriented ownership of the design process as an instrument to support operations. **Traditional academic** models attribute little responsibility for improving the design process and practice to the designer. Instead it is an academic branch of its own focusing on quantitative approaches to analyze and optimize design processes in a similar way as manufacturing processes are optimized.

4.7 Information Technology

LPD emphasizes physical testing as the major knowledge generator. IT is used when phenomena for e.g. *simulation* of specific characteristics are well known and can be modeled with high certainty.

Automation is applied only when an activity is ascertained as value-adding “best practice” and standardized in its execution to such a level that it can be automated through IT-solutions.
Traditional industrial understanding is that everything can be simulated and as much as possible should be simulated. Automation is largely seen as a solution for “waste-reduction”. Activities perceived as wasteful such as administrative tasks (e.g. manual transferring of data between redundant IT-systems) are targets for automation. In **traditional academic** models IT generally plays a side role. VDI 2223 lists and – in the case of well to-be-automated tasks – recommends possibilities to support especially the later phases of the design process by IT tools. In this respect, both simulation and PDM tools are mentioned. A newer (German-only) version of VDI 2221 postulates that integrated CAD tools may support a methodical way of designing. Automation is applied as soon as a task is perceived as regular enough for automation regardless of its status as creative or administrative, value adding or wasteful.

While **traditional** models promote “proper” PLM systems to realize life-cycle optimization, **LPD** realizes many of the life cycle objectives of PLM through the role of the chief engineer who follows a product from cradle to the market. Instead of believing in IT enabled virtual teams and collaboration, “Obeya” (= big room) is used to co-locate all stakeholders and solve significant problems.

5 DISCUSSION

Following the points of comparison in the previous chapter, the main conceptual differences identified between LPD on the one side and traditional product development frameworks on the other side can be summarized as follows. From the comparison in chapter 4 it can be concluded that other differences in single product development process steps and in IT-based as well as organizational realization concepts can be mainly seen as consequences of these basic conceptual differences.

- **Knowledge as a deliverable**
  LPD honors knowledge as a core outcome of the process coequal to the product; knowledge is not to be wasted but to be captured and made reusable systematically. Traditional frameworks – both academic and industrial – see knowledge as something to be available and to be used, but not as in charge of the product development process as such to be built up. While traditional frameworks may talk about *knowledge based engineering (KBE)*, LPD would foster a more *knowledge oriented engineering (KOE*) point of view.
- **Decisions late and sound**
  While traditional frameworks seem to see (even risky) decision making as something desirable the earlier the better to banish uncertainty from the process, LPD intends to keep decisions open as long as possible to base them upon a highest as possible certainty. This is to increase decision quality and endurance and decrease process risks through engineering changes. If certainty is not high enough for sound decisions, proven fallback solutions are kept at hand systematically.
- **Innovation/performance dedication**
  LPD distinguishes knowledge and product creation as two inseparable, but sequential value streams within the product development process. This implies dedicated organizational and project managerial approaches for both streams. Traditional approaches require a distinguished view: While academic models suggest integrated processes from innovation to realization, industrial practice has partially moved towards separated process parts, often concretized through platform or module strategies.
- **Process scalability**
  While academic frameworks strongly focus new development projects (apart from those dealing with engineering change management which are largely descriptive of industrial practice), LPD offers a toolset for both new and adaptive designs. Real new development being the minority of industrial product development processes, this is also reflected in industrial process models.

Knowledge honoring and decision focus seem to be components of LPD different to both academic and industrial frameworks, whereas innovation/performance dedication and process scalability seem to be aspects shared between LPD and industrial processes, but not academic models, see figure 7.

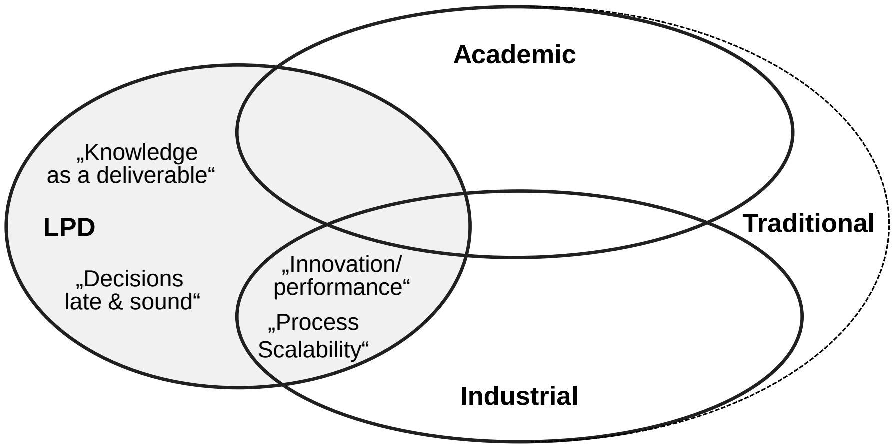

Figure 7: Main differences identified between LPD and traditional frameworks

Main revision points to traditional frameworks could therefore be:

- Knowledge seems to be underrepresented in the existing frameworks; its role and management may have to be redefined.
- Decision points in the existing models have to be reviewed and potentially postponed till later phases.
- A split line between innovation and performance process cycles may have to be established in order to honor both knowledge and product value streams, adequately.
- Scalability to fit different kinds of product and process characteristics seems to be an issue not sufficiently addressed, yet. LPD may contribute some ideas to this.

Further consequences to be drawn could be of more organizational character, e.g. the refinement of roles and collaboration models. These points are considered to be downstream to the more fundamental ones above and therefore not further elaborated on here, but kept in mind for further research.

6 CONCLUSIONS AND OUTLOOK

In this paper, a comparison has been provided between the lean product development concept and traditional product development frameworks such as VDI 2221 and the models of Ulrich/Eppinger and Ullman. Differences to industrial product development frameworks have been pointed out.

Following the discussion in the previous chapter, LPD features major differences in the understanding of product development on a fundamental, conceptual level and thereby also results in distinguished processes and methods on an operational level. With a paradigm being defined as a set of underlying principles which provide a framework for understanding particular phenomena [20], LPD can be understood as a paradigm providing a framework for understanding what makes product development efficient and effective together with methods and processes for doing so. Judged by the maturity of LPD-based processes as executed at, e.g., Toyota, and the efficiency advantages ascribed to these processes, the question in the title of this paper can be answered with a strong tendency towards a sustainable new paradigm. The major contribution of this paradigm is to define knowledge as an explicit deliverable of product development and give it a value stream of its own.

Revisiting the first research question, the basic differences observed lay in the principles of knowledge honoring, decision making, focusing on innovation vs. performing and the scalability of the framework for different characters of product development projects. These differences especially refer to the academic product development frameworks, whereas industrial concepts (in the western/European understanding of them followed in this paper) are partially closer to the ideas of LPD. This suggests that revising the academic frameworks against the background of knowledge-oriented LPD may be worthwhile, the focal points of chapter 5 thereby providing directions for answering the second research question. The differences identified are of fundamental character and may therefore not only suggest to complement existing approaches, but to rework them substantially.

Further research work may first incorporate a direct comparison between industrial and academic frameworks, which was not in scope of this paper. Then, a traditional academic framework may be adapted according to above findings and the results of such an adaptation empirically investigated with regards to engineering time, costs and quality. As the practical acceptance of traditional academic frameworks is still lacking, it may also be a measure to judge on changes potentially introduced through the adaptation of lean product development ideas.

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