Lean Innovation: Introducing Value Systems to Product Development

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Abstract--The implementation of Lean Thinking in innovation management has not been executed systematically yet. For instance high uncertainties of processes or limited possibilities for automation in research and development (R&D) indicate special requirements for the implementation of Lean Thinking. A competitive R&D requires a holistic rethinking for the implementation of Lean Thinking.

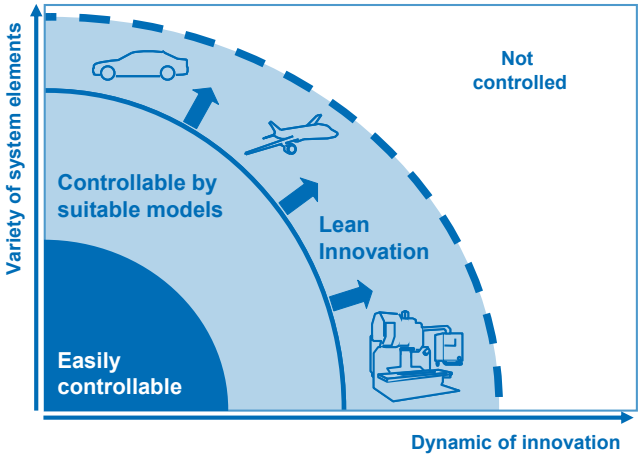
The Lean Innovation System represents the systematic interpretation of Lean Thinking principles regarding to product or process innovation and development. One core element of Lean Innovation is the Value System which is the basis for the value stream design in innovation and development projects. The Value System defines, structures and prioritises 'values' adaptively for one specific innovation project. The values are defined by all relevant stakeholders in the innovation and development process, like external and internal customers, considering company's strategy and culture. It represents the basis for a consequent value oriented alignment of project and processes in R&D.

This paper introduces Lean Innovation and the core findings of the recent survey 'Lean Innovation' of the Laboratory for Machine Tools and Production Engineering WZL at RWTH Aachen University. In a next step the paper focuses on the Value System, describes its elements and shows how to use and benefit from the Value System towards a powerful Lean Innovation.

I. LEAN INNOVATION AS A CONFIGURATION APPROACH

Typical products of high wage countries compete primarily in saturated markets. Some industries show a tendency towards oligopolies. Global markets are consolidated to few providers with little chances of differentiation by technology advances and single innovations [14]. Overcapacities, globalisation, pricing pressure and a multitude of similar product ranges have an impact on various sectors: Besides drastically shortened product life cycles, customers are subdivided into ever smaller market segments. The resulting increase of product variants leads to small production numbers per variant. In combination with escalating costs in R&D, a significant increase in cost pressure for each variant is the result. Thus, return of investments per product decreases, even if the overall number of sold products growths [15].

This intensification has spotlighted the controllability of R&D. Structures of R&D are based on certain models, which allow a high number of system elements (e.g. number of projects, number of variants, number of components and modules), but only a limited amount of dynamic changes. Variety and dynamic constrain each other: The rising innovation dynamics set the boundaries for the variety of controllable system elements (see Picture 1).



Picture 1: Boundaries of controllability in R&D by Lean Innovation

In order to stay competitive, R&D has to cope with increasing level of dynamics in more and more complex product and project systems. Both effectiveness and efficiency &D have to be improved for complex products and project programs. A substantial product differentiation has to be achieved also under limited resources and with intelligently defined economies of scale.

Therefore, the intention of Lean Innovation is the transfer of Lean Thinking[1] to the management of R&D. Lean Thinking is not a universally applicable method, but a concept with different pivotal principles, which have to be transformed individually [18]. The broad success of Lean Thinking especially within manufacturing as Lean Production bases both on the extensive work to interpret the basic principles for manufacturing systems as well as on the broad availability of examples. Comparable guiding themes are still missing for Lean Innovation. The implementation of Lean Thinking in innovation management has not been executed systematically so far [14]. As shown in the next chapter, a survey among 143 companies in the German manufacturing industry in 2007 showed that only a third of the companies have begun to systematically identify waste in product development.

Strongly influenced by the results of the survey and several expert interviews, Lean Innovation represents the systematic interpretation of Lean Thinking principles regarding to product or process innovation and development. The Lean Innovation approach is base on ten key principles that need to be implemented in R&D. These ten principles are introduced shortly in chapter three. The last chapter of this

[1] **Lean Thinking** is an approach to remove waste and increase value adding activities with a focus on customer needs (see e.g. [18], [19])

paper focuses on one core element of the Lean Innovation Principles, the Value System.

II. LEAN INNOVATION IN GERMAN COMPANIES – THE SURVEY

In the recent survey 'More success with Lean Innovation' of the Laboratory for Machine Tools and Production Engineering WZL at RWTH Aachen University 143 R&D managers of the German manufacturing industry[2] were asked about challenges and success patterns [13]. The Objective of the survey was to identify scopes and patterns of action for a Lean Innovation and to quantify their potential.

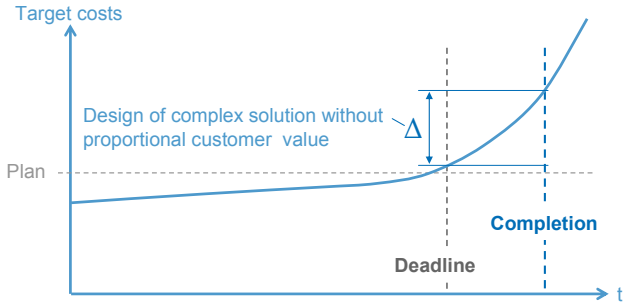
Based on the evaluation of the survey results the companies were classified into outperformers and underperformers, according to the four success factors "market", "finance", "product quality" and "operations".[3] The analysis of the success factors showed e.g. that the vast majority of financially successful companies has already started to identify waste in product development systematically.

The early structuring of value[4], product and process is a key factor for development projects.

The customer value represents the fundamental element in Lean Thinking. In R&D, the effective match of customer needs and product functionalities is one of the most important challenges. Within the survey, 141 innovation managers indicated that their customers use only 70% of the provided functionalities and technical performance characteristics. Thus, 30% of not utilised functionality and performance is tolerated by manufacturers. These 30% are the discrepancy between actual customer needs and delivered product functionalities – the so called "overengineering". The precise determination of the customer values and their consequent implementation into the development process and the product seems to be one of the substantial barriers for a successful R&D.

Complex functionalities and technical features often result in increasing development times. A distinct correlation between the priority of meeting deadlines and market success clearly demonstrates that the outperformers from a market perspective give a clearly higher priority to meet deadlines in the development process compared to less successful enterprises. The on average undervalued priority of meeting deadlines in R&D is reflected in the companies' reaction upon delayed milestones: Once the overrun of a deadline has happened, the majority readjusts their project schedules. Alternatively or additionally, the capacity of personnel is temporarily raised until the termination of the project. Overall, 74% of the answers where applied on these two options. The well considered use of approved solutions or the simplification of a planned technical solution is done far less, in order to meet a deadline. Even though, a delay has happened, these companies will not deviate from their originally planned functionalities and features.

Here, the correlation to the success factor "market" reveals a significant insight: The outperformers fall back to approved solutions to 39% once a milestone was exceeded. However, only 4% of underperformers reverted to approved solutions. A consistent awareness for deadlines forces everyone in the team to focus on really relevant functionalities (see Picture 2).



Picture 2: Focus on fulfilment of customer value by relevant functionalities "on time"

50% of the outperformers mentioned that they flexibly adjust the development budget once the market opportunities change. A delayed project handling also prohibits a fast reaction to the possible improvements of customer value. Around 40% of the companies mentioned that they are able to implement possible improvements into a product, once they are identified, in less then 6 month. Another 40% need 6-12 month and at least a fifth needs over 12 month for an optimisation of the current product.

State-of-the-Art development processes avoid decisions without a sufficient information basis. In average though, the companies' process cycles force decision makers to decide based on insecure foundations. In future, processes need to increasingly consider the particular reliability of information. In order to decide for or against a certain solution concept, this might mean to carry the different, redundant alternatives into the next development phase to collect more information by the next level of conclusions.

An example for decisions based on insecure information is the early limitation of a development projects' design space to a single technical solution. Over three quarters of the

[2] Survey participants are mainly acting in automotive (original equipment manufacturer and supplier, 38%) or plant and machinery construction (36%).

[3] Declaration of the success factors:
- *Finance* includes EBIT and growth in sales over the last five years
- *Market* is based on the development of market share, share of sales of new products and knowledge of customer needs
- *Product Quality* consists of number of technical problems after start of production and the effective identification of product defects at gates or reviews during the development process
- *Operations* specifies by the successful execution of development process (number of changes in product specification; amount of waiting lines; early identification of capacity shortages; flexibility in allocation of resources)

[4] Regarding Womack and Jones [18], **value** can only be defined by the ultimate customer in terms of a specific product, which meets the customer's needs at a specific time at a specific price. Value is created by the producer.

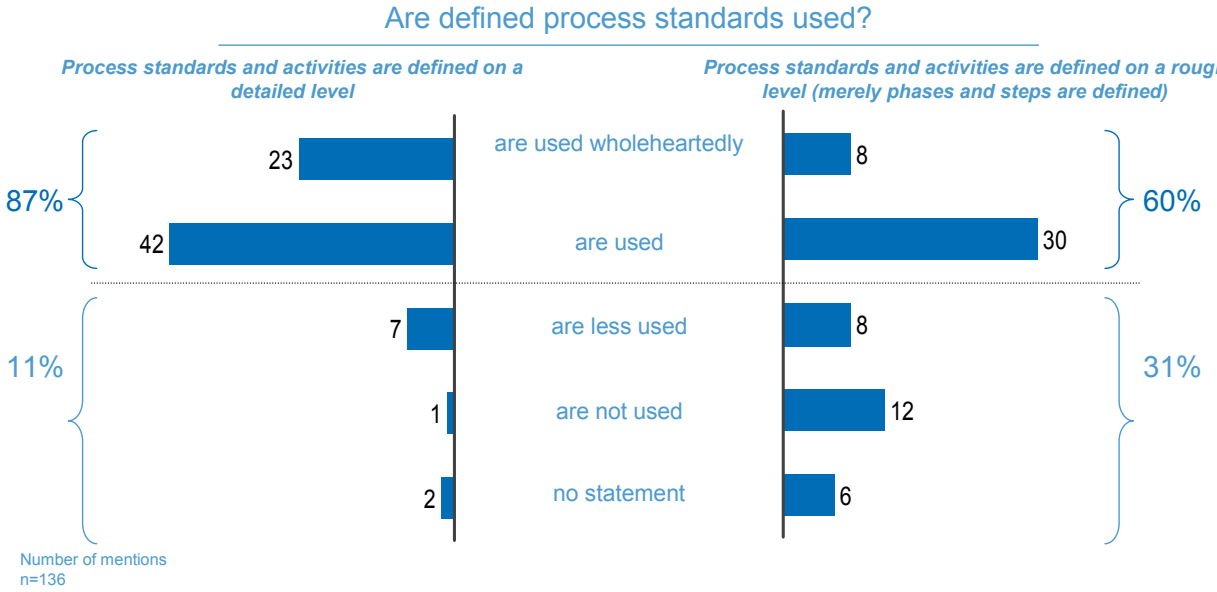
companies indicated that they freeze the technical solution for each component already during the concept development phase. In reverse, this means, that a possible misinterpretation regarding the suitability of a technical solution in the early concept phase can ultimately lead to late changes and iterations.

One example for high development efficiency is Toyotas "Set-Based Concurrent Engineering" [8]. The basic principle is to not make decisions for or against any solutions before an adequate amount of information is available as a foundation for these decisions. Existing goals in terms of cost, quality or time are further specified along with the increasing maturity of development, in order to eliminate the alternatives bit by bit. The key is to prevent decisions from being made too early in the process. Concepts that are not developed any further are being frozen in the current stage of development and well documented in terms of a mature knowledge management.

In spite of large amounts of variants and extensive adjustments for different markets, a systematic evaluation process of new product variant regarding cost and benefit is not standardised in industries yet. 42% of the companies have not defined targets for the use of common parts across product lines, whereas just 4% of them believe that this principle does not work. On the contrary, 29% of the companies specify targets for the application of common parts. Accordingly, the management of communalities is still relatively far away from a status of being a maxim in the product development process. To manage the increasing variety, a specific standardisation and clever product architecture is a necessary element of Lean Innovation. Creating such a basis for all products provides freedom to focus on customer value.

The complex structure of modern development projects demonstrates high demands on the coordination of the development activities. In order to avoid dead times during the development process, almost 80% of the survey participants practice an active waiting line management in their product development successfully: While 73% of those companies without an active waiting line management mention repeatedly emerging dead times, only 25% of the companies with an active waiting line management do so. Possible shortages in the development process as potential reasons for the waiting lines are especially expected during testing phases. Here, test plants, marketing, manufacturing and prototyping are given as bottle necks in development.

The majority of standardised processes and activities are used in every-day-life. But by comparing the processes' degree of usage between those companies that have defined their processes on a high level of detail and those that only describe their processes on a rough level, differences become obvious: Processes that are described on a high level of detail are put into practice in 87%, compared to only 60% of those who are roughly described (Picture 3). The results of the survey clearly show the relevance of putting standard processes into practice: The effective identification of potential product defects by using gates and reviews succeeds almost exclusively in companies that have put their process standards into practice.

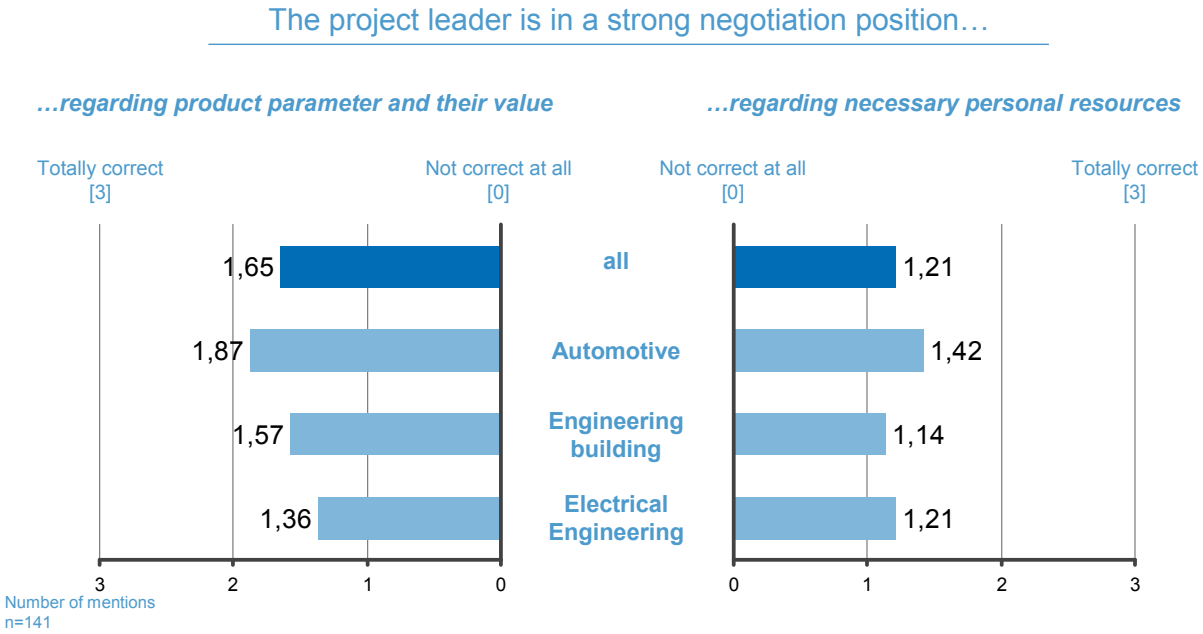


Picture 3: Implementation and detail level of process standards in R&D

On average, successful companies in terms of product quality have entirely put a stage-gate-process with the corresponding process standards into practice. Furthermore, the use of product and process standards and a systematically controlled generation of variants have a positive impact on product quality. This is also proven in this survey: 67% of the outperformers of the success factor "quality" are using a systematic evaluation process for generating new variants. In

less successful companies, a systematic evaluation process is only used by 39%.

A strong project leader - in organisational as well as in technical means - has a sustainably positive impact on a development project's success. As shown in Picture 4, strong project leaders are still exceptions. According to further surveys[5], a promotion of individual responsibility has the fundamental advantage of a higher motivation of the employees. Correspondingly, over three quarters of the companies mentioned to systematically promote the adoption of individual responsibility of their employees in development. The tools and methods used for this purpose differ: The majority focuses on "black box" process modules with the design of sequences of actions in one's own responsibility as well as the design of components in one's own responsibility within certain constraints.



Picture 4: Strong Project leaders are rare

The findings of this survey disclose important success factors, which significantly affect the implementation of Lean Innovation. Especially the analysis of outperformers has shown promising patterns of behaviour: Systematic waste identification, focus on customer value by time compliance, reuse of proven solutions and concepts, flexible allocation of budgets and capacities, product standards and a strong position of project leaders.

III. THE LEAN INNOVATION SYSTEM

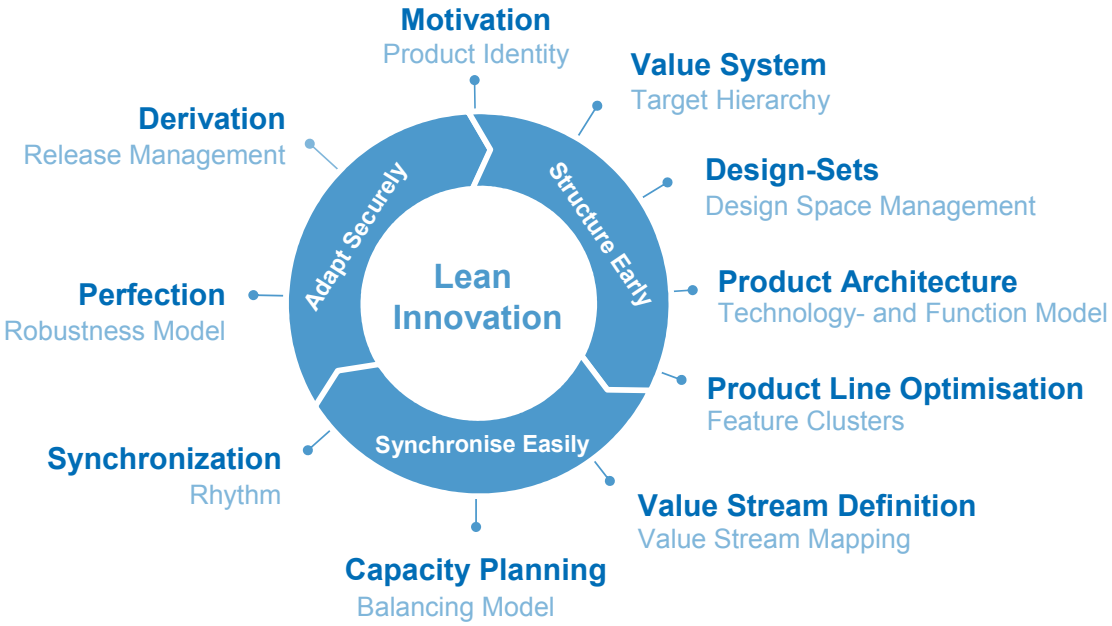
Maintaining a competitive advantage in research and development requires not only increases in effectiveness, but also in efficiency of R&D. Significant product differentiation needs to be achieved also under a reduced deployment of resources. This is the central objective of Lean Innovation – by applying the Lean Thinking principles to R&D management.

So far, this transfer has been initiated in first attempts, but has not been carried out systematically yet. Comparable guiding themes to Lean Production are still missing for Lean Innovation. Lean Innovation today is on its way, getting more systematic. The Lean Innovation approach presented here relies on ten key principles that need to be implemented in R&D (see Picture 5). The ten principles are abstracted into the guiding theme of Lean Innovation, which uses three steps: "Structure Early, Synchronise Easily, Adapt Securely".

Structure Early aims on a motivated project team, concrete, transparent and prioritised requirements and values, as well as the composition of project and process as a basis for an efficient and synchronised development:

- Highly motivated staff builds the basis. The pride of every staff member in the product creates motivation, which is needed for superior products.
- The Value System structures requirements transparent and tailored to suit the specific needs in form of a target hierarchy. Product benefits and targets are prioritised and visible for every stakeholder at any time.

[5] See R&D Benchmark 2003 (www.benchmarking.rwth-aachen.de)



Picture 5: The Lean Innovation principles

- Resulting from these targets, the design space consisting of the realistic concept alternatives. The alternatives are so called Design-Sets, which represent the entirety of all relevant technical solutions. This ensures that the design space of a development project is not narrowed to early and iterations or suboptimal solutions are avoided.
- The architecture of the developing product regarding all functions and technologies has a significant influence e.g. on economies of scale, suitability for production and assembly or the capability for releases along the product life cycle. Basic principles for structuring product architecture have to be defined within in a Function and Technology Model very early.

Synchronise Easily requires value stream mapping[6], capacity planning and synchronisation to arrange all activities as effective as possible:

- The differentiation of creative and repetitive processes is one basic element for value stream definition in a project. For both – creative and repetitive activities – the value stream has to be designed avoiding waste. In doing so, the different degrees of freedom have to be taken into account. While repetitive activities can be determined exactly, creative activities need more degrees of freedom for ideas and try outs. Like a "score" for an orchestra, the target value stream map is an overall working plan for all stakeholder of a project.
- R&D projects suffer, whenever capacity conflicts occur. The results are shortages, waiting times and product quality issues. Capacity levels need to be smoothened and balanced also within R&D. A Balancing Model for capacity planning therefore is a precondition for Lean Innovation.
- The achieved design and implementation of the value stream bases on rhythm. In order to synchronise all resources - even the ones which are used by more than one project -, time-consuming work packages have to be based on a standardised rhythm across all projects.

Adapt Securely provides the basis for a sustainable adjustment of robust products to changing market requirements.

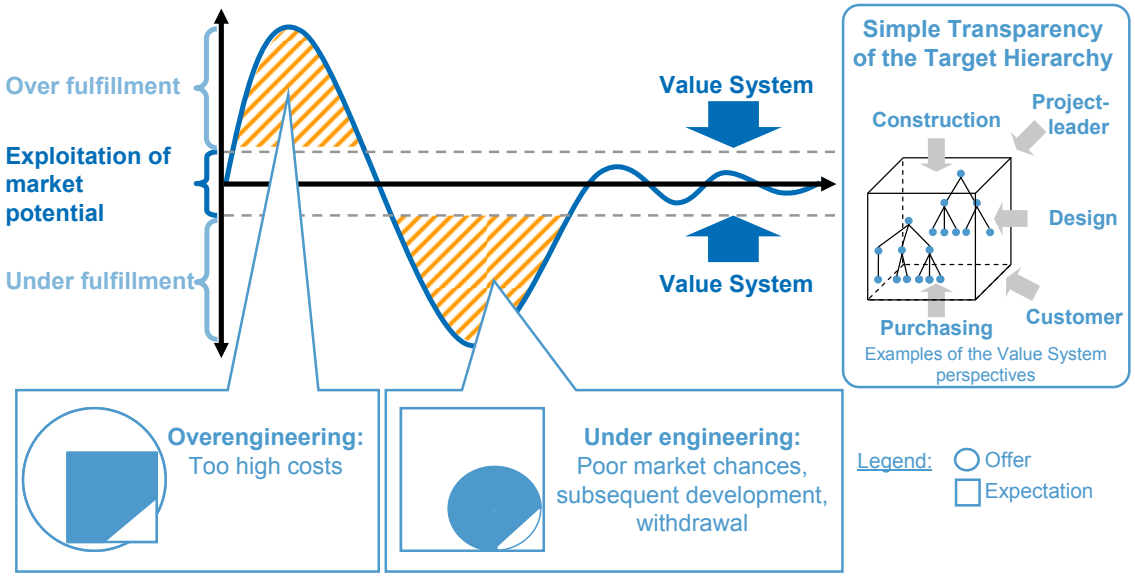
- The increasing integration of functions in various industries shows a lack of available instruments to assess product robustness. A transparent Robustness Model helps to identify and implement residual needs to bring a product to perfection – especially in case of newly developed product functions.
- Lean Innovation has to secure a continuous adaptation to changing market and customer requirements. Products are getting more and more complex with functionalities and components which largely differ in their individual life cycles. This has to be controlled by an effective Release Management, in order to avoid risks and to master unequal innovation frequencies. The result is a constantly "fresh" product from the market perspective.

[6] **Value stream** is a sequence of activities required to design, produce, and provide a specific good or service, and along which information, materials, and worth flows. Value stream mapping is a technique to analyse the information, material and worth flow of a value stream. (see [18], [11])

IV. VALUE SYSTEM

The substantial challenge for innovation and development projects is the exact exploitation of market potentials with products that are precisely aligned to customer needs. The span between over- and under-fulfilment of customer requirements is small and often difficult to identify. Developing a product which meets the customer needs as precisely as possible requires an effective requirement management. The term "requirement" normally addresses requirements in the context of a physical product [1]. The requirement definition starts with the customer, who defines his first intangible wishes. By realising the limitations and narrowing them into possible functional requirements, detailed technical requirements can be developed by the project team [10]. The requirements for most products are multiple and various methods in literature help to identify define and combine them.[7]

In order to provide the customer with a product that satisfies his individual requirements, two main processes must be executed. The first process includes the transformation of customer needs into detailed technical requirements at the beginning of a project. The second process includes the handling of requirements during the development process. In order to deal with changing and new requirements, a consequent configuration management and change management has to be included as well [20]. A frequent cause for wrong decisions and late iterations is the missing transparency of customer values and needs as well as resulting project objectives. Even if customer requirements are known, they run out of focus during projects very often. An emphasis on techniques and technologies – particularly in case of German engineers – leads to Overengineering [12]. Contrarily, lowered competitor prices enforce cost-savings, which provide the risk of under-fulfilment of innovation performance (see Picture 6) [12]. To meet the small target corridor of right requirement fulfilment, all requirements have to be transparent for and easily accessible and well understood by all participants involved into a project.



Picture 6: Focus on value by transparency through a Target Hierarchy

The demand of taking changing requirements and transparency into account exceeds present requirement management approaches. A new requirement management approach is needed in order to provide an effective requirement management [20].

The requirements definition at the beginning of a development project should not end with product specifications. In terms of Lean Thinking, one aim is the value oriented design of processes. The ability to create a Lean Innovation by an implemented value stream in product development needs more than just the right definition of mere customer requirements - relevant customer values and the resulting objectives for a specific development project have to be defined previously, as well. There are significant differences between requirements of development projects. A completely new product development, which e.g. implements an unknown technology, has different requirements regarding project resources, project planning and underlying processes than an incremental development of an existing product. These process requirements have to be defined as well as product requirements, to provide a common target for all participants in the development process. Regarding Krishnan

[7] Compare e.g. Kaul and Rao [4], who build up a conjoint-based product design model from a marketing perspective; Papalambros and Wilde [9] considered engineering design optimization modeling techniques, strategies, and examples; ATC methodology described by Michelena [7] and Michalek [6]; Diaz [2] who describes the selection of one solution out of a Pareto set of optimal products.

and Ulrich [5] one main problem in product development is the effective communication between disciplines like marketing and design, which can lead to suboptimal product designs - even if all relevant information is available. This shows the need for a method for common understanding and compromise [3].

Essential for Lean Innovation is a definition of value for a development project. Therefore starting point of Lean Innovation is a systematic method to define and handle target values and requirements regarding process and product as an enabler for a lean development process – the Value System. The Value System represents a framework for mapping value in a holistic, hierarchical, dynamic and transparent way:

Target Hierarchy

The Target Hierarchy is a basic element of the Value System, which collects and evaluates targets of a development project: In the style of a balanced scorecard the Target Hierarchy addresses - next to the companies strategy, product program design and customer requirements - the interests and objectives of the "internal customers". These are all internal stakeholder like design, marketing, construction, purchasing and others. At the beginning of every project, values and objectives of all stakeholders are derived systematically by the Value System. A consolidated weighting and a clear definition of priorities leads to a hierarchy of targets, which can be accepted by all stakeholders and is a commitment for the process. A further, detailed interpretation and derivation for single tasks is carried out by process owners.

The Target Hierarchy allows a direct derivation of requirements for both product and development process from the Value System. The objective hierarchy does not end with the requirements of a product like the conventional product concept catalogue; it includes the requirements of the development process too.

Dynamics

One difficult challenge in designing the specific Value System is the degree of specification. Similar to a product concept, catalogue targets and specifications need to be precise to avoid development errors [17]. To ensure the functionality of the Value System, all relevant requirements and aspects have to be included. On the other hand, the development process needs space for dynamic changes: According to experience product and project requirements change during large projects [17]. Therefore, all relevant achievements have to be fixed within the Target Hierarchy as well as necessary degrees of freedom. Especially the lower level of objectives has to be configured dynamically. Furthermore, changes require a continuous management process to keep the Value System up-to-date over the course of the project.

Transparency

The missing transparency regarding project targets and customer values is a frequent cause for wrong decisions and iterations. The Value System is a suitable method to offer the necessary transparency during the whole development process – specifically adapted to the needs of every group of stakeholder. The arrangement logic of the objective hierarchy allows the illustration of different perspectives, to offer all groups of stakeholders an understandable, actual and simple picture of the relevant objectives.

As the survey has shown, another success factor of development projects is a strong and engaging project manager. The Value System offers every project manager a good and clear negotiation instrument. Analogue to a contract, all responsible representatives of the stakeholders have to agree and to declare their commitment at the beginning. Hence the Value System is a mandatory "document" to which can be referred later on.

Further more the Value System includes a consequent documentation of targets and values regarding various projects. This enables future project managers to view and learn effectively from older, similar projects.

The Hilti AG[8] is a successful example for a continuous interpretation of a Value System regarding high product value. The complete business model of Hilti is based on a transparent definition of the companies target, purpose and values. The corporate culture is based on these values as well: Titled as a "Cultural Journey", the corporate culture is understood as a journey to track target, purpose and values conjointly. The "Champion 3C Strategy" (**C**ustomer, **C**ompetence and **C**oncentration) helps to identify customer needs and to provide matched, innovative solutions with added value.

Hiltis brand values are defined clearly and form all activities in innovation management fundamentally. Three central brand values are the basis of all product definitions:

1. Maximum Performance – Hilti enables efficient work by technological leading equipments and tools. Hilti products convince by outstanding quality, longevity and easy usability. Sophisticated Technology, ergonomic design and best brand quality ensure maximal performance. Because only the best inspires.
2. Service and Partnership – For Hilti, first class service belongs to first class products. Experienced sales consultants and engineers are operating for customers worldwide and make more than 100.000 contacts per day. Hilti's experts support the construction professionals in all questions and at all times. Hilti is next to its customers and provides services that satisfy.
3. Outstanding Developments – Hilti's engineers develop new products with a high expertise for the specific application regularly. Therefore most important are the customers. The customers' operation methods initiate improvements and new developments frequently. Hilti detects solution, which match the customers' needs perfectly. The aim: Enthusiasm of customers with world class innovations.

[8] Hilti provides leading-edge technology to the global construction industry. Hilti products, systems and services offer the construction professional innovative solutions with outstanding added value. (See www.hilti.com)

These brand values are well-known by all employees of the corporation. All innovation and development projects are integrated into the context of these brand values and define the contribution clearly.

An example is the development of the Combi Hammer TE 70: Value Proposition and requirements were derived by the brand values and communicated in the project team. The brand value "maximum performance" was represented by motors with enlarged power, a longer tool life-cycle and fibre-glass reinforced, robust case materials. A new anti-theft protection completed the service regarding the brand value "service and partnership". The Hilti Lifetime service guarantees two years without costs of repairs and a life-long cost limit for repairs. The brand value "outstanding development" was fulfilled by technical innovations like the "Active Torque Control ATC" or the optimised slipping clutch.

Thus, requirements towards product and process are related to well-known and transparent values. The risk of loosing relation to the aspired product during product design and development is minimised. Every employee who participates within the development process contributes to product requirements that are transparently derived from a corporation-wide valid Value System.

V. CONCLUSION

This paper introduces the Lean Innovation approach and focuses on the Value System - a framework for mapping customer value in a holistic, dynamic and transparent way. This is a powerful method to implement and manage value orientation during the development process. The Value System addresses several critical aspects in product development: A consequent usage of the Value System enforces a clear definition of requirements regarding product and process at the beginning of every project. Thus, it demands involvement and commitment of all stakeholders. In terms of project management the Value System offers dynamic adjustments of changes in project schedules and requirements, a powerful negotiation tool and a possibility to learn from previous projects. Furthermore, the Value System provides transparency of targets, requirements and values specifically for all stakeholders.

Implementing Lean Innovation in a company is more than only the usage of the right methods and tools. To implement Lean Innovation successfully, a rethinking has to be achieved: A culture which identifies needs for change and is prepared for constant change is essential. Systematic methods like the Value System cannot be set up one-time. To implement Lean Innovation on a long term basis, participants have to be involved and get used to a continuing improvement process. Change processes often fail due to a lack of involvement of employees, even if measures are obviously reasonable [16]. Therefore, the implementation of Lean Innovation in general and a Value System in particular has to be adjusted to company-specific conditions.

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