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ANALYSIS OF SUCCESS FACTORS IN LEAN INNOVATION

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1. Introduction

Companies in automotive industry as well as machinery and component manufacturers face increasing complexity and costly product development changes driven by variety in products and production processes [ElMaraghy et al. 2013], [Schuh 2014]. These problems typically derive from failure to capture, utilize and share knowledge throughout the organization [Lorenz et al. 2015]. To master the increasing complexity both effectiveness and efficiency in product development are a crucial aim [Schuh 2014].
Many companies have started to explore the opportunities Lean methods are offering. Since companies cannot afford waste within their product development the adaption of these Lean methods used in production to product development is pursued [Schuh et al. 2016]. However, Lean methods applied in production do not correspond likewise to product development [Schuh 2012]. For example product development requires creative loops within development processes. Otherwise, production is characterized by consecutive processes.
Therefore, this paper investigates to what extent companies apply Lean methods in product development and defines success factors for creating value through these efforts. The effects of these success factors on time, cost and quality in so-called Lean Innovation are analyzed. Moreover, it was analyzed whether several specific success factors or the holistic comprehension of these success factors have an effect on time, cost and quality.

2. Theoretical background

In this chapter Lean Management is described shortly by the five principles of Lean Thinking and the overall goal of Lean Management. Moreover, different approaches for Lean Innovation are presented.

2.1 Lean Management

Lean Management describes the concentration on value creation and the elimination of waste [Womack et al. 2007]. The five principles of Lean Thinking, identify value, map the value stream, create flow, establish pull and seek perfection focuses on the customer and its claim on the product [Schuh 2013]. Lean Management originally derived from the Toyota Production System that has been applied to production since the 1990s with great success. The overall goal of Lean Management is the holistic implementation of Lean within the entire company [Keyte and Locher 2004]. A major contribution to the further diffusion of Lean Management is provided by the adaption of Lean to product development, often referred to as Lean Product Development, Lean Development or Lean Innovation [Hoppmann et al. 2011].

2.2 Approaches for Lean Innovation

In the Literature different authors have, based on the understanding of Lean Thinking, advised approaches for the general application of Lean to the field of product development. Especially Morgen and Liker [2006], who similarly to Womack et al. [2007] analyzed the practices at Toyota and drew their conclusions for product development, have characterized the term of Lean Product Development. They introduced a descriptive model for the product development practice at Toyota, the Lean Product Development System, based on their observations and analysis during their research. This socio-technical system consists of three subsystems which are named process, skilled people and tools & technology as well as 13 subordinated principles. As a result the system counsels either a creation of a levelled product development process flow or the development and enforcement of a Chief Engineer System.

Schuh [2013] chooses a more holistic approach drawing the attention to the entire process of innovation. Aiming for a simultaneous increase in efficiency and effectiveness in the overall process of innovation by adapting Lean principles to R&D management Schuh introduces the Lean Innovation approach. Lean Innovation consists of four phases - Prioritize Clearly, Structure Early, Synchronize Easily and Adapt Securely - and 12 subordinated principles.

In a different approach Ward and Sobek [2014] focus on Lean Product and Process Development. Value focus, entrepreneurial systems designer, set-based concurrent engineering, cadence, flow and pull, and teams of responsible experts define the five core principles of their system for Lean Product Development.

In their extensive literature overview of suggested lean principles Hoppmann et al. [2011] investigate the existing approaches and creates a coherent framework including eleven Lean Product Development systems based on their broad content analyses.

3. Framework for the assessment of success factors in Lean Innovation

Different interpretations of Lean in product development are currently present. Therefore, success factors for Lean Innovation were analyzed. Based on this analysis of existing Lean principles in product development a framework was set up in order to assess all aspects of Lean Innovation. The framework consists of the four dimensions that are crucial for success: the product itself, the development process, leadership and behavior and enablement and tools. The selection of these topics was based on the understanding of how to transfer Lean methods to product development.

The product dimension focuses on enhancing the product´s effectiveness beginning with the strategic positioning. Moreover, transparent customer requirements and systematic identification and planning of the product and its areas of influence have to be determined. The process dimension is assessing the effectiveness of processes for example by evaluating the development of alternative design sets at the beginning of the project. Also whether processes are modularized and standardized with short cycles and iterative feedback loops is considered. The leadership and behavior dimension focuses on proactive handling by decisions based on objective criteria and a mind-set that supports failures as learning opportunities. In order to reduce errors representatives from all affected functions should be integrated and one project manager should be responsible for all aspects of the project´s success. The dimension enablement and tools focuses on knowledge management systems and speed supporting tools like rapid prototyping to increase efficiency. Also a central product-data repository should be used in order to achieve a consistent source of product life cycle data. [Lorenz et al. 2015]

These four dimensions contributing to the implementation of Lean Innovation are listed in Table 1.

Table 1. Four dimensions evaluating the implementation of Lean Innovation

Product	Process
Strategic positioning	Solution-oriented design sets
Holistic and detailed roadmapping	Agile, fast-cycle processes
Transparent product requirements	Flexible workload leveling
Modularized product design	Sequencing and reduced bottlenecks
Optimized product range	

Leadership and Behavior	Enablement and Tools
Proactively handle uncertainty Fact-based, fast-cycle steering Cross-functional collaboration Empowered project manager	Experience- and expertise- driven development Speed-supporting tools Single source of truth

All factors were analyzed within a survey regarding their importance and degree of implementation at the participating companies.

4. Survey on the implementation of Lean Innovation

The following chapter provides an overview on the survey respondents as well as the survey design. In addition, the survey results are presented by evaluating the usage of Lean methods in product development, the success factors in Lean Innovation and the effects of success factors on time, cost and quality.

4.1 Survey design and data

The survey was conducted as a print and web survey and was supplemented by individual interviews of participants. In total 100 valid responses were collected. More detailed information on the respondents is presented in Table 2.

Table 2. Overview of survey respondents

	Category	Number	Percentage
Industries	Automotive OEMs	7	7%
	Automotive suppliers	17	17%
	Machinery manufacturers	32	32%
	Component manufacturers	32	32%
	Others	12	12%
Annual turnover	< €0.5 bn.	34	34%
	€0.5-1 bn.	16	16%
	€1-10 bn.	47	47%
	> €10 bn.	3	3%

To create a generic overview of the effects of Lean Innovation on a company's performance the survey participants included managers and executives from various, globally distributed industrial good industries offering a wide range of products.
Within the survey both qualitative and quantitative data were collected. Each of the 16 factors of the introduced framework was assessed with three types of questions:

- Importance of the factor [Likert scale (1,5)]
- Qualitative assessment of the degree of implementation [Likert scale (1,4)]
- Quantitative assessment of key performance indicators [KPIs]

In the following chapter success factors and performance indicators are investigated. Therefore, the assessment scheme will be illustrated by an example. The qualitative assessment regarding the use of strategic positioning was performed using the following four answer possibilities:

1. General company strategy defined, but not utilized for product development.
2. General company strategy defined and utilized for product development, but no forward-looking process defined to identify/occupy a strategic success position in product development.
3. Forward-looking process defined to identify/occupy a strategic success position in product development, but not always adhered to.
4. Forward-looking process defined to identify/occupy a strategic success position in product development and strictly adhered to.

Each answer possibility represents a different degree of implementation within a manufacturing company. For further analysis key performance indicators were assessed in a quantitative assessment. The assessed KPIs were also used to check the validity of the qualitative assessment results. In total, 22 quantitative KPIs were collected.

4.2 Survey results

The survey results assessing the 16 factors in order to evaluate the degree of implementation in Lean Engineering will be presented in the following chapter. The significant findings of the statistical analysis of the survey data are based on correlations between both qualitative and quantitative questions. The results were analyzed using a two independent samples t-test. It tests whether the means of two normally distributed groups of interval data are equal. Results were identified as significant given a one-sided p-value lower than or equal 5%. The applied test is based on the likely assumption of an equal distribution within each sample and is a recognized method for survey data analyses.

4.2.1 Use of Lean Innovation methods

In the first step, before assessing each of the 16 factors the usage of Lean methods in product development was analyzed within the survey sample. In the questionnaire leading companies in the automotive and engineered-product industry were assessed in the general application of Lean Innovation by the following answer possibilities:

Lean methods in product development …

1. … is not yet considered.
2. … has not yet been implemented, but the project idea exists.
3. … has been implemented in a few projects.
4. … is routinely executed in most projects.
5. … have become the new standard.

On the basis of the response of this question companies were classified as Lean Performers and Lean Followers. 19% of the participating companies are characterized as Lean Performers in case of a routinely executed implementation of Lean Innovation in most projects or if Lean Innovation has become the new standard. The remaining 81% of responses are considered as Lean Followers. The distribution of the usage of Lean methods in product development is shown in Table 3.

Table 3. Usage of lean methods in product development

	Usage of Lean methods in product development				
Answer	1.	2.	3.	4.	5.
Number	21	28	32	15	4
Percentage	21%	28%	32%	15%	4%
	Lean Follower			Lean Performer	

Based on this initial characterization further correlations were analyzed based on the assumption that the application of Lean results in a better performance. Since Lean focuses on the elimination of waste an improvement in terms of time, cost and quality was expected. Therefore, the assessment of relevant performance indicators in time, cost and quality were compared between Lean Performers and Lean Followers. To underline the statistical significanceof the achieved survey results the P-value was used as a reference. The P-value is the probability of finding the result, that the pre-set null hypothesis of a study is true. If the P-value is less than the chosen significance level then the null hypothesis is rejected, i.e. there is a correlation between the examined effect and the implementation of Lean methods. In the course of the survey a significance level of 5% was chosen, meaning that a p-Value lower than or equal to 5% is considered statistically significant.

For the performance indicator time it was tested whether Lean Performers have a higher share of projects completed in time. The results presented in Table 4 strongly support this hypothesis showing a

significant correlation between the application of Lean methods and the completion of projects in time. The sample mean of projects completed in time shows that Lean Performers achieve a value of 71.2% of projects completed in time compared to 48.7% for Lean Followers. With a p-Value of 0.24% the hypothesis shows a strong correlation between performing lean and completing projects in time.

Table 4. Effect of applying lean methods on projects completed in time

	Lean Performers	Lean Followers	Total
Number	19	81	100
Mean	71.2%	48.7%	53.0%
P-value	0.24%		

Evaluating the performance indicator cost by projects completed within budget Lean Performers achieved a sample mean of 78.2% whereas Lean Followers achieved 55.4%. In total, the considered companies completed projects within budget with a sample mean of 53.0%. The hypothesis that Lean Performers have a higher share of projects completed within budget was tested to evaluate the performance indicator cost. This hypothesis is also showing a significant correlation presented in Table 5 considering a one-sided p-value lower than or equal 5% as significant.

Table 5. Effect of applying lean methods on projects completed within budget

	Lean Performers	Lean Followers	Total
Number	19	81	100
Mean	78.2%	55.4%	59.6%
P-value	0.42%		

The last performance indicator quality was tested according to the assessment of projects fulfilling all requirements. Examining the sample mean of companies in projects fulfilling all requirements again Lean Performers are ahead of Lean Followers. It was examined whether Lean Performers have a higher share of projects fulfilling all requirements compared to Lean Followers. This hypothesis could also be verified showing a significant correlation proved by a p-value of 2.09% (Table 6).

Table 6. Effect of applying lean methods on projects fulfilling all requirements

	Lean Performers	Lean Followers	Total
Number	19	81	100
Mean	85%	69.4%	72.3%
P-value	2.09%		

The assessment of projects completed in time, projects completed within budget and projects fulfilling all requirements compared between Lean Performers and Lean Followers shows significant correlations between the application of Lean methods and these performance indicators. In the following section Lean Performers and Lean Followers were analyzed in detail by focusing on different success factors.

4.2.2 Success factors in Lean Innovation

On the basis of the companies self-assessment of the usage of Lean methods in product development the classification in Lean Performer or Lean Follower was described. The following sections of the questionnaire assessed these Lean Performers or Lean Followers whether they are also practitioner or non-practitioner in the 16 factors described in the framework. A company can be classified as

practitioner whether the success factor is mostly or fully implemented otherwise as non-practitioner, irrespective of the classification as Lean Performer or Lean Follower. The results of the qualitative assessment of these 16 factors shown in Figure 1 illustrate that Lean Performers are ahead of Lean Followers in implementing success factors for Lean Innovation. The upper bar represents the Lean Performers and the lower bar the Lean Followers. The left hand side of the zero-percentage-line shows how many companies are non-practitioners in a success factor and the right hand side the practitioners.

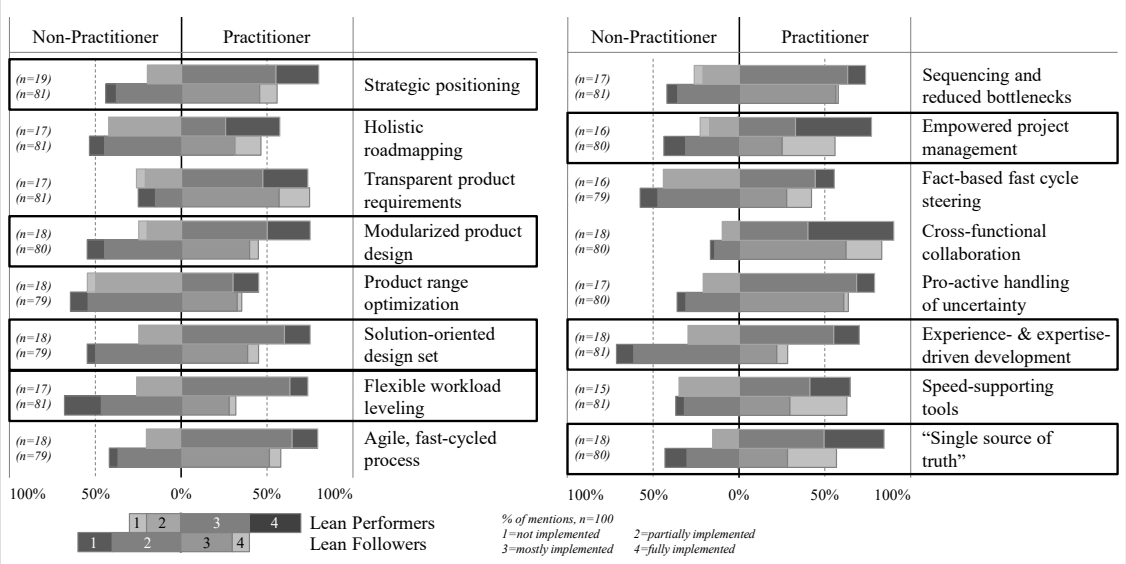

Figure 1. Analysis of the qualitative assessment of success factors and identification of key success factors

As a first step on the basis of the qualitative assessment seven success factors which are demonstrating a distinct difference between Lean Performers and Lean Followers were identified. These seven success factors, so-called key success factors, are named as strategic positioning, modularized product design, solution-oriented design set, flexible workload leveling, empowered project management, experience- & expertise-driven development and "single source of truth".

The strategic positioning assessed the importance of innovation and product development guided by an identified strategic success position. Companies operating as pioneer in this field have already defined a forward-looking process in order to identify a strategic success position in product development. The modularized product design sampled the degree of utilization of modular product systems in new product development. The third key success factor, solution-oriented design sets, characterizes whether a regular parallel development of solution alternatives is implemented in the beginning of the project and followed to systematically reduce alternatives. The flexible workload leveling queries the importance of intelligent product launch and regular capacity review ensuring workload leveling. Empowered project management assesses if there is one strong project manager responsible for the project success in terms of time, budget and quality from concept phase to start-of-production, including personnel resource distribution. The experience- and expertise-driven development describes whether there is a global, easily accessible knowledge management system to ensure maximal re-use of developed solutions in quick paced environment. The last selected key success factor is the "single source of truth" describes whether Product data is centrally stored and managed in a consistent and integrated framework throughout the entire product lifecycle.

4.2.3 Effects of success factors on time, cost and quality

To further investigate the effects of success factors on time, cost and quality in the following chapter, the samples of each success factor were grouped in practitioners and non-practitioners. The subdivision in practitioners and non-practitioners was done on the basis of the qualitative assessment of success factors which assessed the degree of implementation. Companies are classified as practitioners of a

success factor as previously described if the degree of implementation is mostly or fully implemented. Otherwise if companies assessed themselves with a degree of implementation of partially or not implemented they would be classified as non-practitioners. In order to find out whether there is a significant correlation between being a practitioner of the assessed success factor and the performance indicator time, cost or quality the seven key success factors were analyzed. Furthermore, the remaining 9 success factors were analyzed in order to prove whether a differentiation of success factors in practicing Lean Innovation is feasible. Looking at the data shown in Table 7, it can be identified in which success factors practitioners have a significant correlation to assessed performance indicators in projects completed in time, projects completed within budget and projects fulfilling all requirements. The results were analyzed using a two independent samples t-test with one-sided p-values lower than 5% considered as significant. The significant p-values are marked in light grey.

Table 7. Effects on time, cost and quality being practitioner of a key success factor

Type	Success Factor	Projects completed in time	Projects completed within budget	Projects fulfilling all requirements
		P-value		
Key Success Factors	strategic positioning	0,017	0,008	0,236
	modularized product design	0,009	0,332	0,179
	Solution-oriented design set	0,049	0,1193	0,057
	Flexible workload leveling	0,002	0,1558	0,222
	Empowered project management	0,025	0,326	0,341
	Experience- & expertise driven development	0,008	0,033	0,041
	Single source of truth	0,103	0,16964	0,009
Success Factors	Holistic Roadmapping	0,083	0,347	0,358
	Transparent Product Requirement	0,064	0,235	0,282
	Product Range Optimization	0,009	0,033	0,034
	Agile, fast-cycled process	0,002	0,005	0,027
	Sequencing & reduced bottleneck	0,007	0,2068	0,193
	Fact-based fast cycle steering	0,032	0,130	0,366
	cross-functional collaboration	0,315	0,274	0,308
	pro-active handl of uncertainty	0,016	0,023	0,195
	speed-supporting tools	0,185	0,430	0,041

For the identified and previously described seven key success factors the analyzed data supports the hypothesis that these success factors have a significant correlation between the samples of practitioners and non-practitioners as well as projects completed in time. Therefore, it could be demonstrated that being a practitioner has general effects on time for these seven key success factors. The hypothesis that practitioners and non-practitioners have a significant correlation on cost assessed by projects completed within budget and on quality assessed by projects fulfilling all requirements is not strongly supported by the sample.

The further analysis of the 9 remaining success factors shows that also these factors present significant correlations in time, cost and quality. As a result this sample does not support the hypothesis that only being practitioner in the key success factors has significant effect on projects completed in time, projects completed within budget and projects fulfilling all requirements. Moreover, a holistic examination of the success factors is important in order to implement Lean Innovation successfully.

In total, only three success factors, experience- and expertise driven development (one of the classified key success factors), product range optimization and agile, fast-cycled process, were identified which have significant correlations between practitioners and non-practitioners and time, cost and quality.

Examining the columns of Table 6 it can be discovered that the success factors mainly have a significant correlation on projects completed in time. This was proved for 11 of 16 success factors by the sample. A significance regarding cost and quality was only proved by five of 16 success factors.

5. Lean Innovation Stage model for continuous improvement

The study has shown that there is a significant correlation between being a practitioner or a non-practitioner and the effects on time, cost and quality. For more than 50% of the defined success factors the survey revealed a positive effect of being a practitioner evaluated by a p-Value lower than or equal to 5% considered as significant.

In the following, a concept for the implementation of a continuous improvement model in product development will be described in order to develop companies to practitioners in the range of Lean Innovation. This model supports companies in mostly or fully implementing success factors of Lean Innovation.

The implementation of a continuous improvement model requires a company to critically and thoroughly scrutinize their current degree of implementation of each success factor as a precondition to the process of continuous development and improvement. In the course of the evaluation a company assesses its performance according to the scale mentioned above for each single success factor classifying them as practitioners or non-practitioners for each specific success factor. This creates a general overview of the company's level of implementation regarding each of the distinguished success factors.

In a next step it is essential to identify a company's individual key success factors enabling maximal growth of a company's overall performance through Lean Innovation. These key success factors can vary from company to company depending on the given conditions and parameters of the companies operational and economic environment. The survey however shows that certain success factors benefit a company's overall performance concerning time, cost and quality focusing on automotive industry as well as machinery and component manufacturers. These particular success factors have been identified as: strategic positioning, modularized product design, solution-oriented design set, flexible workload leveling, empowered project management and experience- & expertise-driven development.

Based on these data the foundation for the implementation of Lean Innovation along with the process of continuous improvement and development is build up.

This process derives from the Japanese term "Kaizen", which describes all activities striving for a continuous improvement process for the purpose of increasing the companies` overall performance by focusing on human creative potential in problem solving. Therefore, employees, which maintain a high level of qualification and are adaptive as well as receptive to changes, are fundamental for a successful implementation of Lean methods. If employees are not integrated into the change management processes, it will have a strongly negative influence on the confidence in the project and therefore on the success of change. The most important challenge is to implement these Lean methods extensively and comprehensively.

Regarding the implementation of Lean methods, change management plays an important role and therefore the phases in change management have to be considered when implementing continuous improvement by Lean methods. Müller-Stewens describes the process of successful change in five phases [Müller-Stewens and Lechner 2011]. The first phase is characterized by the development of a rough concept for the change project as well as the evaluation of a potential for conflicts and is followed by the kick-off phase which introduces and initiates the process and sensitizes for change. The insertion of changes into the system is subject of the third phase, the roll-out. Finally the last two phases contain the adoption and consolidation to sustain the momentum and to transfer the change into a steady state. The range of these two phases normally comprises several years of considerable efforts.

The frame conditions for motivating and developing employees to accept and adapt to change have to be given in order to achieve a successful implementation of Lean Innovation. The current status of the implementation of Lean methods within the organization can be classified by the Lean Innovation Stage Model (Figure 2). This model is part of the Lean Innovation approach described by Schuh [2013]. Moreover, the model describes how changes in structures and behaviors can increase the effectiveness of Lean Innovation.

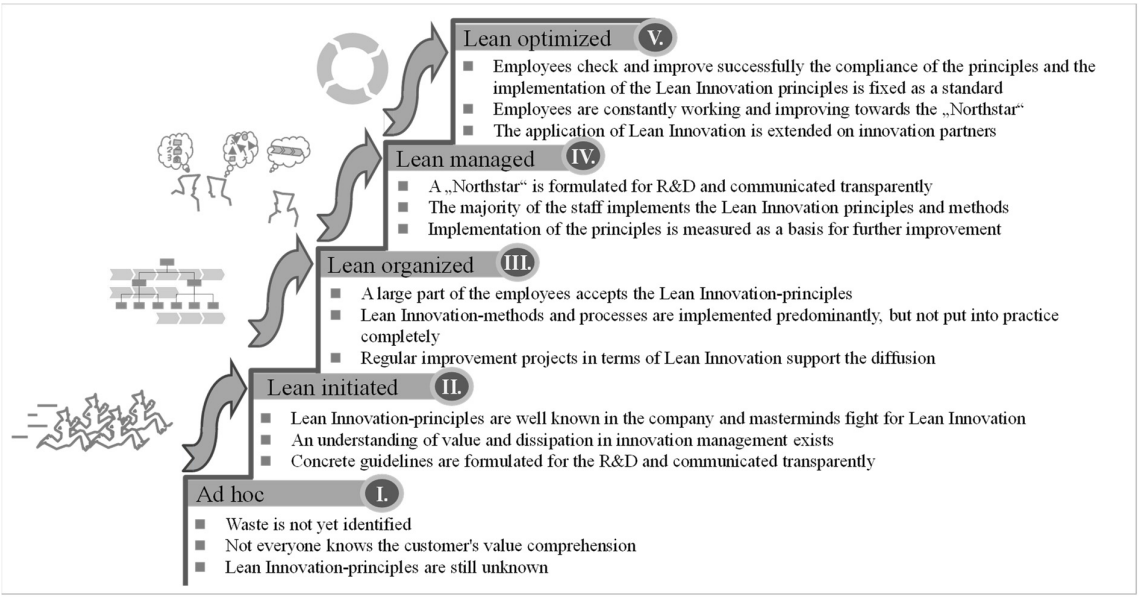

Figure 2. Five stages of the Lean Innovation Stage model

The first stage of the model, Ad hoc, summarizes a not structured engagement in Lean with first initiatives of single employees. It is the beginning of an individual and specific interpretation of Lean Innovation principles as well as the formulation of first approaches.

Once a systematic engagement in Lean Innovation is achieved for the first time the Lean initiated stage is reached. In the context of this stage spheres of activities for a gradual and structured implementation were chosen. Further roles and responsibilities for the Lean transformation process were defined and accompanied by a systematic and purposeful training of employees in Lean methods.

Companies implementing Lean principles with acceptance of the majority of employees can be ranked in the third stage. The so-called Lean organized stage describes companies fulfilling the implementation of the basic methods in Lean in most instances. However, companies do not pursue these methods completely. At this stage it is up to the management to establish the Lean Innovation ideas fully into the daily routine by enforcing them regularly with examples and different cases.

If Lean Innovation is implemented professionally in product development, companies can be classified in the fourth stage called Lean managed. This stage focuses on continuous improvement of the achievements in order to obtain an automatic and bottom-up managed improvement process. Additionally, companies who have reached the Lean managed stage try to reach a defined level of Lean Innovation across company boundaries including suppliers and business partners.

The Lean optimized stage symbolizes the peak of Lean Innovation. Companies reaching this stage have implemented Lean Innovation to perfection. The implementation and continuous improvement of Lean Innovation is anchored in the entire organization. In addition, employees are able to breach guidelines in order to implement own findings.

The Lean Innovation Stage Model describes the continuous improvement progress best as an incremental and advisable approach to develop companies to practitioners of single success factors. It is important to stabilize the achievements within the current stage and by achieving the next stage. Moreover, a company needs to include employees of different departments and hierarchy levels in the implementation of Lean Innovation to consolidate the current stage.

6. Conclusion

The analysis of the presented survey confirmed that companies assessing themselves at the forefront of applying Lean Innovation, so-called Lean Performer, achieve an increasing performance in product development. These companies have a significantly higher share of projects completed in time, within budget and fulfilling all requirements and therefore can achieve competitive advantages. Moreover, the

participating companies were differentiated into so called practitioners and non-practitioners. These practitioners and non-practitioners were examined by grading and dividing them within 16 assessed success factors. Lean Performers especially succeeded in the inclusion of the identified key success factors strategic positioning, modularized product design, solution-oriented design set, flexible workload leveling, empowered project management, experience- and expertise-driven development and "single source of truth". The investigation of each success factor concerning impacts on time, cost and quality indicates that the position at the forefront of a success factor, a so-called practitioner, is mostly significant on projects completed in time. For the evaluation of cost and quality a significance was only indicated for five of 16 success factors. Furthermore, the companies self-assessment into Lean Performers allows no clear conlusion that only the identified key success factors have an significant effect on projects completed in time, within budget and fulfilling all requirements.
To fully utilize the potentials of Lean Innovation an holistic examination of the success factors is important in order to implement Lean Innovation successfully. Therefore, the classification of companies in the Lean Innovation Stage Model and necessary steps for a further development up to a "Lean optimized" enterprise were introduced. This Model support companies in the implementation of success factors to a mostly or fully implemented stage.

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