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Local Manufacturing - Strategic Operationalisation Of Lean Methods In Manufacturing-related Small And Medium-sized Enterprises (SME)

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Abstract

The economic, social and ecological crises of recent years have shown that a change in our understanding of production and value creation is necessary. A more even distribution of production capacities can promote social and economic stability. The ability to produce locally unavailable products or spare parts at short notice (e.g. manufacturing medical-products during the pandemic) avoids CO₂ emissions due to transport and increases local production sovereignty and resilience. This means that production structures need to become more dynamic and responsive for spontaneous demand. Increasing local production at the place of need seems to be a solution that addresses the problems raised. When looking at currently available local production structures, small and medium-sized enterprises can be found at most locations. Unfortunately there is still a lack of productivity compared to industrial production in this enterprises. One form of overarching organisation and corporate culture that is largely established as standard in industry is the Lean Business Model. The introduction of such a strategy offers potentials for increasing the productivity and performance of a company regardless of its size. However, the methods and principles are not consistently applied in small and medium-sized enterprises. In the context of this work, studies were identified that deal with the feasibility of implementing Lean Methods in the manufacturing sector worldwide. The results were bundled into a new data model and subjected to a secondary analysis. The aim is to obtain a complete assessment of all lean implementation methods according to *VDI2870 Holistic Production Systems*. The suitability of the implementability in small and medium-sized enterprises is extended by an evaluation with regard to the target dimensions time, costs and quality. This creates a new possibility for strategic operationalisation of the Lean Methods for manufacturing companies.

Keywords

Lean Thinking; Local Manufacturing; Lean-Methods; Operational Strategy; Small and medium sized Enterprises

1. Introduction

Our way of life, politics and economy have been affected by numerous crises in recent years [1]. The CO₂ concentration in the atmosphere worldwide has increased by about 44 percent in the last 150 years and industrialisation has made a major contribution [2]. Manufacturing companies bear a great responsibility in overcoming these Problems [3]. Furthermore, the Covid 19 pandemic has exposed the vulnerability of our global linear supply chains [4,5]. The war in Ukraine also demonstrates the challenge that manufacturing companies face in times of crisis. In Ukraine, for example, a massive shift of companies from eastern to western Ukraine is currently being observed. These often small and medium-sized enterprises (SMEs) face

the challenge of reorganising all relevant means of production in a new environment within a very short time. The multiple crises call for a structured response. A more distributed and local form of manufacturing close by the point of need could help to change the production sector [6] by making it more resilient, helping to achieve ambitious climate targets and creating an appropriate degree of production sovereignty. Today local production is represented by SMEs in a high degree [7]. In addition to the industrially driven value creation in large companies, SMEs have a major impact on the production sector, with about 99.4% of all private sector companies belonging to this category in 2018 in Germany [8]. A similar distribution can be found in all major economies [7,9]. The integration of local SMEs into dynamic manufacturing networks might be a way to promote production at the place of need. An essential aspect of economic efficiency for manufacturing companies is their own productivity. The Lean Business Model an ubiquitous standard of highly productive and industrial manufacturing according to current estimates, is still not being applied to the necessary extent in SMEs [10]. The orientation of the approach is still industrial. In Germany, for example, the understanding of the Lean Business Model for manufacturing companies is represented by a uniform standard. This is a guideline of the *Verein Deutscher Ingenieure (VDI)* called *VDI2870 Holistic Production Systems* [12,11]. Within the framework of *VDI2870*, 35 Lean Methods are assigned to the seven principles of lean. [13, 10, 14]

A common international understanding of the Lean Business Model exists only to some extent; the international studies consulted later show this clearly. Individual principles are missing or others appear, and the catalogue of Lean Methods also varies in length [7]. The principles and methods listed in *VDI2870* are therefore not part of a general understanding of lean [15]. Improvement potentials and possibilities for increasing productivity through the implementation and integration of the Lean Business Model have been proven in numerous case studies [16].

2. Objective of Research and Current Status

2.1 Objective of Research

SMEs are part of the economic success in many countries. Increasing productivity could be achieved by implementing a Lean Business Model. At the operational level, this requires an understanding of Lean Methods. For this, every company needs a specific strategy to fulfil their needs. [14, 17]

SMEs usually do not have the necessary resources (time, personnel and costs) to deal with the possibilities and potentials of a Lean Business Model as intensively as they would like and to design a strategy that is suitable for the company [18]. This problem is to be countered by developing an overarching picture of the feasibility of implementing the 35 Lean Methods in SMEs in the manufacturing sector. By combining and systematising results from several studies, a new data basis is created for conducting a secondary analysis. Only companies in the manufacturing sector are included in the analysis. The results of this overarching analysis on the measure of feasibility will be expanded to include an aspect of strategic operationalisation. In *VDI2870 'Holistic Production Systems'* the methods are sorted according to design principles, the syntax presented here leaves this sorting and follows a problem-oriented approach in the form of the division into the three target dimensions according to McKinsey: costs, quality and time. [19,11]. The research question answered in this paper is,

which Lean Methods are particularly suitable for strategic operationalisation in the target variables of costs, quality and time when implemented in small and medium-sized enterprises (SMEs)?

The aim is therefore to create opportunities for the better implementation of Lean Methods in SMEs, based on an international and transparent data basis. At the same time, an overview for easier method selection with regard to a chosen target dimension is to be made possible.

2.2 Current Status

This literature study was preceded by an initial research on the topic of lean method implementation in SMEs, which showed that there is no internationally uniform understanding of the adaptation of Lean Methods in SMEs, while on the other hand there is a broad understanding of the industrial lean process. In particular, some older scientific contributions do not adapt the Lean-Method Model introduced in *ISO 9000 Series Quality Management Principles* and *ISO 9001:2015 Quality Management Systems – Requirements* [20], [17]. The first surveys on this topic can already be found before the turn of the millennium. In 1998, for example, Voss et. al. described for the first time in "Made in Europe: Small Companies" methods or principles which, from today's perspective, can be assigned to the international understanding of the Lean Business Model. With the *Areas of Practice* mentioned there, there are two similarities to the Lean Methods defined according to *VDI2870*. In his work SMEs from all sectors were considered [21]. Another overview is provided by Kennedy et. al. 2003 in "*A comparison of manufacturing technology adoption in SMEs and large companies*", where 19 production-relevant variables are listed, three of which clearly coincide with Lean Methods. These are analysed in terms of implementation in SMEs in the manufacturing sector [22]. Matt et. al. published a comprehensive overview of the implementation of lean production methods in 2013, which includes 14 of the 35 Lean Methods according to *VDI2870* and 19 other lean production methods some of which are now considered part of the seven basic lean principles or are assigned to other concepts of production organisation. Some of the Studies do not have a transparent presentation of the data or there was no differentiation with regard to the production sector. [17]

3. Introducing Lean Methods for Strategic Operationalisation

3.1 Method Catalogue of Lean Principles According to Guideline VDI2870

The Lean Business Model is a business ideology that is a pervasive standard of the global corporate world involved in manufacturing [23,24]. It was designed to avoid waste of resources through organisational means and changes in Toyota's Production System (TPS). At the same time, increasing quality was a primary goal of this management orientation [25]. Today, there is still international ambiguity regarding the methodological conceptualisation in relation to the Lean Business Model and a generally accepted definition. While there is consensus on the fundamentals, opinions become more fragmented the closer one gets to practical implementation. In the following, the understanding of the Lean Business Model in terms of Holistic Production Systems (GPS) according to *VDI2870* will be taken as a basis [12,11]. The aim is to organise and structure production to exclude activities that do not add value. Instead, processes are aligned with the needs of the customers.

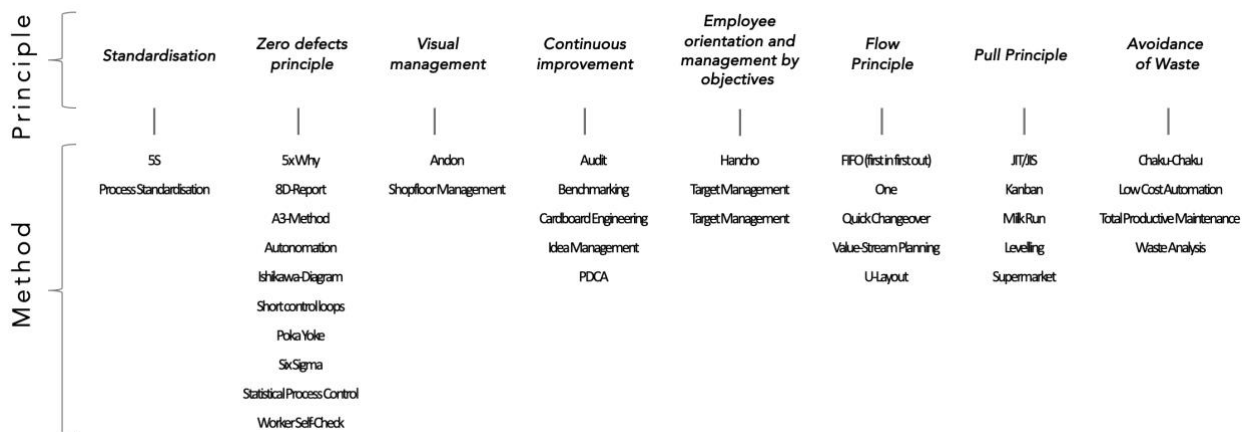


Figure 1: Lean Methods Assigned to the Lean Flow Principles.

According to *VDI2870*, the Lean Methods of GPS are subdivided as shown in Figure 1. The diagram shows the seven basic lean flow principles according to *VDI2870*, which are defined as Standardisation, Zero Defects Principle, Visual Management, Continuous Improvement, Employee Orientation and Management by Objectives, Flow Principle, Pull Principle and Avoidance of Waste. A total of 35 different Lean Methods are assigned to these lean principles. In the following, the extent to which these have already been implemented in SMEs is examined.

3.2 Classification of small and medium-sized Enterprises (SME) and Producing Enterprises

The secondary analysis presented later deals with the implementation of Lean Methods in SMEs in the manufacturing sector. These will first be defined, using the classification of enterprise categories introduced by EU Recommendation 2003/361/EC. Micro, small and medium-sized enterprises are defined as all enterprises that employ no more than 249 persons, have an annual turnover of less than 50 million euros or an annual balance sheet total of no more than 43 million euros. Furthermore, no more than 25 % of the voting rights in the company may be held by a government agency or a public corporation. At the same time, only companies from the manufacturing sector should be considered. The term manufacturing industry comes from the German Classification of Economic Activities (WZ) and is a generic term for five economic sectors. Subordinate to the manufacturing industry is the processing industry (classification WZ08-C). All industrial enterprises that convert raw materials and/or intermediate products are assigned to the manufacturing industry. This includes the manufacture of basic and production goods as well as capital goods. The manufacturing sector can be equated with industry or with the industrial sector. The manufacturing sector is characterised by machine production, a structured division of work steps and production in production facilities. For the analysis, the study data primarily (>90%) used was collected from SMEs that can be assigned to the manufacturing sector. [8]

4. Methodical Approach

4.1 Literature Review

The literature search was conducted with the help of the portal *Web of Science*, the search portal *Scopus* and the *Online Library of the Helmut Schmidt University*. First, the *Scopus* database was searched for all publications with the keyword "Lean" in the title that were published after 2011. By limiting the year, the necessary topicality can be guaranteed. As a result of the search, 18,026 titles were identified. The search results were therefore narrowed down by including the terms "manufacturing or management or thinking" and the number of titles was reduced to 3628. In a next step, the search was restricted further by adding the terms "small or medium or enterprise or enterprises or SME". With the search performed in this way at *Scopus*, 142 sources were finally identified. In the next step the same search was carried out in *Web of Science*. The adjusted literature corpus from the two searches resulted in a total of 155 titles, meaning 30 titles were listed twice. Three further sources were identified via the web search of the library of Helmut Schmidt University, so that a total of 158 could be considered. The publications were then pre-screened. Based on the titles and abstracts, the literature corpus was reduced to a pre-selection of 33 publications for further consideration. These were analysed in more detail (reading abstracts, methodology, scope, etc.) to identify all studies that deal with the implementation of Lean Methods. In the same process, the trustworthiness of the reports was checked on the basis of the authors and the publisher. All sources of the pre-selection could be viewed in full text. The list of sources and the pre-selection can be found at the following link DOI: 10.17632/hhsf7hgmck.1.

In the next step, the sources were classified and systematised with regard to the characteristics of the data used. In the corpus of literature defined during the literature search, nine scientific studies were identified that conducted data surveys among small and medium-sized enterprises (SMEs) in the manufacturing sector

in various countries. A selection of the studies shown in Table 1 was used for the secondary analysis [23,26]. Some studies mainly consider lean principles in their surveys of companies, while the authors only partially address the methods listed in VDI 2870 [24,27]. In order to facilitate the development of customised operationalisation strategies, only studies that deal in detail with the implementation of methods and distinguish between at least ten different methods are considered.

Table 1: Overview of the Relevant Studies.

RELATED STUDIES	AUTHOR	MENTIONED METHODS	CONSIDERED SME'S	REFERENCE
Lean Implementation in SME in Less Developed Countries - Some Empirical Evidences From North Africa	Belhadi (2017)	18 (51%)	84	[28]
Lean manufacturing in Brazilian small and medium enterprises-implementation and effect on performance	Godhino (2016)	<10	N/A	[29]
Validity and reliability of lean enterprise frameworks in Indian manufacturing industry	Jasti (2014)	<10	N/A	[30]
Application of lean thinking in supply chain management by the small and medium sized manufacturers in China - A status survey	Lau (2013)	<10	N/A	[31]
Enterprises Characteristics And Lean Outcome - An Empirical Evidence From Vietnam Manufacturing Enterprises	Nguyen (2022)	15 (43%)	6	[32]
Lean implementation in small- and medium-sized enterprises An empirical study of Indian manufactures	Sahoo (2017)	12 (34%)	24	[33]
A review on issues of lean manufacturing implementation by small and medium enterprises	Shirmali (2017)	<10	N/A	[34]
Implementation of Lean Six Sigma in small- and medium-sized manufacturing enterprises in the Netherlands	Timans (2011)	11 (31%)	51	[35]

4.1 Secondary Analysis: Data Structure and Evaluation Criteria

The literature research shows that there is already some work on the degree of implementation of the Lean Business Model in SMEs, by combining the results of the studies an improved data basis can be created. The greatest challenge here is the harmonisation of data. The evaluation criteria of the individual studies were analysed and systematically combined by defining a Likert scale. For this rating, scale values from one to five were used. A rating of "one" means that only an insufficient implementation of the method under consideration can be determined and less than 20% of the companies have engaged with the method. A rating of five on the Likert scale means that an implementation of the method could be determined across the board in more than 80% of the companies considered and that it is particularly suitable for use in SMEs. The existing evaluations of the individual studies were successfully synchronised through our processing.

Figure 2 shows the distribution of companies in different major regions of the world that were considered. In total, 165 companies from the three regions mentioned could be considered in the following assessment. During the processing of the studies, it became apparent that there are different designations for the individual methods within the studies; this was taken into account in the synchronisation of the data. The distribution graph on the left in Figure 2 shows how many of the companies of the total number of 165 were surveyed in the evaluation of a method. A closer look at the map shows that there are no recent studies on the implementation of Lean Methods in the major business locations of the USA and China. Existing studies either do not distinguish between manufacturing and other types of companies or they are outdated. There was a research peak on the topic of lean in the 1990s; in the course of digitalisation and concepts such as Industry 4.0, it may be interesting to gain a current overview here.

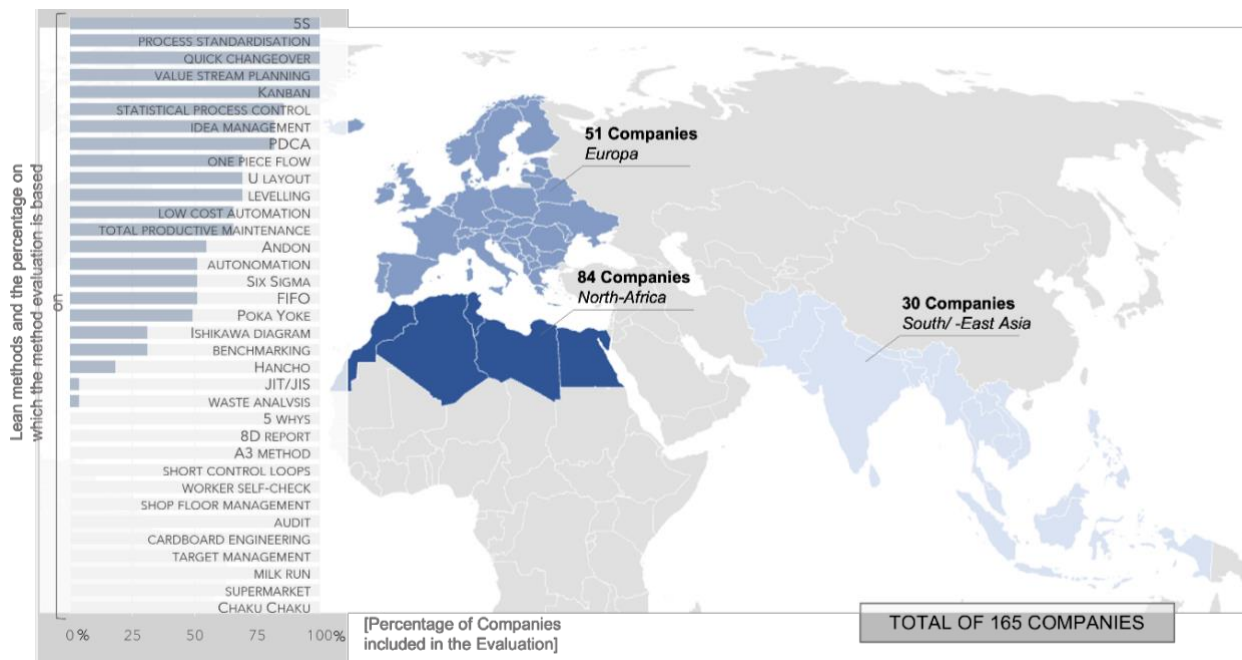


Figure 2: Distribution of Studies and Share of Companies Surveyed.

5. OUTCOME OF THE ANALYSIS

5.1 Presentation of the Results

By combining the various studies on the implementation of Lean Methods in SMEs, it was possible to improve the validity of a methods implementability in a first step. While only one study took more than 50% of the Lean Methods into account, when looking at the studies individually, a statement on 66% of the methods can be made by combining the data. In addition, the significance was improved by cumulating the number of companies surveyed on which the individual methods rating is based on.

Table 2: Lean-methods and their evaluation in terms of suitability and target variables.

		Lean Methods and Principles according to VDI2870																																		
Lean Principle		STD	ZDP	ZDP	ZDP	VM	CI	ZDP	CI	CI	AW	FP	OM	CI	ZDP	PP	PP	PP	AW	PP	FP	CI	ZDP	STD	FP	VM	ZDP	ZDP	ZDP	PP	OM	AW	FP	FP	AW	ZDP
Lean Method		5S	5x Why	8D report	A3 method	Andon	Audit	Automation	Benchmarking	Cardboard Engineering	Chaku-Chaku	FIFO (first in first out)	Hancho	Idea management	Ishikawa diagram	JIT/JIS (just in time/)	Kanban	Leveling	Low Cost Automation	Milk Run	One Piece Flow	PDCA	Poka Yoke	Process Standardisation	Quick Changeover	Shopfloor management	Short control loops	Six Sigma	Statistical Process Control	Supermarket	Target Management	Total Prod. Maintenance	U-Layout	Value Stream Planning	Waste Analysis	Worker Self-Check
Overall Suitability		4				4		4	3			5	2	4	3	3	3	2	3		2	3	1	3	3			2	3			2	2	3	5	
Quality		8				11		12	6			9	7	12	6	3	3	2	3		7	7	4	9	3			5	9			2	2	3	5	
Cost		4				4		8	6			5	4	12	6	5	9	2	9		7	7	2	6	7			3	3			7	2	7	15	
Time		8				7		8	6			5	4	12	6	5	9	4	6		7	7	2	9	10			3	3			2	7	10	10	
		Continuous improvement = CI							Standardisation = STD							Visual management = VM							Flow Principle = FP													
		Employee orientation and management by objectives = OM							Zero defects principle = ZDP							Avoidance of Waste = AW							Pull Principle = PP													

Table 2 shows the values assigned to the methods in the column *Overall Suitability*. The general evaluation was combined with an assessment of each method on the three target variables of cost, time and quality. The evaluation of the effect of the individual methods on the target variables was carried out in analogy to *VDI2879*. By combining the two evaluation systems, it was possible to define an assessment for each method on a scale of 1-15, which allows a direct assessment of whether a method is suitable for achieving the selected objective when used in SMEs. Assessments with a very high value were additionally coloured darker in the table. For example, the method *Waste-Analysis* was evaluated in all studies with a high degree of implementability combined with its effect on the *Reduction of Costs* the total rating get the maximum number of 15. The introduction of an Idea Management is considered a suitable method for positively influencing all three target dimensions to a high degree according to *VDI2879*. In accordance with this, our evaluation found a high degree of implementation of the method, which indicates that the introduction of an *Idea Management* in SMEs is possible to a higher degree, despite known limitations, such as fewer specialist departments, more diffuse individual employee workload, lack of resources. In general, the table shows the scores of all methods for achieving the optimisation of each target variable. In the next step, therefore, a possibility for the strategic operationalisation of the methods in the three target variables will be presented.

5.2 Strategic Operationalisation Regarding Three Target Factors: Quality, Time and Cost

To better align production in one of the target variables, a new rating for each Lean Method was introduced before. Normally the methods are combined by focussing the Lean-Principles. The introduced overview now gives the opportunity to expand the approach of designing a lean Strategy for a producing SME. In the next step, a possibility for the strategic operationalisation of the methods in the three target variables is presented. For this purpose, the methods and their evaluation have been visualised in Figure 3. The Lean Methods were presented in a Web-Diagram. The Diagram has two coloured areas, in each half of the Lean-Methods are listed. The separation occurs at a value of 8.

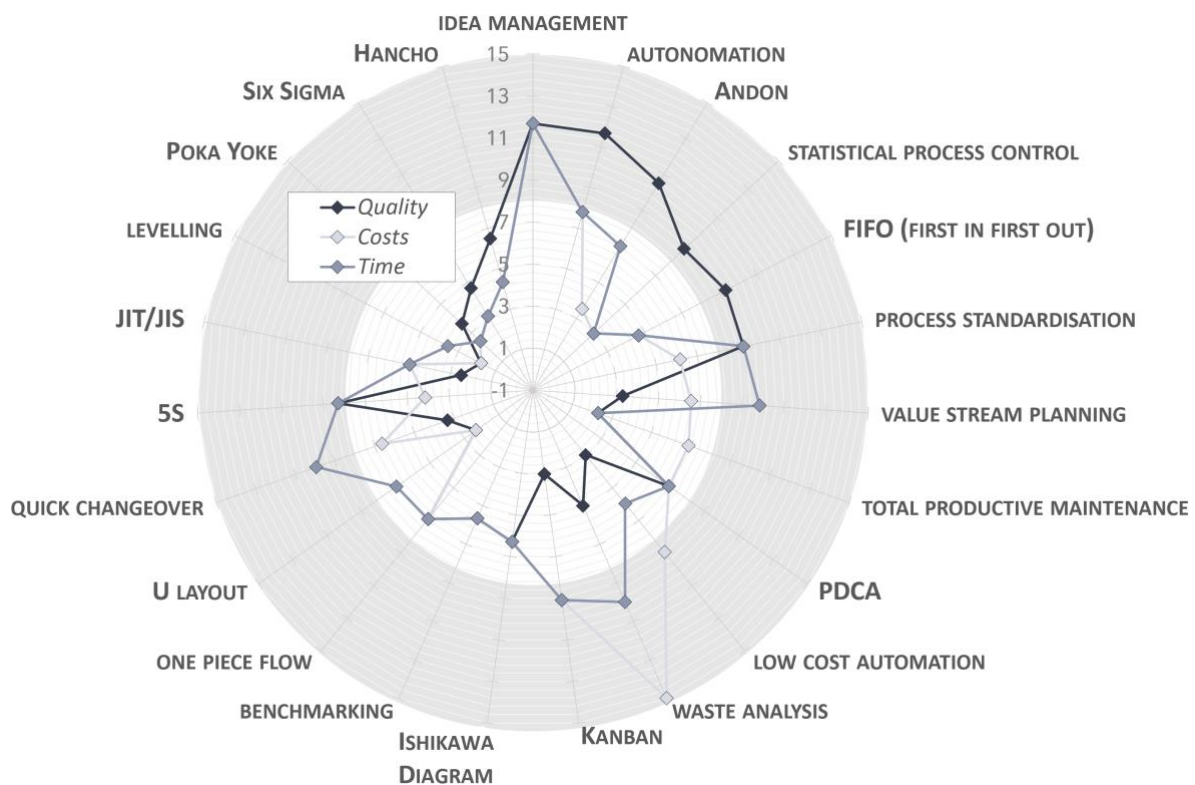


Figure 3: Illustration of the Lean Methods in the Target Variables of Time, Quality and Costs.

In order to achieve optimisation of the target variable *Time*, the Lean Methods of *Waste Analysis*, *Idea Management*, *Process Standardisation*, *Kanban*, *Quick Changeover* and *Value Stream Planning* should be focused on. It should be taken into account that some of the Methods are usually introduced together with other Methods of the Lean principle as you see in Figure 1 - here it should be critically questioned in each case, whether or not other additional Lean Methods should be considered as well.

The sustainable orientation of the organisation of production towards the target quantity of *Quality* can be positively influenced to a particularly high degree by taking into account the Lean Methods of *Idea Management*, *Autonomation*, *Andon*, *Statistical Process Control*, *5S* and *FIFO*. Here, too, the introduction of individual Lean principles, such as *Standardisation*, would usually be accompanied by a general *Process Standardisation* in addition to the *5S* method.

The introduction of lean manufacturing, optimised for the target parameter of *Costs*, should place particular emphasis on the methods of *Waste Analysis* and *Low Cost Automation* for SMEs. In addition, the introduction of a *Kanban* system and *Idea Management* could be suitable for achieving the goals. Again, some Lean methods should be introduced in combination with other methods of the corresponding Lean principle. When introducing the pull principle, methods such as a supermarket are also suitable for optimising one's own production.

6. Discussion and Future Research

The distribution of the companies involved shows that there is a deficit of modern and up-to-date studies on the implementation of Lean at the operationalisation level in SME; there is a need for further research action here. It is also critical to see that economically strong regions of the world are not represented by corresponding studies. With regard to the data itself, it must be critically assessed that data could not be found for all methods. In the case of methods for which no data could be found, this does not mean that they cannot be of use to SMEs, it simply means that none of the companies surveyed have tried it yet. By combining the studies, it was possible to generate a more comprehensive statement on the various methods. The evaluation is based on the fact, that the suitability of Lean Methods can be assessed at the degree of implementation, which leaves out the fact that some methods may not be promoted strongly enough or that there are gaps in knowledge. In addition, the synchronisation of the data was done in some cases by deriving a suitable Likert scale based on the number of mentions found in the survey, so minor deviations must be assumed. Nevertheless, with the results of the secondary analysis the use of Lean Methods for SMEs is getting easier. The new evaluation was combined with an available evaluation to assess the suitability of a method for improving a production system in the target variables of time, costs and quality. This results in the possibility of targeted operationalisation of Lean Methods in the target variables mentioned. Through the integration of multiple investigations regarding the integration of lean methodologies in SMEs, an initial enhancement in validity was achieved. While individual studies considered only a fraction, the new data allows for conclusions to be drawn on approximately 66% of the methods. Furthermore the evaluation of individual methods could be placed on a better evaluation basis (increased number of surveyed companies) by combining the studies. The distribution of the companies involved shows that there is a deficit of modern and up-to-date studies on the implementation of Lean at the operationalisation level. By extending the analysis to other regions and by specifying the approach to synchronising the data even better results could be achieved. It could be interesting to add further data in the future, if necessary, to compare the data with studies from before 2011 or to compare the data according to the OECD economic ranking.

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Biography

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