

Wrocław University of Economics
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Ph.D. thesis summary

Lean Manufacturing Maturity Model

by

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Table of content

1. INTRODUCTION.....	3
2. THE PROBLEM STATEMENT, RESEARCH OBJECTIVES	6
3. RESEARCH METHOD	7
4. RESULTS AND CONCLUSIONS	10

1. Introduction

The first and second decade of the 21st century is a period characterized by dynamic changes in the conditions of functioning of production companies. Continuous technological progress, globalization of markets, IT revolution and increased pressure on environmental protection are just examples of challenges, which today's organizations are facing. In addition, there is a significant increase in the importance of clients, which, thanks to easier access to information, become even more demanding. The multitude and variability of all mentioned above factors causes, that the risk, uncertainty and level of complexity in running a business are higher than ever before.

Changes in the external environment lead to internal changes in the way the manufacturing companies operate. Companies wanting to compete in such dynamic conditions must ensure, that their operational solutions provide flexible production and rapid response to changing consumer expectations. For many organizations, meeting these requirements go along with necessity to implement new management models and concepts.

One of the most popular concepts of managing production companies, which serves as a response to the challenges of the modern market, is Lean Manufacturing. Its principles emphasize operational flexibility, focus on providing value to the customer and ensure continuous improvement of organizations. Therefore, it addresses all current trends occurring in the organization's environment. Thanks to this, Lean Manufacturing is currently used by companies from around the world, constituting a modern paradigm of managing production companies.

The Lean Manufacturing concept is now well established in the theory of management, where its first publications and researches took place at the end of the 1980s. Despite passing of over 30 years, this concept is still enjoying the growing popularity among scientists and practitioners around the world. Studies conducted by D. Samuel, P. Found and S. J. Williams indicate an increasing number of Lean publications in the years 1987 - 2013 (Figure 1).

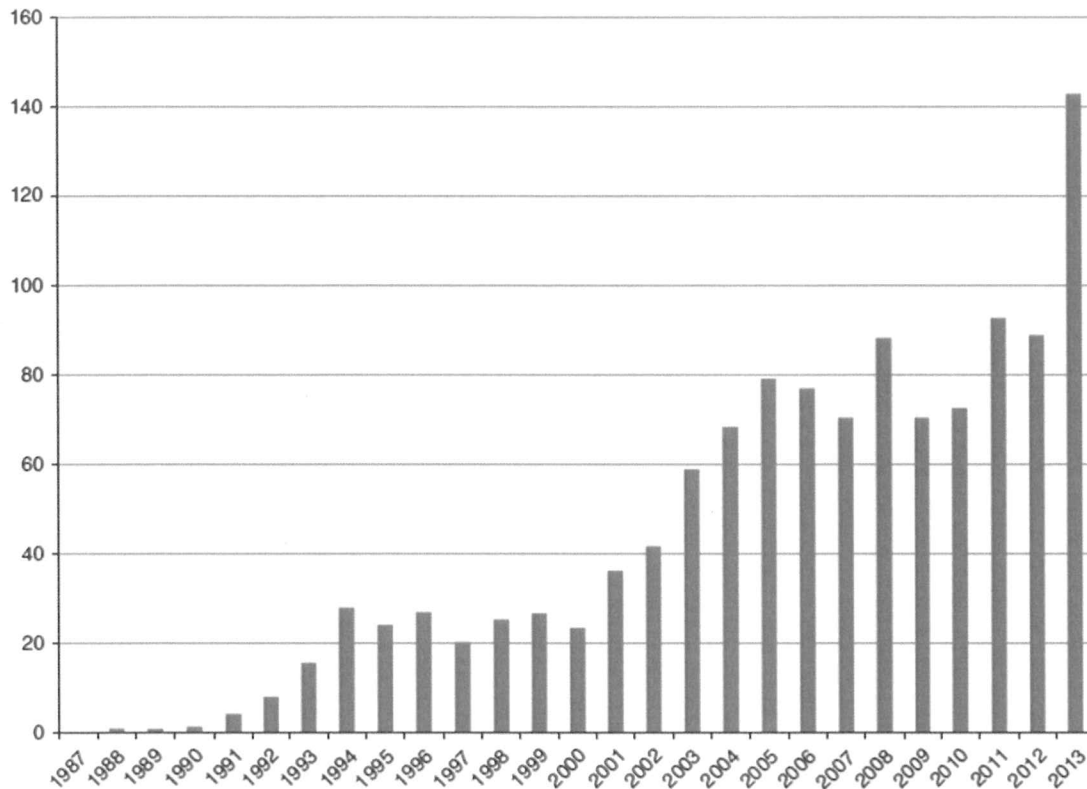


Figure 1. Lean related publications in years 1987-2013

Source: (Samuel, Found, Williams; 2015; s. 1391)

To check whether the popularity of lean production was also maintained in 2014-2018, the author conducted an analysis using the Google Trends tool. It allows to get information about the quantity, origin and timing of chosen queries in the Google search engine. The achieved results show, that the frequency of Lean Manufacturing queries increases yearly, which indicates the continued popularity of this concept (Figure 2).

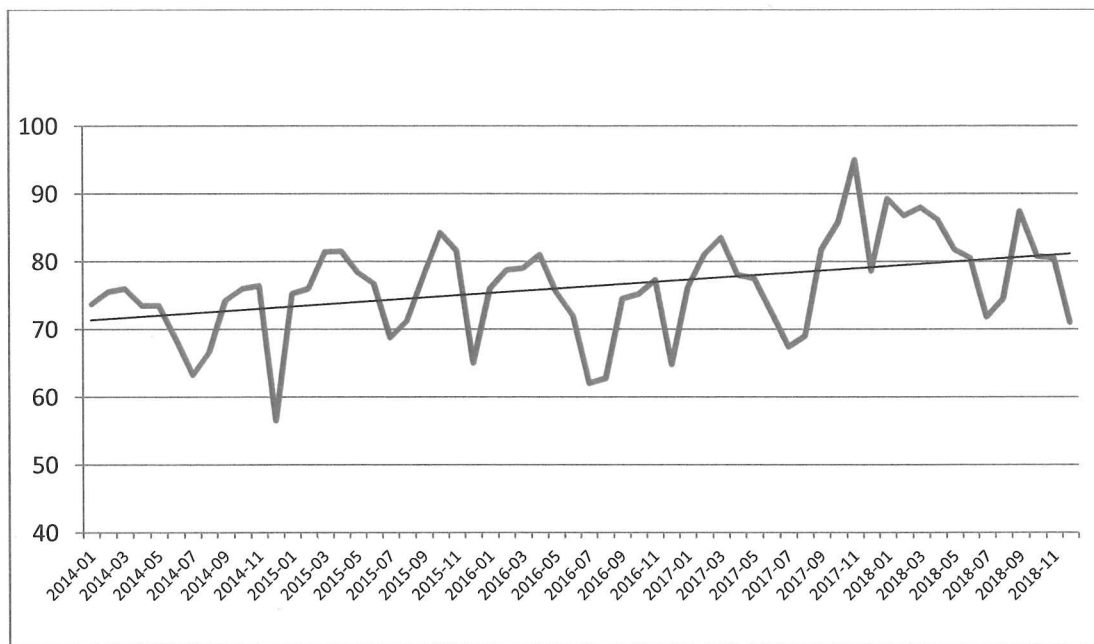


Figure 2. Frequency of Lean Manufacturing queries in Google search in 2014-2018

Source: self-made study

Despite the growing interest in the subject of Lean, it turns out, that the successful implementation of its principles is still a big challenge for many organizations. Researches on the effectiveness of Lean Manufacturing implementation in manufacturing companies present the following results:

- 50% of companies in North America do not achieve goals set before implementation (Richter; 2011),
- 2% of companies in the US achieve their goals fully, 24% achieve their goals partly (Pay, 2008),
- 10% of companies in the United Kingdom fully meet the objectives related to the implementation of Lean Manufacturing (Bhasin; 2008).

These studies indicate, that the vast majority of companies using the Lean Manufacturing are not able to fully achieve the business goals set before implementation. This fact allows to draw conclusions, that although theoretical knowledge in the field of lean production is already extensive, there is still a need for researching solutions supporting its effective implementation.

This need is visible not only from the business perspective, but also from the scientific one. J. Bhamu and K. S. Sangwan, who conducted an analysis of over 200 works on Lean Manufacturing (2014), identified the following research areas, which require further exploration:

1. application of Lean Manufacturing in small and medium-sized enterprises,
2. use of Lean in logistics and supply chain,
3. no model / process supporting the implementation of Lean Manufacturing,
4. definition of cultural and organizational conditions for the implementation of Lean Manufacturing,
5. unification of Lean Manufacturing tools, methods and techniques,
6. integration of Lean Manufacturing with other production systems and philosophies,
7. development of homogenous Lean Manufacturing measurement metrics.

2. The problem statement, research objectives

Taking into consideration the above-mentioned business challenges and identified gaps in the existing literature, in particular the points 3, 5 and 7 indicated by Bhamu and Sangwan, the research problem of this dissertation was defined. It is **the lack of an systematic and comprehensive Lean Manufacturing model, which supports assessment and implementation of this concept in manufacturing companies.**

In connection to such stated research problem, the research objective is to **develop a Lean Manufacturing maturity model, which will ensure systematic and comprehensive implementation and assessment of this concept in manufacturing companies.**

Mentioned above maturity models, enjoy growing popularity in the business environment, allowing the companies to standardize the implementation process of the chosen field, measure the progress made and identify the necessary steps to take. Thus, the Lean Manufacturing maturity model will provide a valuable response to identified research and business needs.

Achieving of the research goal is supported by the following research questions:

1. What structure of the Lean Manufacturing maturity model provides a comprehensive and systematic measurement of the implementation of this concept in manufacturing companies?
2. What procedure for conducting the Lean Manufacturing maturity assessment supports the implementation of this concept in manufacturing companies?

The above stated questions clarify the purpose of the work, providing a detailed description of the model's structure and the method of use. The answer to the first question allows to precisely determine the components and subcomponents of the instrument, organizing lean production methods and techniques in a single, coherent approach. The answer to the second question will aim at designing an assessment process, which enables effective application of the developed model in business environment.

3. Research method

The research method used in the work is based on the maturity models development process proposed by T. de Bruin, M. Rosemann, R. Freeze and U. Kulkarin (2005). It has also been supplemented with an additional step regarding the comprehensive literature studies, which derives from method suggested by J. Becker, R. Knackstedt and J. Poppelbub (2009). Finally, the research method consists of four steps described below.

3.1 Analysis of existing Lean Manufacturing maturity models

The first step in the process of designing the maturity model was to analyze the structure of existing Lean Manufacturing models. In order to do so, a list of twenty six instruments, which were identified as a result of a systematic literature review, was used. The carried out analysis was aimed at answering the two questions:

- What are the desirable characteristics of Lean Manufacturing maturity models?
- What are the current gaps in knowledge about Lean Manufacturing maturity models?

In order to answer the above questions, each of the identified instruments has been thoroughly analyzed in terms of the following criteria:

- Evaluated characteristics, indicating which aspects of Lean Manufacturing are subject to measurement in existing models.

- Measurement methods, indicating the method of evaluation and quantification of results.
- The field of application, specifying whether existing models are applied in practice or research.
- Method of validation, indicating whether and how individual models have been tested.

The first step of the research method enabled a synthetic summary of the current state of knowledge in the field of the Lean Manufacturing maturity models, indicating their desirable characteristics and identifying research and practical gaps. The results obtained were the justification for the need to develop the original, Comprehensive Lean Manufacturing Maturity Model, which will bring value added to the existing state of art.

3.2 Designing structure of the maturity model

The second stage of the research method was to design the structure of the Comprehensive Lean Manufacturing Maturity Model. In order to address the identified research and practical gaps, as the first step, it was necessary to determine the scope of the model. It concerned definition of the following issues:

- Concentration of the model - making a decision whether the model will be general - regarding the functioning of the organization in a holistic approach, or domain-based - developed for a specific field, such as project or process management.

- Recipients and stakeholders of the model - defining the group of people for whom the maturity model is developed. It is also a decision about people who should be involved in the implementation and application of the model.

- Model application method - deciding whether the model should be used for self-assessment, external evaluation or evaluation by the practitioner.

- Motivation to use the model - determining what added value will be created using the model.

The next phase of designing the maturity model was to determine its structure and to fill it with substantive knowledge. To do so, the broad literature review was used. As the outcome of this method, the main framework of the instrument has been developed. The process of designing the maturity model structure consisted of four steps:

1. Defining of basic categories ensuring comprehensive Lean Manufacturing maturity assessment.

Defining the Lean Manufacturing criteria describing each category.

Defining the way of measuring criteria (determining the scale and number of maturity levels).

Describe each of the criteria using specific levels of maturity.

The Lean Manufacturing model obtained as a result of the above-mentioned steps was the final result of the literature studies, creating the basis for its further empirical testing.

3.3 Empirical testing

The third stage of creating the maturity model was testing in real business conditions. It was aimed at achieving two effects:

1. empirical verification whether the developed Comprehensive Lean Manufacturing Maturity Model has all desirable characteristics, which were defined as a result of the literature review,

2. getting information about the imperfections of the model, which will enable its further improvement.

In order to achieve such goals, a decision was made to use the method of comparative case studies. The designed study was based on conducting the Lean Manufacturing maturity assessment using the developed maturity model in four enterprises: two with low anticipated maturity and two with high anticipated maturity. This type of extreme case analysis allows to draw conclusions from lower number of data and is widely regarded as a valid form for qualitative research.

The research procedure applied at this stage consisted of five steps, based on the guidelines for Robert K. Yin's book called "Case study in scientific research. Designing and methods "(2014), which are presented below.

1. Case design
2. Preparation for data collection
3. Data collection
4. Data analysis and ordering

5. Gather feedback

6. Verification and improvement of the model

3.4 Model finalization

The final stage of the research procedure was the finalization of the Comprehensive Lean Manufacturing Maturity Model. As a result of the literature studies and the empirical verification, the final structure of the model and the assessment procedure were designed. Thanks to this, the fourth step of the research method presented final conclusions on achieving the research objective and answering the research questions.

4. Results and conclusions

The main research objective of the study was to develop a Lean Manufacturing maturity model, which will ensure systematic and comprehensive implementation and assessment of this concept in manufacturing companies. Achievement of this goal was supported by the following research questions:

1. What structure of the Lean Manufacturing maturity model provides a comprehensive and systematic measurement of the implementation of this concept in manufacturing companies?
2. What procedure for conducting the Lean Manufacturing maturity assessment supports the implementation of this concept in manufacturing companies?

Referring to the questions stated above, as the result of the thesis, the Comprehensive Lean Manufacturing Maturity Model was developed. Below are presented the main conclusions related to the structure and process of using the created instrument.

4.1 Structure of the Comprehensive Lean Manufacturing Maturity Model

As a result of the reviewing of existing maturity models, conducting literature studies and performing case studies in four manufacturing companies, the final structure of the Comprehensive Lean Manufacturing Maturity Model was developed. The instrument was designed to fulfill all of the desired characteristics, which were identified through the literature review. These are:

1. providing an assessment of four categories of Lean Manufacturing: Leadership, People, Process and Results,
2. providing measurable value of Lean Manufacturing maturity,
3. enabling distinction between companies with low and high Lean Manufacturing maturity,
4. enabling quick and easy self-assessment,
5. relying on data and facts,
6. providing information on the existing gaps and possible areas for improvement.

In order to ensure all of the characteristics are covered, the structure of Comprehensive Lean Manufacturing Maturity Model is composed of three elements: categories, criteria and maturity levels.

Categories of the model

The categories of the Comprehensive Lean Manufacturing Maturity Model constituted the basic structural framework of the entire instrument. They represent the main groups reflecting the fundamental principles of the Lean Manufacturing concept. In this way, the Comprehensive Lean Manufacturing Maturity Model was based on four categories:

- Leadership - regarding aspects such as company vision, leadership commitment to Lean implementation, strategic planning and providing necessary resources and infrastructure.
- People - taking into account employees' commitment to continuous improvement, taking responsibility for the process, increasing the knowledge and competence of the company's employees and creating inter-functional teams.
- Process - regarding the scope of implementation of tools and Lean principles in manufacturing and supporting processes, assessing the degree of "leanness" and elimination of waste from production areas.
- Results - assessing the degree of business results improvement.

It was concluded, that only the measurement of all four aspects provides a comprehensive assessment of the Lean Manufacturing maturity in production companies. This type of distinction

allows determining the strengths and weaknesses of a company, distinguishing cultural aspects (leadership and people), toolbox implementation (process) and business output (results).

Criteria of the model

The criteria of the Comprehensive Lean Manufacturing Maturity Model state the characteristics of its main categories. They present a set of management practices and methods, which should be implemented from the perspective of leadership, people, process and results. In total, as a result of a detailed review of the literature, twenty-eight evaluation criteria were defined.

- Leadership
 - Lean Manufacturing as a long term vision.
 - Operational level management engagement.
 - Senior level management engagement.
 - Understanding of Lean Manufacturing concept by management.
 - Creating formal structure supporting Lean Manufacturing implementation.
 - Hoshin Kanri (strategic management).
- People
 - Employees engagement in continuous improvement and problem solving.
 - Understanding of Lean Manufacturing concept by employees.
 - Developing employees knowledge and competences.
 - Taking ownership.
 - Using of multifunctional and interdisciplinary teams.
- Process
 - Identifying value from the perspective of the customer.
 - Mapping current state and identifying waste.
 - Creating flow.
 - Creating pull system.
 - Integration of internal logistics with production requirements.
 - Supplier management.
 - Built-in quality.
 - 5S.

- TPM.
- Standard work.
- Visual management.
- Results
 - Customer satisfaction.
 - On time delivery.
 - Quality.
 - Cost.
 - Safety.
 - Employee satisfaction.

Maturity levels

The final step in shaping the structure of the Comprehensive Lean Manufacturing Maturity Model was to design a way to measure each criterion. As the outcome, the developed model uses a five-stage maturity scale. Levels of maturity allow detailed characterization of each criterion, enabling unambiguous determination of the current level of the enterprise. Additionally, the descriptive character of this method allows for more precise indication of existing gaps and quick identification of the necessary improvement actions.

In order to define individual levels of maturity, general descriptions from the organizational maturity model of the organization according to ISO 9004 were used. This model consists of five progressive levels: (1) No formal approach, (2) Reactive approach, (3) Stable, formal system approach, (4) Focus on continuous improvement, (5) Best in class performance. Based on this scale, the following general descriptions of maturity levels have been defined in the Comprehensive Lean Manufacturing Maturity Model:

- A. Informal implementation - visible cases of informal application of a given criterion.
- B. Standardization of implementation - starting the formal application of a given criterion with varying degrees of success.
- C. System implementation - a criterion implemented in a systemic way in an enterprise. The first positive effects resulting from the implementation are visible.

- D. Continuous improvement - the criterion fully applied in an enterprise. Visible continuous improvement in the scope of a given criterion. Positive effects are sustained.
- E. Best-in-class implementation - all areas successfully apply the given criterion with visible positive effects. The implemented solutions are an example of best-in-class and are constantly improved.

For each of the twenty-eight criteria, a detailed descriptions of the maturity levels from A to E were determined. The maturity level was then assessed based on fulfillment of individual characteristics. To achieve the next level for a given criterion, all requirements for lower levels should first be met.

4.2 Assessment process using the Comprehensive Lean Manufacturing Maturity Model

The second research question of the thesis concerned defining the assessment process, which will support the implementation of Lean Manufacturing. As a result of the research, the assessment procedure was created, which was based on the guidelines of Robert K Yin from the book "Case study in scientific research. Designing and methods "(2015). The established theoretical framework was then subjected to empirical tests in four manufacturing companies. Finally, the designed Lean Manufacturing maturity assessment process consists of the four steps presented below.

Preparation to data collection

In order to prepare companies for the assessment, the preparatory procedure was developed (table 1).

Table 1. Preparatory procedure to the assessment

Step	Description	Time
1	Sending the preparatory documents to the assessed company <ul style="list-style-type: none"> • initial assessment agenda, • list of people required to attend in the assessment, • list of documents necessary to prepare, • empty template of the Comprehensive Lean Manufacturing Maturity Model. 	One month before the assessment.
2	Phone conversation with the company representative to finalize the agenda and discuss technicalities.	Two weeks before the assessment.
3	Confirming the final agenda.	One week before the assessment

Source: Self-made study

The first step, concerns early delivery of preparatory documents to the assessed company, to ensure better preparation to the upcoming audit. By providing initial agenda, list of requested available people and empty template of the model, the company will be able to plan the time and resources necessary to carry out the assessment. On this step, the assessed company should receive also the list of necessary documents, which should be available during the audit. It should ensure a more efficient and faster evaluation process during the assessment process. As a result of the research, the following list of documents needed during the audit was defined:

- vision and mission of the company,
- strategic goals of the company (annual, several years),
- plan of implementation / application of Lean Manufacturing,
- employee skills matrix,
- employee training plan,
- organizational structure,
- documents from the continuous improvement activities workshops,
- customer satisfaction survey results from the last three years,
- results of the employee satisfaction survey from the last three years,
- results from the last three years from the company level for indicators of: delivery, quality, costs, safety.

Data collection

The second step in the assessment process is to collect data through an audit evaluating the Lean Manufacturing maturity level. It should be performed using the developed Comprehensive

Maturity Model. This model is intended for the self-assessment of the surveyed company, therefore the suggested auditors should be a Lean practitioner or a director / manager of a given company. The final data collection process is presented below.

Part 1 – Leadership. Estimated time: 60 min.

An interview with a representative of the senior management of the company and a representative of the continuous improvement department (if there is one).

Scope:

- mission and vision of the company's development,
- Lean Manufacturing strategy in the company,
- commitment of senior management in the implementation of Lean Manufacturing,
- knowledge of senior management in the field of Lean Manufacturing,
- infrastructure for implementing Lean Manufacturing,
- strategic management (Hishin Kanri).

Part 2 - People. Estimated time: 30 min.

An interview with a representative of the human resources department and a representative of the continuous improvement department (if there is one).

Scope:

- employee knowledge development programs,
- Lean Manufacturing training programs,
- programs of engaging employees in continuous improvement.

Part 3 – Leadership/ People/ Process. Estimated time: 240 min.

Going through the production area (Gemba Walk) with the selected production manager and the representative of the continuous improvement department (if there is one).

Scope:

- conversation with production employees (evaluation of job satisfaction / knowledge of Lean Manufacturing),
- interview with a manager and a leader of production areas (satisfaction assessment / Lean Manufacturing knowledge),

- use of Lean Manufacturing tools,
- flow in the production area,
- visual management,
- internal logistics and supply chain management,
- daily production management.

Part 4 – Results. Estimated time: 60 min.

Review of the business results of the company with a chosen company representative.

Scope:

- safety,
- delivery,
- quality,
- cost,
- employee satisfaction,
- customer satisfaction.

As presented, the suggested process of the data collection is divided into four parts, corresponding to the main categories of the maturity model. Such a structure prevents the auditor from being forced to "jump" between different categories of the model, thanks to which the data collection is easier to carry out. In order to ensure a more reliable and faster assessment, it is also suggested that, according to the recommendations from the previous step, the examined company should previously prepare the required documents. Meeting this condition is key to ensuring efficient measurement of Lean Manufacturing maturity level.

Analysis of collected data

The next step in the process of assessing the Lean Manufacturing maturity is the analysis of the collected data. Based on observations recorded during the audit, documents reviewed and interviews conducted, a summary report of the conducted study should be prepared at this stage.

It is suggested that the report should contain the following information:

- description of the assessment process,
- maturity level results for each criterion of the model,

- strengths of the assessed company in each category (Leadership, People, Process, Results),
- gaps of the assessed company, which prevent it from achieving a higher level of maturity,
- suggested improvement actions which will allow the assessed company to achieve a higher level of maturity.

Presenting the summary report and collecting feedback

The final step of the Lean Manufacturing maturity assessment process is to present the results of the summary report and obtain feedback from the examined company. It is suggested to be performed in a form of a meeting with company's representatives, which were involved in the assessment, or other stakeholders indicated by the company. The meeting should have the following course:

1. presenting the results of the maturity levels for each criterion of the model,
2. presenting the company's strengths for each category of model,
3. presenting the identified gaps that prevent the achievement of a higher level of maturity,
4. presenting the improvement actions, which should allow to achieve a higher level of maturity,
5. collect feedback from participants and answer questions.

4.3 Final conclusions

The Comprehensive Lean Manufacturing Maturity Model, which was developed as the result of the this research, is the only one from twenty six identified models, tools and instruments, to possess all six desirable characteristics identified in the literature review. This conclusion has been argued in the following paragraphs.

1. Providing an assessment of four categories of Lean Manufacturing: Leadership, People, Process and Results,

The structure of the model is based on four categories: Leadership, People, Process and Results, and twenty-eight criteria assigned to them. Literature research

indicates that such a construction of the instrument allows a comprehensive measurement Lean Manufacturing implementation in a chosen company. Conducted case studies confirmed this assumption, not identifying any additional categories or criteria of the model.

2. Providing measurable value of Lean Manufacturing maturity

As a result of the case studies, it has been proven that the use of the developed maturity model provides a measurable value of the Lean Manufacturing implementation level. Based on a five-level maturity scale, the developed instrument allows to measure each criterion of the model. Thus, as a result of the assessment process, the examined enterprise will obtain a measurable value of the implementation degree for twenty-eight characteristics of Lean Manufacturing.

3. Enabling distinction between companies with low and high Lean Manufacturing maturity

The obtained maturity results of the four researched companies allow to state, that the developed model makes it possible to distinguish between companies with low and high maturity level. The result of measurements made it clear, that two companies are characterized by higher maturity in applying Lean Manufacturing principles than the two other. The Comprehensive Lean Manufacturing Maturity Model allows distinguishing the implementation level for each of the twenty-eight assessment criteria, enabling comparison between each of the assessed company.

4. Enabling quick and easy self-assessment

The conclusions obtained from the case study in company D prove, that using the assessment process developed in the research using, allows quick and easy self-evaluation of production companies. It should be remembered, that this criterion is only achieved if the company being assessed makes all the necessary preparations before the audit. This condition has been identified as one of the key, to successfully carry out the measurement of Lean Manufacturing maturity level.

5. Relying on data and facts

The conclusions from the case studies indicate, that the assessment performed with the Comprehensive Lean Manufacturing Maturity Model is based on objective data and facts. The

descriptions of each maturity level, which were used in the instrument, have been formulated in a quantitative and unambiguously way, not allowing their subjective interpretation. Thanks to this, the measurement result should be objective and repeatable.

6. Providing information on the existing gaps and possible areas for improvement

Thanks to the use of descriptive levels of maturity for each of the criteria in the model, the instrument enables providing information on the existing gaps and suggested improvement actions. The summary reports, which were prepared for each of assessed companies prove this point. It is also worth noting, that each of the assessed companies indicated this characteristic of the model as its strongest feature.

Taking into account the above arguments, the Comprehensive Lean Manufacturing Maturity Model is a significant extension of the current knowledge in the use of maturity models in the field of lean production, complementing the existing research gaps. The developed model addresses also the problem of inconsistency in the understanding of the Lean Manufacturing concept, which principals have "blurred" with the increase in its popularity. The structure of the instrument developed as a result of the research, indicates the most important methods and techniques of lean production, at the same time specifying the recommended order of their implementation. The model thus can serve the function of a compendium of knowledge in the field of Lean Manufacturing, which can be used by both practitioners and academics.

From the perspective of using the instrument in business environment, the Comprehensive Maturity Model enables fast, simple and objective self-assessment, indicating the current level of company's maturity and defining the improvement actions recommended for taking. In this way, it fills the identified gap in lack of practical assessment tools, which support the process of implementing the Lean Manufacturing concept.

An important scientific contribution of this dissertation is also designing the Lean Manufacturing maturity assessment process, using the Comprehensive Maturity Model. The measurement procedure developed as a result of the case studies may be used in any production company, providing a comprehensive examination of the degree of implementation of lean production. It is recommended, to use the designed procedure on a regular basis by Lean coordinators or management staff in order to control the company's current maturity and support in the further transformation process.