Linnéuniversitetet
Institutionen för teknik

A Model For Assessing and Evaluating Production Process Effectiveness When Applying Lean Production -A Case Study

Author: Tuğba Demirci

Supervisor: Ia Williamsson

Examiner : Basim Al-Najjar

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Abstract

Measurement is an important process for companies to evaluate their production systems. The purpose of this study is to create a model which will help to companies if they want to measure effectiveness of the production processes when applying lean production. The model consists of twelve steps and considers strategies that has effects on production processes in different perspectives. In order to examine these perspectives systematically, balanced scorecard was used as a tool. Thanks to balanced scorecard measures that is used to reach aim of the model were chosen. In the model pilot processes were offered to implement new production strategy. After measuring effectiveness of two situation of process -before and after implementation- comparison was made with the use of radar chart tool. The result of the model is balanced measurement system and determining effectiveness of the production process when applying a production strategy. The model has been implemented in a manufacturing company, Melam that is implementing lean production. At the end of the case study lean measures were identified and production process effectiveness was determined. According to determination further decisions were given by decision makers. Implementations were not found enough and thanks to the model, applying an unsuccessful implementation was prevented.

Key Words: production process effectiveness, lean production, measurement

LIST OF DEFINITION

Performance measurement : the process of quantifying the efficiency and effectiveness of action (Neely, 1996).

Performance measure : a metric used to quantify the efficiency and/or effectiveness of action (Neely, 1996).

Performance measurement system : the set of metrics used to quantify the efficiency and effectiveness of action (Neely, 1996).

Effectiveness : achievement of maximal outputs at given resources (Malega, 2007).

Efficiency : measures that show how beneficial the company is using its resources (Malega, 2007).

Just in Time (JIT) : a system that goods are peoduced and purchased just before the company need (Businessdictionary, 2012).

Kanban : a technique that plans materials requirement. It is developed by Toyota Corporation. in this technique work-centers signal with a card when they wish to withdraw parts from feeding operations or the supply bins. Kanban means a visible record or sign in Japanese (Busineesdictionary, 2012)

Jidoka : innovation that is employs automatic and semi-automatic processes to reduce mental and physical load on the workers (Busineesdictionary, 2012).

Single Minute Exchange of Die (SMED): an approach aims to reduce set-up times of machines (Garg et al., 1998).

Poka Yoke : an approach to 'mistake proofing' in all aspects of customer service, manufacturing, customer service etc. (Busineesdictionary, 2012).

Total Productive Maintenance (TPM) : a methodology that is designed to ensure that every machine in a production process always makes its required task and output rate of the machine is never disrupted (Busineesdictionary, 2012).

Kaizen : a term for a gradual approach to reach higher standards in quality enhancement and waste reduction, as doing small but continual improvements involving everyone from the chief executive to the lowest level workers (Busineesdictionary, 2012).

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Vaxjö, 2012
Tuğba Demirci

LIST OF CONTENT

LIST OF FIGURES

LIST OF TABLES

1 Introduction

In this chapter, an introduction of the thesis is presented with description of the background, the problem discussion and the task developed around the subject are included.

1.1 Background

Quality, flexibility, low cost, availability and performance are international factors which have been around as long as there has been competition (George, 2003). Nowadays, competitiveness increases because of globalization and in order to survive in this competitive environment, companies have to pay attention to these factors (Burgess and Gibbons, 2010).

Many separate philosophies such as lean production, Six Sigma, TQM have evolved to achieve competitive goals. Lean production is one of these philosophies that focuses on eliminating waste, reducing cost, improving quality and uses various proven tools (Cudney and Elrod, 2011) such as one piece flow, visual control, kaizen, 5S, standardized work, work place organization (Garg et al., 2010). Waste consumes resources but does not add any value to the manufacturing systems and Garg et al. (2010) explains waste as more than the minimum amount of time, effort, space, parts, materials, and equipment that are necessary to add value to product. Lean production provides operational efficiency and benefits to manufacturing businesses. In addition, the principles of lean production can be applied in every industry across the globe (Womack et al., 2007) but, in this study focused on implementation in manufacturing companies.

As mentioned before lean aims to improve the production process and therefore, the results of lean implementations should be defined in quantitative terms to determine if expectations have been achieved or not (Goel et al., 2004) and this is considered as measurement. According to Neely et al. (1995) someone cannot manage it if he or she does not measure. Performance measurement helps to know where the process is directed, what have been accomplished and what is left to achieve. It provides a standard for manufacturing process so that everyone in the company is working toward the same goal (Ali et al., 2008). Lean production is a multi-dimensional approach which affects various aspects of the production such as reducing cycle time, downtimes. Therefore, it is important to measure these effects with right performance measures.

Since lean implementations take lots of time, most companies start the implementation of lean production techniques with a pilot project. It is preferred to implement lean in the other scopes of company after the success of the initial project. Thanks to the pilot processes, companies save time as not implementing an unsuccessful process to all company.

1.2 Problem discussion

Despite the remarkable progress that was gained over recent years in change programs such as Lean production, Total Quality Management, Six Sigma, measuring and managing performance in a change environment presents a challenge that has not yet been satisfactorily resolved (Bayliss et al., 2012; Tangen, 2004). Traditional performance measurement systems are commonly focused on cost and management accounting developed in the late nineteenth and early twentieth centuries. Many companies are still primarily relying on traditional financial performance measures (Neely,1999). Ali et al. (2008) identified five main problems, with traditional management accounting techniques for performance measurement, such as, lack of relevance, cost distortion, inflexibility, lagging indicator and hindrance. There is a need for new performance measurement systems in manufacturing industries since customers' expectations require them to use the management techniques that focus on higher quality, performance and flexibility.

It is possible to evaluate the production system based on performance-related data and organizations usually collect good data about processes but does not know how to turn them into valuable information (Bhasin, 2008). It is not always obvious how companies should measure their production performances. Schmenner and Vollmann (1994) stress the importance of identifying the critical dimensions in a performance measurement system (what to measure) and the optimum characteristics of the measures (how to measure). According to Jonsson and Lesshammar (1999), most companies either using wrong measures or fail to use right measures correctly. Therefore, most of manufacturing companies need to seriously consider changing their performance measurement systems. According to Paranjape (2006), organizations use generic measures with little consideration of their relevance. If measures are not right one, it may encourage the wrong type of behaviors. The measures need to focus on the company's production strategy in order to provide the right information about the system and motivate the right behaviors.

Lean production has effects on economy, human resource, customer, production process, supplier and environment. These effects can be determined by using performance measures. Lots of performance measures have been developed and used for different purposes (Garg et al., 2010). Time performance measures solely concentrate on time and neglect other operational performance measures such as quality and cost. On the other hand financial measures are not related to quality, time. For this reason Bhasin (2008) offers using a combination of right performance measures and investigating impacts of lean in order to assess if the organization has been successful in adopting lean.

1.3 Presentation of Problem

Companies try to make their process effective and stay competitive by using some philosophies such as lean production. Since implementing this kind of processes takes lots of time, pilot implementations are made (Bioki et al., 2012). Then, the company decides if improvements are sufficient enough to extend the scope of the implementation. In order to decide, they should be able to define right measures that identify effectiveness of production. These measures are right if they focus on the company's production strategy such as lean production. Two questions need to be answered: What are the characteristics of a company's production strategy? And, what is the correct measurement system for these characteristics?

1.4 Problem formulation

The main research problem in this thesis is:
How to measure effectiveness of the production process when implementing lean production?

1.5 Purpose

The purpose of this thesis is to develop a model to assess and evaluate production process effectiveness when applying lean production.

1.6 Relevance

Selection of effective measures for performance measurement is the key to achieve stated goals. In the literature, there are satisfactory guidelines for design of performance measures (Paranjape et al., 2006). Despite that, these measures have weak links to measure effectiveness of production process when implementing lean production. According to literature survey that is done in this study there is no previous research regarding how to select the measures to be used for assessing the effectiveness of lean production process. In order to fill this gap a model will be developed by using a case study.

As a result of the limitations of the traditional performance measures many researchers have suggested that a combination of performance measures (Bhasin, 2008). In practice there are many problems about selecting and designing correct performance measures to measure effectiveness of production process. These measures should provide information that is necessary for the decision making process of the company. This study aims to help companies select the type of measures to assess the effectiveness of lean production applications.

1.7 Limitations and Delimitations

Limitations:At the time of the project due to lean had been implemented, datas are not collected by authors. The decision of implementation success depends on measures that consulting firm has.

Delimitations:Scope of the project is limited to measure lean impact on the manufacturing process since lean production is solely implementing to this process.

1.8 Time Frame

The primary timeframe of this thesis is shown below:

	Task Name	Duration	Start	Finish
1	Introduction	29 days	Mon 02.04.12	Fri 18.05.12
2	Research methodology	10 days	Mon 16.04.12	Fri 27.04.12
3	Theory	55 days	Mon 16.04.12	Fri 29.06.12
4	Model Development	5 days	Mon 02.07.12	Fri 06.07.12
5	Empirical Findings	21 days	Fri 20.04.12	Fri 18.05.12
6	Analysis	15 days	Mon 09.07.12	Fri 27.07.12
7	Results	10 days	Mon 16.07.12	Fri 27.07.12
8	Conclusion	4 days	Fri 27.07.12	Wed 01.08.12
9	Report Review	4 days	Mon 02.08.10	Thu 05.08.10

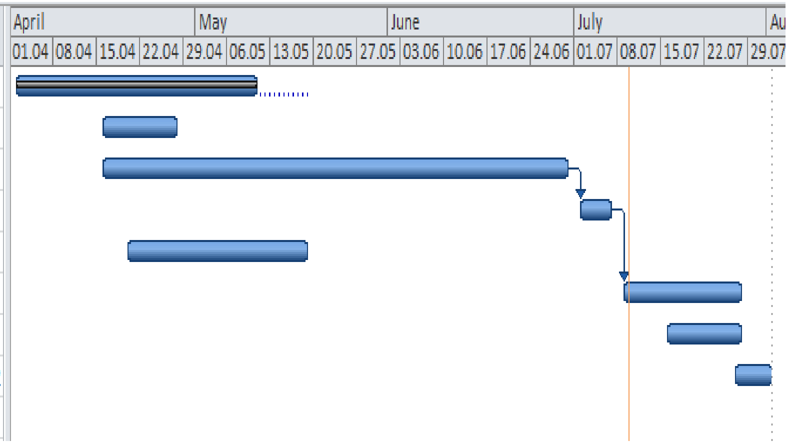

Figure 1.1 Time Frame of the Study

2 Research Methodology

In this chapter, short definitions of research methodologies and methodology used one for this thesis are presented.

2.1 Scientific Perspective

In theory of science, there are two main scientific perspectives called positivism and hermeneutics. These are developed by Auguste Comte. From positivism perspective, research is seen as an objective process and researcher is like an observer who describes and explains particular social phenomena. For the positivist, theory consists of three components. These are (a) concepts or constructs, (b) statements linking these concepts together, and (c) rules to connect concept with the empirical world measurement (Brannick and Coghlan, 2007).

Hermeneutic that takes place in the late nineteenth and early twentieth centuries, concerns the problem of interpretation, and has therefore been central to various customs of scripture scholarship, of rhetoric, of legal studies and of literary criticism. Its strategy is identifying the clear meanings first and then use this understanding to make sense of the more obscure and confusing passages (Kidder, 1997).

This study was built on scientific basics and has positivist perspective. Theory part gives better understanding to study.

2.2 Research Approach

Researchers can develop models through the use of deductive, inductive and abductive reasoning (Sachdeva, 2009). Deduction involves development a theory that is subjected to a strict test. It refers to testing the theory and checking general rules and claims that it describes a specific situation. Induction is a technique which data is collected, analyzed and as a result making formulation of a theory. In addition, abductive approach is a combination of other approach that mentioned.

Differences between these approaches to research:

Deduction emphasizes	Induction emphasizes
- Scientific principles - From theory to data - Explaining relationship between variables - Collecting quantitative data - Researcher independence of what is being researched - Highly structured approach - Necessity to select samples of sufficient size in order to generalize conclusion	- Gaining an understanding of the meanings of human attach - Researcher is the part of the research - Collecting qualitative data - More flexible structure - A close understanding of the research context - Less concern with the need to generalize

Figure 2.1 Deduction and Induction Emphasizes (Saunders et al., 2009)

In this study deductive approach is used for literature research and model development, inductive approach is used while merging of data collection. It means in this study abductive approach is used.

2.3 Research Method

There are three methods while conducting a research. They are quantitative, qualitative and mixed method. Quantitative method uses numbers rather than words, on the other hand qualitative method uses words and information that is gathered by this method can not be measured. Two research methods and analysis procedures have their own strength and weaknesses. There is inevitably relationship between technique that is chosen and the research results. So mixed method is used to have strong results. Mixed research method uses quantitative and qualitative collection techniques and analysis procedures either at the same time or one after the other but does not combine them. It means quantitative data is analyzed quantitatively and qualitative data is analyzed qualitatively (Saunders et al., 2009)

Since this study is a case study qualitative method is followed to understand and analyze the problem and results.

2.3.1 Data Gathering

Data collection is a phrase used to describe a process of preparing and gathering data and material. According to Yin, (2009) there are six different tools and methods for data collection to carry out a scientific study in case studies as shown in figure 2.2.

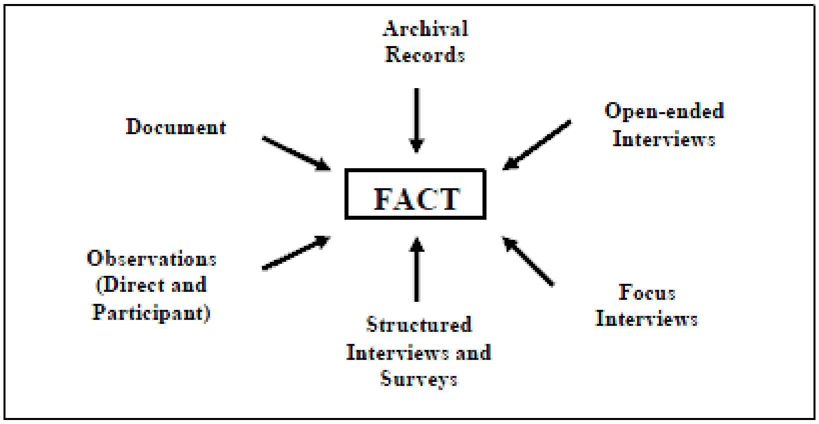

Figure 2.2 Methods for Data Collection (Yin, 2009)

There are two types of observation methods as mentioned in the figure. Participant observation is done by attending in the events while direct observation is done by gathering data directly by the researcher during visiting company. In addition this method, document consists of letters, written reports, newspapers, etc. Detailed and exact information can be gained easily with this method but every time it is not possible to access information because of blocked documentation (Yin, 2009).

Interview that should be based on carefully prepared questions is one of common method when performing case studies. It is important to determine right questions in order to gather preeminent information needed for case studies (Easter-by Smith, et al, 2002).

Besides these methods, literature review, contains scientific journals, books and magazines, is one of the most important data gathering methods. It is necessary and important to find the most suitable literature for research and to learn which literatures that already exist within the area of the study in order to avoid any replications (Saunders et al, 2009).

In this case study we will do participant and direct observations in order to analyzing current situation in the production lines at the case company and also interviews will be done with different employees and researchers to get necessary knowledge for a better understanding of problem and current and initial situations. Furthermore data will be gathered from literature review in order to put the theoretical part needed for this report in context and compare the result.

2.4 Results Evaluation

2.4.1 Validity

Validity is concerned with whether findings are really about what they want to appear about (Saunders et al., 2009).The validity of measurement can be divided into three types;

a- Internal validity: It concerns to plan research and check accuracy of collected data
b- Construct Validity: It concerns with establishing right measures for concepts being studied.
c- External Validity: It is generalization of results for other situation (Yin, 2009).

In this study, correct different data collection methods are used and these are associated with wide range of theory.

2.4.2 Reliability

Reliability refers to extent to which your data collection methods or analysis procedures will yield consistent findings. It can be determining by following questions;
Will the measures give the same results on other situations?

Will similar observations are made by other observers?
Is there clearness how sense was made from the raw data? (Saunders et al., 2009).

In this thesis, results are examined objectively and most of the terms will be discussed upon by the company involved. Therefore results will be the same regardless of the observer. Several measurement methods are compared in order to gain right measures.

2.5 Summary of the Research Methodology

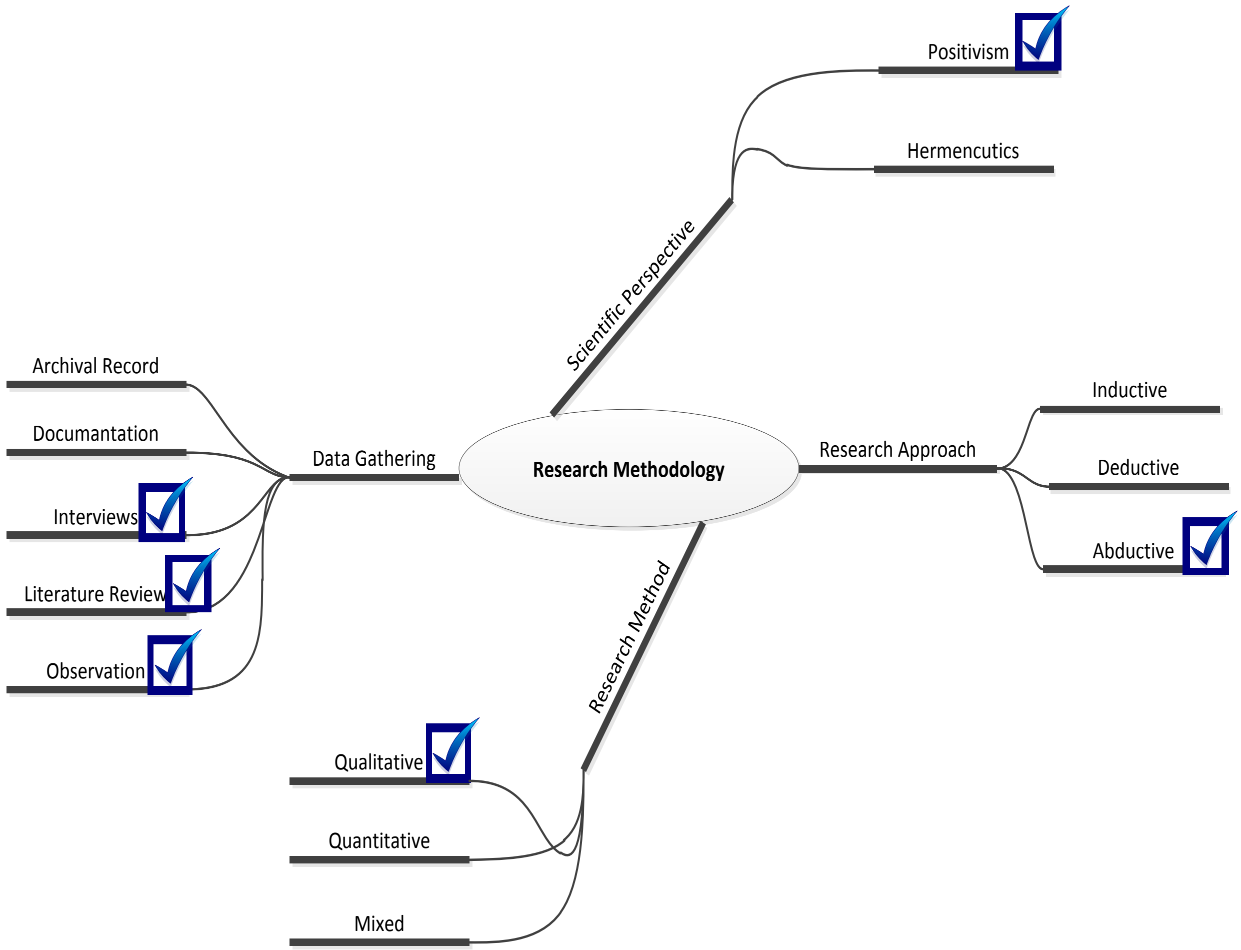

Figure 2.3 The Frame of Research Methodology

3 Theory

This chapter presents theoretical subjects, which are used in this study.

3.1 Lean Production

Automobile industry is always one of the most important economic activities worldwide. It has changed the principles of production. First change happened after World War I as evolving the production system from craft production to mass production. After that change, the United States began to lead world economy because of using mass production. Then, second change took place after World War II when Eiji Toyoda and Taiichi Ohno pioneered the concept of lean production (Womack et al, 2007). The term lean production first appeared in 1990 the book machine changed the world (Capital, 2004).

The major aim of lean production is to produce high quality products in an efficient and economical way. This means reducing waste in all areas of production and using less time to produce (Smith and Hawkins, 2004). Lean production looks for perfection and it means zero defects, zero inventories,high quality and a high product variety. Although these objectives have not been fully achieved yet, their importance lies in the culture of continuous improvement (Womack et al, 2007).

An important part of lean production is elimination of all forms of waste. Waste for a production is anything which does not add value to the product. The types of wastes are gather under 7 headings as stated by Ohno (1988), which are as follows ;

Overproduction: It implies to produce components that are made for no specific customer. Since it leads to another form of waste, the inventory overproduction is one of the most important forms of waste. An example of this waste is to produce according to the capacity of the line, not according to customer demand.

Waiting: It shows the lost time between operations or during operations due to forgotten material, planning errors and unbalanced lines. People, equipment and product waiting do not add value to the customer.

Transportation: It refers to unnecessary movement of materials. For instance, moving items around the operation with double and triple handling of WIP, does not add value.

Processing: Poor component design and maintenance can make process itself nothing but waste and can be eliminated. This type of waste is easy to identify and remove.

Inventory: It causes the stack of products and materials in any part of the process. The inventory is important since it is often used to hide problems in the process operation. All types of inventory cost money.

Motion: It is defined as any movement that is not necessary to finish operation. For instance, human movements that are not necessary. While people are moving they do not add anything to the product process.
Defective products: It states producing defective parts during the process. It is quality waste and generally very important in operations. Total cost of such waste is more than that has traditionally been considered (Womack et al, 2007).

Lean production uses techniques to achieve its aims. These techniques are;

1. JIT
2. Kanban
3. Jidoka
4. SMED
5. Poka Yoke
6. 5S
7. TPM
8. KAIZEN (Sharma, 2010)

According to Womack and Jones (2007), lean production makes cycle time, lead time shorter and these ensure lower cost of production. In addition thanks to lean production quality of product and production increase. Number of defects is decreased with high quality and it contributes to protection of the environment. This production strategy provide cleaner and more comfortable place for employees and so number of accident and time of absenteeism decrease.

3.1.1 5S (Sort, Set in Order, Shine, Standardize, Sustain)

5S is a system to have less waste, optimise quality and productivity through maintaining an orderly workplace and using visual signs to achieve operational results. The practice of 5S comes from first letter of 5 Japanese words and translates as: sort, set in order, shine, standardize and sustain.

Sort : is the first "S" and refers to sorting tools, equipments on the work place, relocate or remove all components that is unnecessary or not used often.
Set in order : means "a place for everything and everything in its place". It aims to organize the work place.
Shine : refers to clean the work area. It involves improving the appearance of the work area and housekeeping efforts. Everything should stay clean.
Standardize : everyone in the organization must be involved in the 5S effort. 5S should be implemented with the same way to everywhere.
Sustain : refers to making sure 5S implementation is followed by the personnel. 5S is a culture and it has to be ingrained into the organization.

3.2 Communication in Companies

Coulter and Robbins (2003) state informations need to be communicated to convince in companies. Communication is established in three ways, up to down, down to up and lateral. It is occurred between managers and employees in firms. Due to lack of good communication mistakes are made and improvement that the company needs is not achieved. Therefore, receiving information from teams and informing employees about how processes are progressing have high importance. Regular feedbacks are made by management in order to improve communication and stimulate further involvement. It is vital to give feedback to employees.

3.3 Production Effectiveness

Effectiveness is defined as achievement of maximal outputs at given resources which are used while producing product. Measuring production effectiveness gives evaluation of relationship between results which are formed by the inputs that are consumed and the given production. The effective production produces more product by the given inputs or produces same amount product by the less inputs. The goal of production is to achieve the highest effectiveness of production (Malega, 2007).

3.4 Measurement

Measurement is the process of observing and recording the observations that are collected as part of a research effort. In today’s global market, companies are forced to provide the foundation to base action on, action that would lead the organization in direction to reach its goals (Henshaw, 2006).

Measurement has become such an accepted approach within organizations (Robbson, 2004). According to Henshaw (2006), Lord Kelvin emphasizes its importance as saying “When you can measure what you are speaking about, and can express it in numbers, you know something about it; but when you cannot measure it, when you cannot express it in numbers, your knowledge is of a meager and unsatisfactory kind.” The process consists of three items. Such as, an object to measure, results of measurements and finally results that should be manipulated in order to be useful.

Measurements can be used to see where you are, make comparison, identify problem. In addition it clarify the relationship between effort and result, creates a common language, gives a motivation for change and leads to continuous improvement (Neely, 1995).

3.5 Metric

The basic definition of a metric is a standard of measurement. According to Neely et al. (1995), a metric can be defines as a notion used to quantify the efficiency and effectiveness of an action.

Metric aids evaluating of measured quantity objectively. Measurement of any property of a system is in fact to determine a value for the metric. So, metrics: (a) provide information for logical decision-making, (b) are used to compare systems, (c) provides to evaluate options. All metrics may need different data, so the type of it is to be considered and according to metric, data should be gathered. As using metrics, systems can be managed more effective (Durmus and Özmen, 2012).

3.6 Performance Measurement (PM)

PM is a topic that is often discussed but not defined. In literature, the definition of PM is the process of quantifying performance and performance can be defined as the efficiency and effectiveness of action.

Companies design performance measurement system with performance measures that is a metric used to quantify performance. Some authors are suggested performance measures can be used to affect the implementation of strategies, others thought it as a part of strategic control system. A framework for performance measurement system design is shown in Figure 3.1 (Neely, 1996).

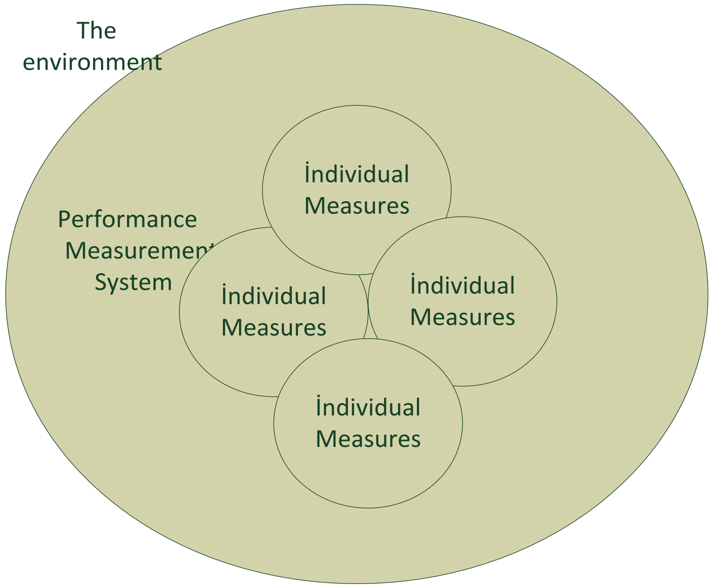

Figure 3.1 A Framework for Performance Measurement System (Neely, 1996)

Issues to take into consideration when designing a performance measurement system according to various authors is shown in figure 3.2.

Individual Measures	Measures should be clearly defined/easy to understand Measures should be purposeful Measures should be practical Measures should form part of the control loop Measures should be cost effective
Performance Measurement System	The system should provide data for monitoring past and planning future performance The measurement system should provide a balanced picture of the business The measurement system should not contain any measures which conflict with one another
Performance Measurement System & the Environment	The performance measurement system should reinforce the firm's strategies The performance measurement system should match the firm's culture The performance measurement system should provide data for external comparison

Figure 3.2 Issues to Take Consideration When Designing a Performance Measurement System (Neely, 1996)

3.7 Financial and Non-Financial Measurements

Performance measures is divided into two types, financial and non-financial. Financial measurements are expressed in monetory states, non-financial measurements can not expresses in monetory states. As an example for financial measures can be profitability and for non-financial measures can be market shares (Simons, 2000).

Before 1980, performance measurement systems were focused on cost. After, some authors have argued that measurements are too focused on financial terms and financial measures have some disadvantages;

- Financial measures are not directly concerned strategy of the companies.
- Financial measures may pressure managers for short-term results and prevent improvements.
- Financial measures do not control processes as a whole system.
- Financial measures do not determine the cost of quality, lead time reduction (Tangen, 2004).

Although these disadvantages, financial measures have some advantages such as being certain and objective. Because of financial measures' limitations, authors suggest using them with non-financial measures. Balancing financial and non-financial measures provides accurate infomation about the company (Tangen, 2003).

3.8 Strategy and Measurement

"What gets measured gets done" statement indicates the importance of performance measurement that are in same line with the strategy. Supporting strategy by measures is vital to ensure employees work for common goals. Without well defined strategy, it is hard to know what the company should measure and achieve objectives of the organization. Therefore, strategy is the most important factor while determining a measurement system (Ali et al., 2008).

3.9 Balanced Scorecard (BSC)

Balanced scorecard is a performance measurement matrix that measures the operating and economic performance of an organization. It aids to translate strategies into measures. BSC is developed by Robert Kaplan and David Norton in 1990 and this BSC summarizes metrics in four perspectives. The perspectives are financial, customer, internal business operations and learning and growth as shown in figure 3.3. It is a template which can be adapted to individual specific purposes. while Kaplan and Norton suggest four perspective as others have found more or less perspectives. These measures need to be evaluated targets first, metrics second.By setting targets first, the appropriate metrics can be chosen. BSC is balancing financial and non-financial measures while chosing right metrics (Fleming, 2011).

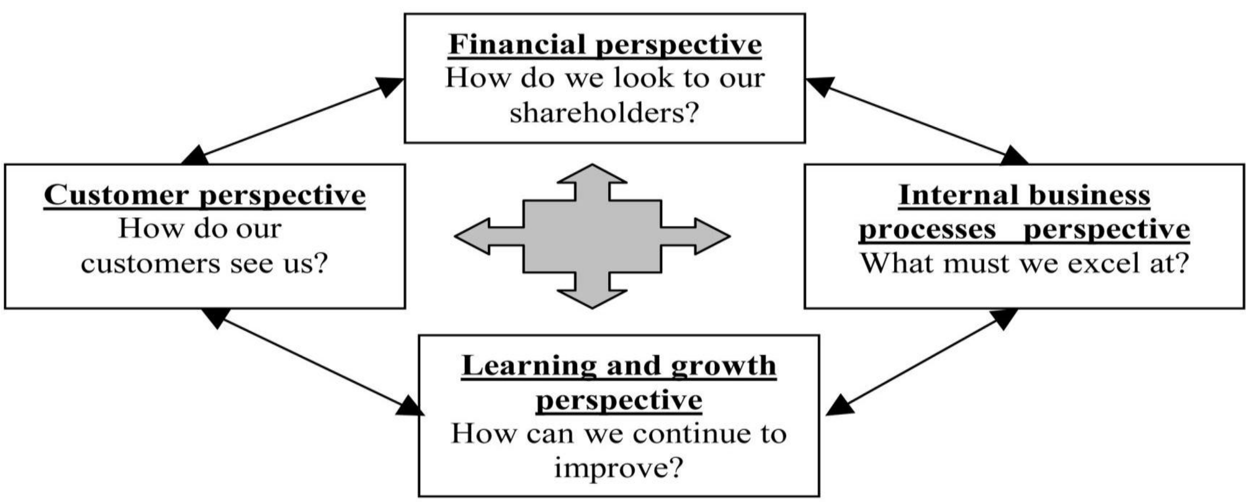

Figure 3.3 Balanced Scorecard (Kaplan and Norton, 1996)

According to Kaplan and Norton (1996) the four perspectives are:
The financial perspective identifies the concrete outcomes of the strategy in traditional financial terms such as shareholder value, lower unit costs, revenue growth, and profitability.

The customer perspective contains general customer outcomes, such as satisfaction, retention, and growth. It should explain who the organization's target customers are, what they demanded and how the company satisfy them.
The internal business operations perspective considers the impact activities have on customer service and on performance. In this perspective production, manufacturing, delivery and product development are the most discussed factors.

The learning and growth perspective defines the culture of the organization that is the most important to the strategy. It considers employee empowerment and metrics include employee satisfaction, employee morale and problem resolution.

3.10 Radar Chart

Radar chart is a method that is used to state the data points in multidimensional space. It is visual way of showing results and ensures important information about process's situation. It is used as a benchmarking tool for example while assessing lean production. Thanks to radar chart decision makers can see difference between two different conditions easily (Hong, 2008).

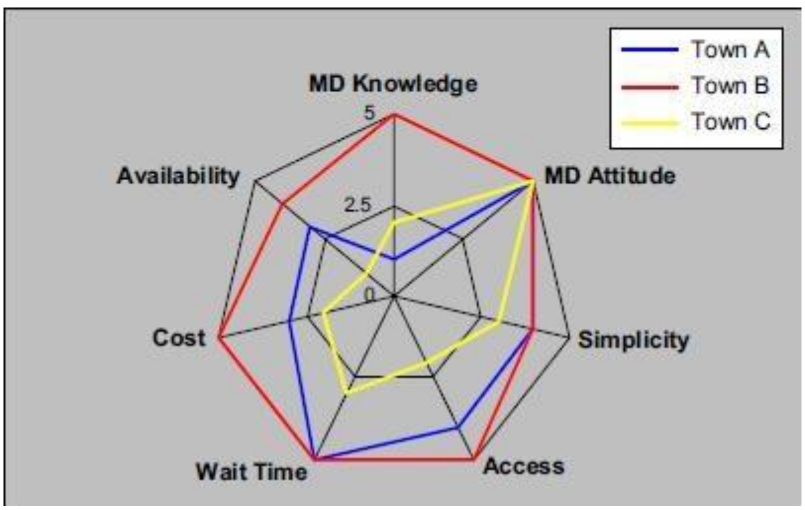

Figure 3.4 An Example of Radar Chart (Saarya, 2007)

3.11 Overall Equipment Effectiveness (OEE)

In manufacturing, productivity and quality are the most important and used metrics of performance. OEE was proposed as an approach to evaluate the achieved progress through the improvement initiatives, by Nakajima (1988) and he defines OEE as a metric or measure for the evaluation of equipment effectiveness. Then its evaluation scope has expanded. While one of the researcher used it to measure the performance of whole processes (Barber et al., 1999), the other one defined OEE to evaluate the effectiveness of a product line manufacturing system (Dal et al., 2000). OEE has been increasingly used in industry not only for controlling and monitoring the productivity of manufacturing equipment but also as an indicator and driver of process and performance improvements (Barber et al.,1999).

Measure of OEE is introduced as a powerful benchmarking key performance indicator focusing on three process efficiencies: availability, performance and quality (Burgess et al., 2010). It allows to make internal and external benchmarking. In manufacturing companies, studies are carried out to have effective process with higher performance and these studies can be measured with OEE such as Dal et al. (2000) has done (Barber et al.,1999). OEE is metric to say where you are and as internal benchmarking, the initial OEE measure of a manufacturing line can be compared with future OEE values of the same line, thus the level of improvement success can be quantified (Dal et al., 2000). On the other hand as external benchmarking OEE determines production level as 85 percent through the world. The ability to compare internal performance against external competition and vice verse is a critical attribute of any performance measurement system and avoids the problem of short-term thinking and also gives strategic focus (Burgess et al., 2010). OEE provides a useful guide to aspects of production process where inefficiencies can be targeted.

3.11.1 The Six Big Losses

The goal of OEE is to identify losses and waste. Chronic and sporadic disturbances cause different losses and waste in manufacturing processes. Nakajima (1988) explains that achieving equipment effectiveness by eliminating the six big losses:

Downtime losses

Breakdown losses result in time losses and defective products. These losses account for a large part of the total losses are sudden and unexpected.

Set-up and adjustment losses result from downtime and defective products that occurring when production of one product ends and the equipment is adjusted to meet the requirements of another product.

Speed losses

Idling and minor stoppage losses occur when production is interrupted by a temporary disturbance or when a machine is idling.

Reduced speed losses refer to the difference between equipment design speed and actual operating speed. Different reasons might result in speed losses. Some examples mechanical problems, defective quality, overtaxing or abusing the equipment.

Quality losses

Quality defects and rework are losses in quality caused by malfunctioning production equipment.

Start-up losses are yield losses that occur during the early stages of production, from machine start-up to stabilization. The stability of the process, technical skills of operators, equipment maintenance level and more are with regarding to the volume of these losses.
These losses are formulated as a function of a number of mutually exclusive components. these are availability (A), performance efficiency (P) and quality rate (Q) (Barber et al.,1999).

3.11.2 The Functions of OEE

OEE:Availability

There are planned and unplanned down time in a process. Planned downtime is the time that the equipment is down due to planned activities such as lunch, breaks, meetings etc.

On the other hand unplanned downtime is the time that the equipment is down due to breakdowns, setups, adjustments, minor stoppages, changeover etc.

The availability rate measures the ratio of the actual operation time to the loading time that is the total time minus planned time losses. Operating time is loading time minus unplanned downtime (Burgess et al., 2010)

$$Loading\ Time = Total\ Loading\ Time - Planned\ Down\ Time$$

$$Operating\ Time = Loading\ Time - Unplanned\ Downtime$$

$$Availability(\%) = \frac{\text{Operating Time}}{\text{Loading Time}} \text{x100}$$

OEE:Performance Efficiency

Nakajima (1988) measures a fixed amount of output, and in his definition performance indicates the actual deviation in time from ideal cycle time. It takes into account unrecorded down time that is third and fourth big losses. In order to calculate performance efficiency ideal cycle time is needed.

$$Performance\ Efficiency(\%) = \frac{\text{Theoretical Cycle Time x Amount Processed}}{\text{Operating time}} \text{x100}$$

OEE:Quality Rate

In production system some products are rejected due to quality defects and the quality rate takes into consideration these quality loses that is last two of the six big losses (Jonsson and Lesshammar, 1999). Defects are parts that could not meet the quality definition at first time.

$$Quality\ Rate = \frac{\text{Amount Processed} - \text{Defective Amount}}{\text{Amount Processed}} \text{x100}$$

$$OEE = Availability\ x\ Performance\ Efficiency\ x\ Quality\ Rate$$

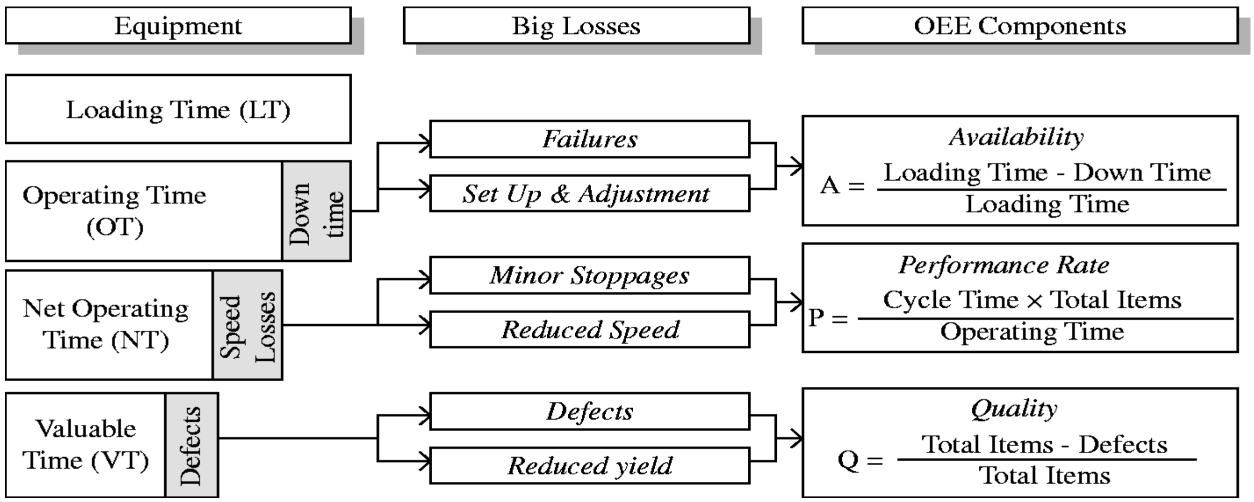

Figure 3.5 Calculation of OEE Based on Six Major Production Losses (Braglia, 2008)

3.12 Down Time

The amount of time that an asset is not producing a product or service. Down time is divided into two as planned down time and unplanned down time. Planned down time is the time for maintenance and planned processing preparation. On the other hand sometimes the system being down because of power failures system. It is called as unplanned down time. Unplanned downtime can not planned so production is replanned (Bixler, 2008).

3.13 Cycle Time

Cycle time is the time takes to make one individual product. Organisations that focus on cycle time as a productivity measure, can both improve quality and decrease delivery time, thus creates a more satisfied customers. It is important factor for customer because it shows response time to market. Long cycle times cause high cost, higher inventories, and poor customer service (Rother, 2003).

3.14 Lead Time

The manufacturing lead time concerns the time from the start of the production process, till the warehouse receives product. It includes set-up time, processing time, waiting time in queue and moving time between workstations. When lead time becomes shorter product cost decrease and machines are used more efficiently (Díaz de Cerio, 2009).

3.15 Productivity

Productivity is one of the most vital measure that shows competitiveness of the company. It is defined as ratio of output to input. There are different ways to calculate productivity.

Partial productivity: uses ratios of output to one source of input such as capital, material. It is easy to calculate but hard to measure on an aggregated level.
Total-factor productivity: uses the ratio of output to the associated capital and labor input. It is hard to calculate, but gives opportunity to compare different units or companies.
Total productivity: uses the ratio of output to all input factors. Total productivity is similar to total-factor productivity, but it also contains intermediate goods, such as energy (Tangen, 2003)

3.16 Takt Time

Takt time is defined as the time must pass to produce one piece of product. Takt time determine how quickly products should be produced. It is called as the voice of the customer. It synchronizes the sales rate and the production rate (Ohno, 1988). The time is given in minutes or seconds and the formulate is as following:

$$Takt\ Time = \frac{Available\ Time}{Demand}$$

4 Model Development

In this chapter, reasons for the need of developed model and steps of developed model is given.

4.1 Literature Survey

In order to be able to see whether there had been previous studies regarding to measurement of production effectiveness and assess measures that are used to determine effectiveness of production when implementing lean production, a literature survey has been done. The literature survey was mainly performed in EMERALD, science direct, and IEEE databases. At the same time other literature survey was performed in books. Table 4.1 presents a result of the literature survey with used key words.

Key Words	Investigated Articles	Relevant Articles	Authors
Lean Production and Measure	1	0	-
Lean Indicators	0	0	-
Lean Metrics	0	0	-
Performance Measurement and Lean	7	1	Bhasin (2008)

Table 4.1 Results of Literature Survey

Among searched and examined articles, one of them, which is written by Bhasin (2008), was found relevant with the purpose of this study. He considered how should a measurement system be and the article is about lean production’s success. Although he talked about measurement systems, he did not mention about implementation of a measurement system and did not develop any model in this article. In addition, none of articles describe same model that is developed in this thesis.

4.2 Development of the Model

This model is developed to improve the decision of measurement system, it is combining balanced scorecard and radar chart. In addition the choice of measures are supported by a question list. This model consist of 12 steps. It starts with step 1 where the user has to define its production strategy that will use. Then the user will define goals of the strategy to decide what should be measured. After this step, the user will found out performance measures to utilize while deciding performance measures. In step4, the user will prepare a match list by using goals that is defined in step2 and performance measures that is found out in step3. Thanks to the match list, the user will see which goal is measured with which measure and list them in balanced scorecard according to their perspectives. In this step, the user will answer some of questions that is prepared according to authors and decide if measures that is listed in BSC appropriate or not. If they are appropriate, the model continues, but if it is not model goes back to step3 to investigate new measures. In step6, the user will identify pilot process. Because the model suggest using pilot process not to lose time while implementing a new strategy to all company. After identifying the pilot process, in step7, performance of the process will be measured and results will be saved to use for comparison. In this step, the user will perform radar chart to make results more visible. In step8, the user will implement new strategy by using tool of strategies to pilot process in order to improve the performance of the process. After that in step9, the user will do same transactions that is done in step7 to the process. In step10, the user will compare two situation -before and after lean implementation- by using radar chart and in this way, the user will see the difference easily. Then in step11 the user will consult expertise to decide if the difference that occurred because of the new strategy is enough or not. According to this decision the next step is determined. If the difference is not sufficient model goes back to step8 to implement the strategy in a better way to make higher difference. But if it is sufficient the model continues to last step and in step12 the user will implement same implementations to all company to achieve increase in performance in all factory.

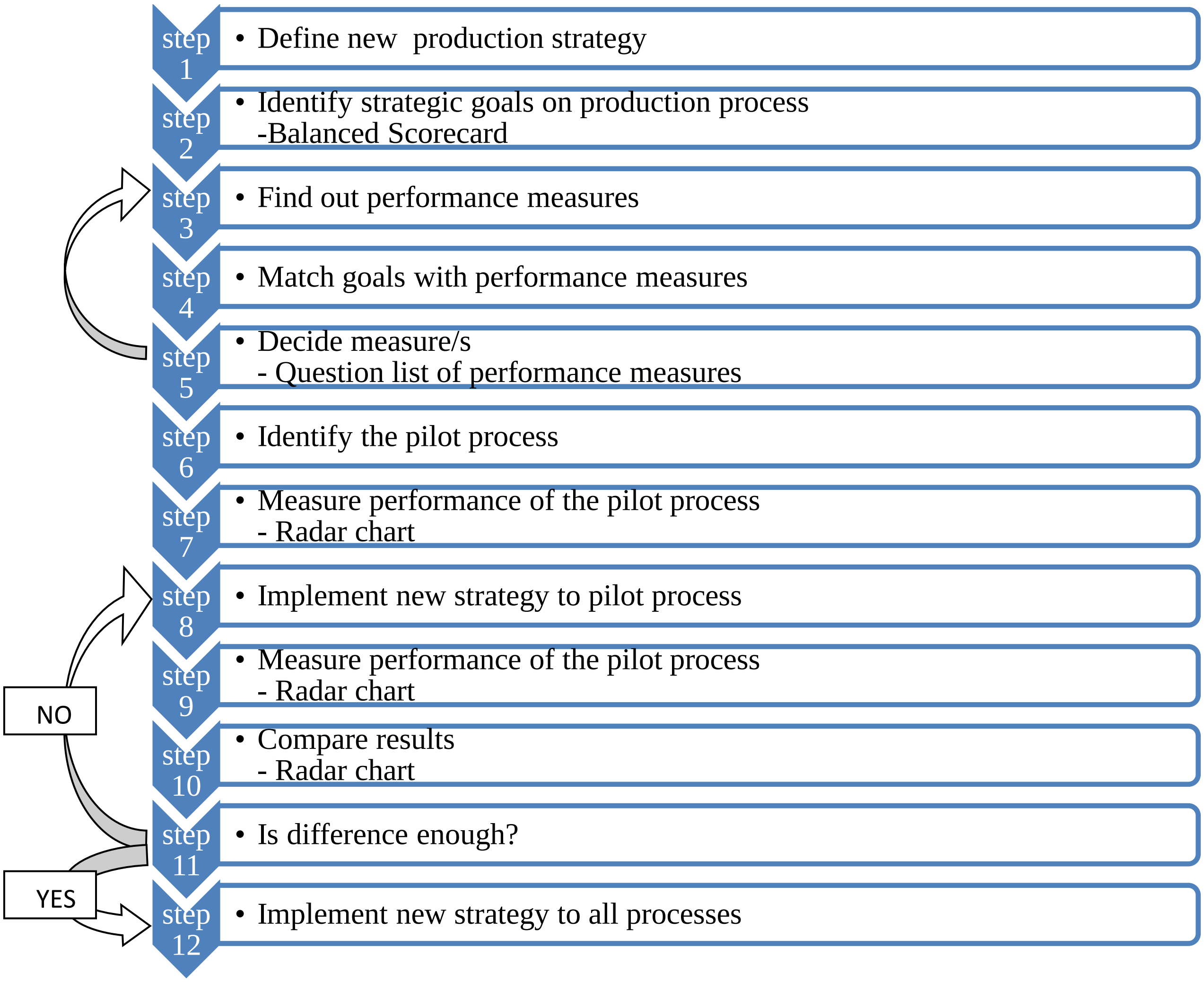

Figure 4.1 Developed Model

Step1: Define New Production Strategy

The first step of the model is to define new strategy of the company to produce products. Because production strategies refer how they will reach the goal of the company and it is important to have measurement system that depends on strategy as mentioned in 3.8. For instance lean production is used as production strategy in companies. This step will used as input of Step2.

Step2 : Identify Strategic Goals on Production Process

All production strategies make some changes on the process to achieve strategic goals. Goals are examined in different perspectives by using balanced scorecard. These perspectives can be human resource, production process, financial perspectives. All goals are evaluated through their type. For instance lead time is about production and lower lead time goal belongs to production perspective. Identifying strategic goals of the strategy is important to decide which measures should be used while making decision about success of implementation of the strategy.

Step3 : Find Out Performance Measures

There is some performance measures that can be used to reach aim of this model. These performance measures should be found out to decide with which of them effectiveness of production process is measured and with which of them changes happened because of new strategy is determined. This step and step2 will be used as input for step4.

Step4 : Match Goals with Performance Measures

In this step, identified goals in step2 and performance measures that is found out in step3 is matched. For instance according to 3.11 OEE includes quality and down time factors. It means when a change happened in these factors OEE change. So this measure should be used as lean measure. As a result of this step, measures that cover goals are determined.

Step5 : Decide measure/s

According to step4 performance measures, that will be used to measure effectiveness of production process, is determined. Determined measures through step4 are put in balanced scorecard. In other words measures are listed in different perspectives by using balanced scorecard according to their perspectives. Before making decision about measures questions that has prepared according to figure 3.2 is given in appendix2 and answered by authors. In this way eligibility to factors that set by authors is ensured. If measures are not appropriate according to result, the model goes to step3. If measures are appropriate next step is done.

Step6 : Identify the Pilot Process

Implementing new production strategies takes time, so companies prefer to implement new strategy to pilot processes. For this reason step6 involves identification of the pilot process.

Step7 : Measure Performance of the Pilot Process

When performance measures and pilot process are determined, performance of the pilot process can be measured. Measurement is made according to measures decided in step5. Results of this step is recorded in a list that is shown in appendix3 and according to this list score list is prepared and radar chart that is mentioned in 3.10 is performed to assess lean production implementation.

Step8 : Implement New Strategy to Pilot Process

This step involves implementation of new strategy to pilot process. Implementations are made as using tools of strategies e.g 5S, Poke Yoke. This step causes some changes on effectiveness of production. Because of this implementation, measurement results change.

Step9 : Measure Performance of the Pilot Process

After implementation of new strategy to pilot process, performance of process changes and these changes can be measured with performance measures that is determined in step5. Results of this step is saved by using appendix4 and radar chart is performed to use in step10 to see differences because of new strategy.

Step10 : Compare Results

In order to decide if implementation of new strategy is successful, radar charts that are obtained from step7 and step9 are compared by decision makers.

Step11 : Is Difference Enough?

This step involves decision problem for decision-makers. There should be difference on results between two situation-before strategy implementation and after strategy implementation- and this difference is observed in step10. It depends on decision-makers whether difference between results is enough or not. According to conclusion of this step, next step is determined. If the difference between results is enough, model continues to step12, if the difference is not enough model goes back to step8 in order to make more difference as implementing new strategy in a better way.

Step12 : Implement New Strategy to All Processes

If the difference is enough to reach the goal of the company, implementations should be implemented to all processes in the factory. In this way, increase in performance is achieved at all of the factory.

5 Empirical Findings

This chapter includes the data that is collected at the case company during the study.

5.1 Company Description

Melam was founded as a sister company of Spaljisten AB 1997 on behalf of IKEA to produce standard drawer components. Melam optimized the production drawer components through a straight and streamlined layout where large-format of particle board as brought in at one end and out came a finished drawer component, which was quite unusual during first years and Melam has continued to develop this concept and further refined the process through continuous improvement.

2004-2005 Splajisten is sold and Melam is relocated to its current rented premises at Hammarvagen. At the same time, a major investment is carried out in a new production line in order to both increase capacity and to become more efficient.

2008 is the next major investment decision after agreement with Swedspan to start production of plinths to Hultsfred PAX factory. There, a line to take care of the waste when Swedspan produce the wardrobe sides was created. During the same time there was a reinvestment into a line.

IKEA is still the biggest customer of the company and it has three shifts as morning, evening and night with 27 employees.

5.2 The Product

The company is producing side and back panels for furniture drawer that is named Birkeland, Hemnes, Inreda and Malm with different sizes. Malm has the biggest portion in the case company.

The company uses particular board, foil and glue as raw materials. The sizes of particular boards depends on the product is back or side panel. Foil is used to wrap particular boards and has three different colours. The colour changes according to customer's demand. Finally, glue is used to paste foil and particular board.

Figure 5.1 The Product

5.3 Process Description

The company is producing four kind of products in three production lines. Each line has strip, running and cross cut saws, moulder, wrapping, checking and drilling machines, glue pot and robot. Back panel is produced in line2 and sides are produced in line1 and line3. During production, the same equipments are used and almost the same operations are made for each product.

Firstly, particular boards are driven with forklift near the strip saw machine. Eight particular boards is cut according to width of ordered product, at one time. After, each cutting board is transferred by band conveyor to moulder machine that shapes board. The next phase in the production line is wrapping. This operation is done by wrapping machine as pasting foil and shaped parts with glue that is melting in a pot near the wrapping machine. After these, covered parts go to running saw. The cross cut saw cuts the part according to the desired length. Then, drilling machine drills the parts and checking machine looks for quality of holes. Later, 126 products are gathered on a place after checking machine, robot loads them onto the pallet and put paper between gathered products. When there is 504 products, conveyor transports them to checking and then packaging station that is the last phase of the process.

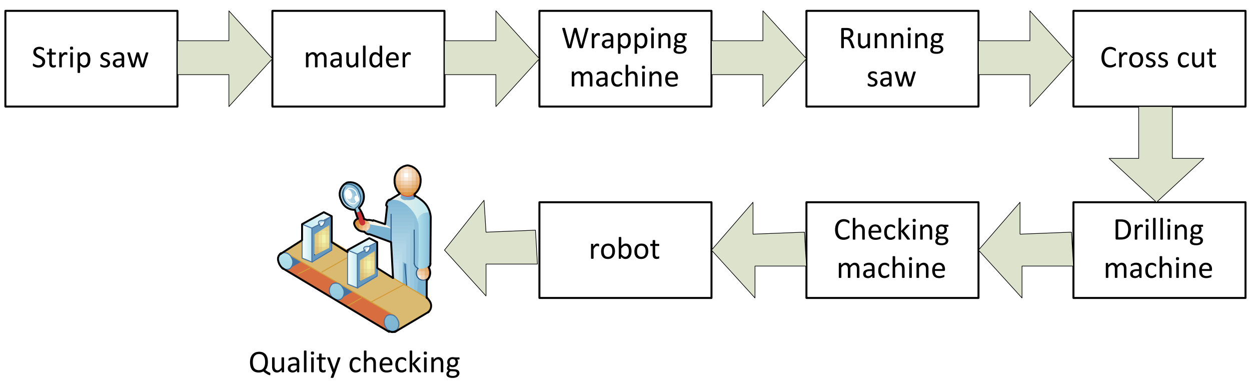

Figure 5.2 The Production Line

5.4 Lean Implementation in Melam

The last years, a lot of time has been invested to develop the skills of the company by running different various improvement projects. They aim to reduce setup times, produce more product with higher quality, standardize processes, have better communication between maintenance ,plan department and production.

In order to achieve these goal, the company invest in a lean project and for the project they have chosen line2 as a pilot line. As the first improvement, they have been implementing 5S that is lean tool. According to 5S, the company sorts tools as used and unused. Then used tools are brought closer to the line and arranged with regard to frequency of utilization. The company has problems that prevents production such as about material, lack of operator and information. So they standardized solves of the problems. On the other hand the company have different setups for each product. Because of that, setup adjustments are standardized,too. Instructions on how to use the tools is defined and all these standards are hanged as written on boards near of the line.

5.5 Data Collection

In this thesis all datas are gathered from consulting firm except score of communication between employees and score of communication between employees and managers measures. These measures are taken by asking two employees that are working on pilot process to give number how well they communicate each other and managers from 1 to 5 for their relationship. These numbers make up the score of measures. Numbers rise if the results are improved. Measurement results that is given in appendix3 and 4 such as OEE, productivity is calculated by author by using obtained informations.

5.5.1 Downtimes

Melam has planned and unplanned down times. Planned down times are for lunch 30 minutes, breaks for other needs 15 minutes. Unplanned down times is recorded by employees for one product, named Malm 724 x 170 for day, 3 shift. Measurement is made for pilot process.

	Total Planned Downtime	Total Unplanned Downtime
Before Lean Implementation	45 minutes	26985 s
After Lean Implementation	45 minutes	21677 s

Table 5.1 Downtimes

5.5.2 Cycle Time

The company has therotical cycle times for all products and all processes. Because of using one product in this project, its cycle time is given. Cycle time of Malm 724 x 170 is 58 second.

6 Analysis

In this chapter the model is implemented at the case company Melam AB.

Step1: Define New Production Strategy

The company has aims while producing products and can reach these aims with using some different production strategies such as lean production as Melam is using.

Step2 : Identify Strategic Goals on Production Process

Lean production has goals on production process according to 3.1 and dividing these goals in 6 perspectives helps us while deciding performance measures in a balanced manner. Goals are defined in figure 6.1 by using BSC that is mentioned in 3.9.

Production Perspective	Human Resource Perspective
1- Lower lead time 2- Lower cycle time 3- Higher quality 4- Less down time 5- Higher productivity 6- Lower set-up time 7- Less inventory	8- Less absenteeism 9- Less complain 10- Less accident 11- Better communication 12- More training program
Supplier's Perspective	**Financial Perspective**
13- Delivering on time 14- Ordering on time 15- Less supplier	16- Profitability
Environmental Perspective	**Customer’s Perspective**
17- Less Defect	18- Delivering on time 19- Producing on time 20- Less complain

Figure 6.1 Lean goals for Production Process

Step3 : Find out Performance Measures

OEE, lead time, cycle time, down time, takt time and some other measures that is shown in appendix1 has been selected as considering goals of lean production.

Step4 : Match Goals with Performance Measures

Production strategies cause change on performance of production system, but every performance measure do not measure every change. Therefore, relation between performance measures and effects of lean production is showed in a table in appendix1. In this way, possibility of not measuring any goal is eliminated.

Step5 : Decide Measure/s

According to step4 OEE, lead time, productivity and other measures are chosen and shown in 6 perspectives by using BSC in figure 6.2.

Production Perspective
- Lead time
- OEE
- Productivity
- Average inventory of raw material
- Average inventory of WIP
- Average inventory of finished products

Human Resource Perspective
- Time of absenteeism
- Number of complain
- Number of accident
- Score of communication between employees
- Score of communication between employees and managers
- Number of suggestion
- Number of training hours

Supplier's Perspective
- The percentage of delivering on time
- The percentage of ordering on time
- Number of suppliers

Financial Perspective
- Profitability

Environmental Perspective
- Percentage of defect

Customer's Perspective
- The percentage of delivering on time
- The percentage of Producing on time
- Number of complains

Figure 6.2 Suggested Lean Measures for Production Process

Questions in appendix2 that is prepared according to figure 3.2 is answered by author to decide if measures are appropriate or not. Score that is obtained by answering these questions is 4.54. This score is the ratio of total score that is given for each question to the number of questions. It means measures are appropriate for the company. So for next steps these measures will be utilized.

Step6 : Identify the Pilot Process

In the company all processes are using same machines in lines. But they are producing different parts of products. It will make easier implementation of same changes to other scope of the company. In Melam, line 2 that is producing back panel of last product, is chosen as pilot process.

Step7 : Measure Performance of the Pilot Process

Figure 6.2 involves measures that are used in this step. Before lean production implementation performance of the process is measured. After measuring, results are recorded in the list that is given in appendix3 by consulting firm. According to this list, score list is prepared. Then, radar chart is performed in accordance with percentage part of the score list.

Perspective	Score of perspective	Average	Percentage	Target
Production	20	3.33	66.6	100
Human resource	17	2.43	48.6	100
Supplier	10	3.33	66.8	100
Financial	3	3	60	100
Environmental	4	4	80	100
Customers	10	3.33	66.6	100

Table 6.1 Score List for Six Perspectives Before Lean Production Implementation

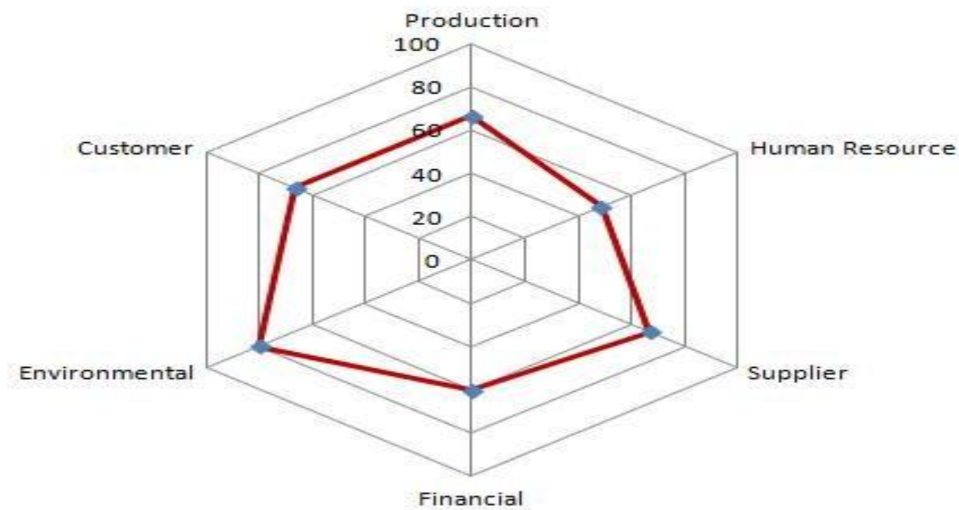

Figure 6.3 Radar Chart Before Lean Production Implementation

Step8 : Implement New Strategy to Pilot Process

The company had decided to implement lean production as new strategy and they have used 5S as tool of this strategy. Implementations are stated in 5.3.

Step9: Measure Performance of the Pilot Process

After lean production implementation measurements were made , results are recorded in the list that is given in appendix4. According to this list radar chart is performed.

Perspective	Score of perspective	Average	Percentage	Target
Production	22	3.67	73.4	100
Human resource	26	3.71	74.2	100
Supplier	10	3.33	66.6	100
Financial	3	3	60	100
Environmental	4	4	80	100
Customers	11	3.67	73.4	100

Table 6.2 Score List for Six Perspectives After Lean Production Implementation

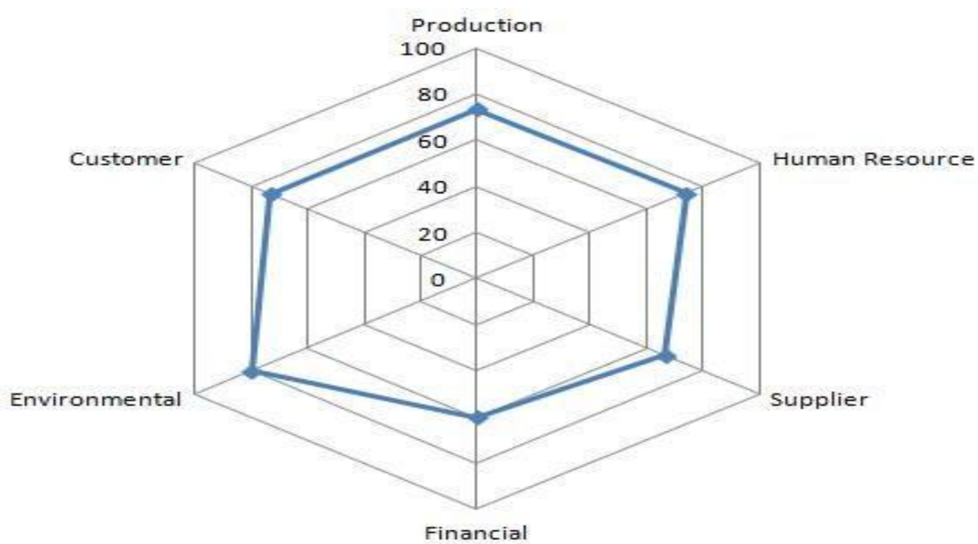

Figure 6.4 Radar Chart After Lean Production Implementation

Step10 : Compare Results

Results that is listed are showed in radar charts figure6.3 and figure6.4. Each chart shows one situation. Comparing two states is easy by performing one chart that includes two situations.

Difference that is occurred because of lean production implementation, between two state is seen in figure 6.5. Consulting firm that is decision-maker for Melam uses this chart to give decision about success of lean implementation. According to figure 6.5 there is no difference in financial, environmental and supplier perspectives can be said. The biggest difference has occured in human resource perspective. After this perspective, respectively production and customer perspectives comes.

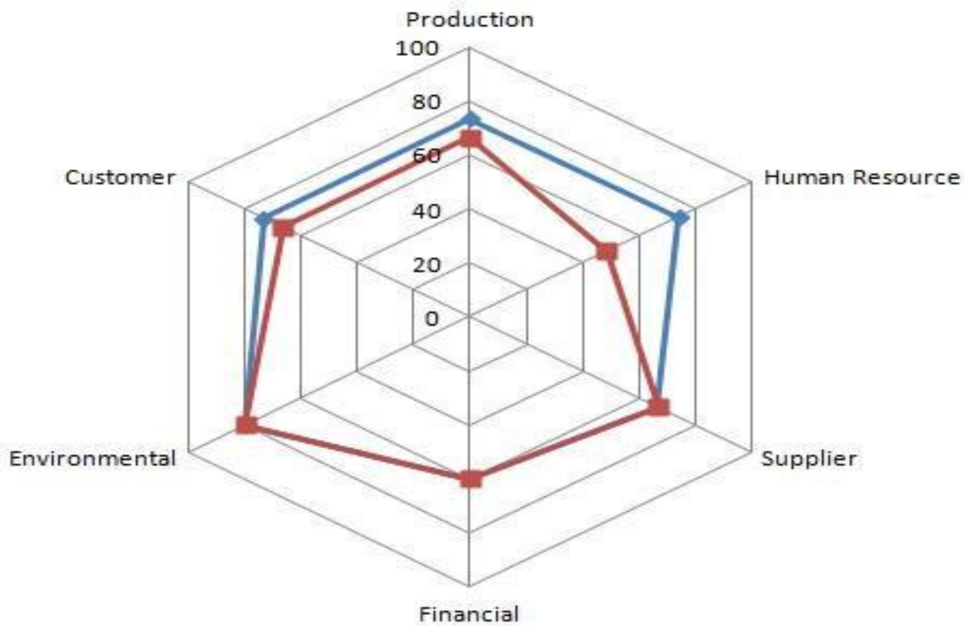

Figure 6.5 Radar Chart Before and After Lean Production Implementation

Step11 : Is Difference Enough?

In this thesis, consulting firm is chosen as decision maker. There is no rule while giving decision. It depends on expectation of the company from the implementation. According to interpretation in step10 consulting firm decided the difference is not enough. So according to the model the process should go back to step8 and the model continues to down from step8.

7 Results

In this chapter, what is achieved in this study is represented based on analysis chapter.

In this thesis, it is found out, balanced scorecard is useful while creating a measurement system that is focused on the strategy. Affects of changes that is caused by the strategy can be seen on production process effectiveness by using these measurement system. In addition, radar chart ensures an excellent opportunity to compare multidimensional factors. Thanks to this structure of the model, the company measures its production process effectiveness systematically. The company controls their decisions, with iterations if neccessary, and know what they should do in the next step.

Step1

As first step of the model, new production strategy that will be measured success of implementation in the project is defined. Melam wants to implement lean production as a strategy to the company. All project takes shape based on defined strategy. Because the company should decide its measures according to production strategy not to give wrong decisions.

Step2

Balanced scorecard is used to balance measures of the company in figure6.1. In order to decide measures that is used to measure effectiveness of the production strategy, the company should determine goals of the strategy. This is done by using balanced scorecard. In this project lean production is already defined as strategy and in this step lean production's goals are listed in balanced scorecard. According to 3.7 balanced scorecard is adapted and it has 6 perspectives in this study. These perspectives are production, human resource, supplier's, financial, environmental and customer's.

Step3

Companies use different measures such as takt time that is used by Mortimer (2006), but all of them is not suitable for every situation and company. So performance measures are found out as considering goals that are defined in step 2. For Melam measures that are found out listed in appendix1.

Step4

While deciding performance measures companies should choose measures based on the strategy as mentioned in 3.8. In order to ensure being based on the strategy, match list is prepared. Thanks to this list goals of the strategy and measures that is found in step3 are matched and possibility of not measuring any goal is eliminated.

Step5

In this step balanced scorecard that includes measures that is used to achieve aim of the project is performed. Measures are selected according to match list in 6 perspectives. By this step, balanced measurement system is created. According to 3.5 measures should have some properties and in this step it is checked if measures that is listed in balanced scorecard is appropriate or not. As a result measures does not need to be redesigned. So the model continues with measures that is listed in figure6.2.

Step6

Companies are implementing new strategies to improve their production processes. Implementing new strategies to all factory requires more effort than implementing to pilot process. Therefore, choosing pilot process is suggested in this model. For Melam line2 is selected as pilot process and 5S that is tool of lean production is implemented to just this line.

Step7

Until this step, measures based on strategy and pilot process are determined. In order to see effectiveness of the production when applying a production strategy, the company should have results of before strategy implementation. Therefore, in this thesis before implementing lean production, measurement is made according to measures that is decided before and results are recorded in a list (appendix3). Than according to this list score list is prepared and then radar chart that is mentioned in 3.10 is performed to make comment easily about the situation in 6 perspectives.

Step8

After having results of measures for pilot process before new strategy implementation, the strategy can be implemented. Melam has been implemented lean production as defined in 5.4 by using 5S as a tool.

Step9

Because of implementing new strategy, effectiveness of the production processes changes. In order to determine these changes measures that is defined based on production strategy and appropriate according to 3.5 are used. In this thesis measures that is identified for lean production is utilized and results are saved in the list (appendix4). As has been done previously in step7, radar chart is performed through score list that is prepared according to result list and given in table6.2.

Step10

Measurements are made for two situations until this step. In this step, all perspectives are compared for two situation to make decision if implementation is successful or not. For this thesis through two score lists that are created in step7 and step9, radar chart is performed. Thus, difference that is caused by implementing new strategy is seen clearly.

Step11

As defined before in step10 thanks to radar chart difference between two situations is seen clearly. In this step decision maker such as consulting firm in Melam decides if the difference is enough to implement the strategy to all processes in the same way or not. In this thesis the difference is not enough for consulting firm. So, the model goes back to step8. It means Melam should implement new strategy, lean production, in a better way. For instance using other tools of lean production such as JIT, kanban that are defined in 3.1 may make more difference. Thanks to the model, companies do not spend time and money for an ineffective implementation.

Step12

If a company decides the difference between two situation is enough, the company should implement new strategy to all company in the same way. Therefore, they obtain more efficient achievement.

8 Conclusion

In this chapter, conclusion of the study is given.

8.1 **Answer to Problem Formulation**

The problem formulation presented in this thesis was;

✓ *How to measure effectiveness of the production process when implementing lean production?*

In order to solve this problem a model is developed. It contains all processes from deciding new strategy implementation to deciding to extend scope of the implementation. It aids to create a measurement system that is based on strategy of the company. The model ensures balanced measurement system and aims to consider all areas that the strategy has effects. The model proposes using pilot processes while implementing new strategies. It can systematically decide the time when the strategy should implement to all company. When a company that is using lean production wants to see effectiveness of the production process can use this model and see what is changed in the company because of the strategy for all areas such as customer perspective.

The developed model is tested and analyzed in a real production company, Melam AB, that prefers to implement lean production.

8.2 Evaluation and Criticism of the Model

The developed model provides a map to companies that wants to measure effectiveness of the production process when implementing a production strategy. The model starts with defining production strategy that the company wants to see effects on effectiveness of the production process. By usage of BSC and radar chart tools value of the model is increased. Feedback and control are ensured thanks to questions in model.

One weak point of the model could be not controlling feedback parts due to the restriction such as time. Although in case study, implementations are not found enough, going back in model could not be tested. In addition when the thesis had began, implementations were already made. Therefore, measures that has been chosen depended on informations that consult firm had.

9 Recommendations

In this chapter, recommendations and future research parts are presented.

9.1 General Recommendations

Generally i recommend companies using this model when they want to implement a new strategy and want to see the difference because of the implementation.

9.2 Recommendations for the Case Company

In this case, changes happened in customer, production and human resource perspectives because of lean implementation. It is seen, 5S is not sufficient to achieve enough improvement. In order to have more improvement they should use other tools that is used while implementing lean production such as TPM. In this way the company can improve the effectiveness of the production and implement the same strategy to all scopes. In addition the company should implement the model at management level.

9.3 Future Research

The developed model needs more application at real cases in order to increase the validity and fill knowledge gaps. The model can be applied in different kind of companies and different departments of the company. Feedback parts can be tested. In addition, some other models can be incorporated to make it useful for other cases too.

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APPENDIX 1 Match list to decide measures

Goals / Measure	1	2	3	4	5	6	7	8	9	10
OEE			✓	✓						
Lead time	✓	✓				✓				
Cycle time						✓				
Downtime										
Takt time										
Productivity					✓					
Avarage inventory of WIP							✓			
Avarage inventory of finished product							✓			
Time of absemteeism								✓		
Number of complain									✓	
Number of accident										✓

Not : Goals' numbers are given according to numbers in figure 6.1

Measure \ Goals	11	12	13	14	15	16	17	18	19	20
Score of communication between employees	✓									
Score of communication between employees and managers	✓									
Number of suggestion	✓									
Number of training hours		✓								
The percentage of delivering on time			✓							
The percentage of ordering on time				✓						
Number of suppliers					✓					
Profitability						✓				
Percentage of defect							✓			
The percentage of delivering orders on time								✓		
The percentage of producing on time									✓	
Number of complains										✓

Not : Goals’ numbers are given according to numbers in figure 6.1

APPENDIX 2 Question list of performance measures to determine appropriateness of measures

	Strongly Disagree	Disagree	Neither Agree Nor Disagree	Agree	Strongly Agree
Measures are clearly defined and easy to understand	1	2	3	4	5
Measures are purposeful	1	2	3	4	5
Measures are practical	1	2	3	4	5
Measures are part of the control loop	1	2	3	4	5
Measures are cost effective	1	2	3	4	5
The system provides data for monitoring past and planning future performance	1	2	3	4	5
The system provides a balanced picture of the business	1	2	3	4	5
The system does not contain any measures which conflict with one another	1	2	3	4	5
The system reinforces the firm's strategies	1	2	3	4	5
The system matches the firms culture	1	2	3	4	5
The system provides data for external comparison	1	2	3	4	5

- Mean > 3 good
- Mean ≤ 3 redesing

APPENDIX 3 Results of before lean production implementation

	1	2	3	4	5
Production Perspective					
Lead Time	9-10 d	7-8 d	5-6 d	3-4 d	1-2 d
				✓	
OEE	0-10 %	10-30 %	30-50 %	50-70 %	70-100 %
			✓		
Productivity	0-10 %	10-30 %	30-50 %	50-70 %	70-100 %
				✓	
Avarage inventory of raw material	1101-1200	1001-1100	901-1000	801-900	0-800
		✓			
Avarage inventory of WIP	21-25	16-20	11-15	6-10	0-5
				✓	
Avarage inventory of finished goods	1101-1200	1001-1100	901-1000	801-900	0-800
			✓		

Suppliers' Perspective					
The percentage of delivering on time	0-10 %	10-30 %	30-50 %	50-70 %	70-100 %
				✓	
The percentage of ordering on time	0-10 %	10-30 %	30-50 %	50-70 %	70-100 %
				✓	
Number of suppliers	6+	5	4	3	2
		✓			

Environmental Perspective					
Percentage of Defect	70-100 %	50-70 %	30-50 %	10-30 %	0-10 %
		✓			

Human Resource Perspective					
Time of absenteeism in a week	16-24 h	11-15 h	6-10 h	1-5 h	0
	✓				
Number of complain in a week	21-25	16-20	11-15	6-10	0-5
		✓			
Number of accident in a week	8-9	6-7	4-5	2-3	0-1
			✓		
Score of communication between employees	1	2	3	4	5
			✓		
Score of communication between employees	1	2	3	4	5
and managers			✓		
Number of suggestion in a month	0-3	4-7	8-11	12-15	16-19
		✓			
Number of training hours in a month	0-3	4-7	8-11	12-15	16-19
			✓		

Financial Perspective					
Profitability	0-2x	2x-4x	4x-6x	6x-8x	8x-10x
			✓		

Customers Perspective					
The percentage of delivering on time	0-10 %	10-30 %	30-50 %	50-70 %	70-100 %
				✓	
The percentage of producing on time	0-10 %	10-30 %	30-50 %	50-70 %	70-100 %
				✓	
Number of complains	16-19	12-15	8-11	4-7	0-3
		✓			

APPENDIX 4 Results of after lean production implementation

	1	2	3	4	5
Production Perspective					
Lead Time	9-10 d	7-8 d	5-6 d	3-4 d	1-2 d
				✓	
OEE	0-10 %	10-30 %	30-50 %	50-70 %	70-100 %
				✓	
Productivity	0-10 %	10-30 %	30-50 %	50-70 %	70-100 %
				✓	
Avarage inventory of raw material	1101-1200	1001-1100	901-1000	801-900	0-800
		✓			
Avarage inventory of WIP	21-25	16-20	11-15	6-10	0-5
					✓
Avarage inventory of finished goods	1101-1200	1001-1100	901-1000	801-900	0-800
			✓		

Suppliers's Perspective					
The percentage of delivering on time	0-10 %	10-30 %	30-50 %	50-70 %	70-100 %
				✓	
The percentage of ordering on time	0-10 %	10-30 %	30-50 %	50-70 %	70-100 %
				✓	
Number of suppliers	6+	5	4	3	2
		✓			

Environmental Perspective					
Percentage of Defect	70-100 %	50-70 %	30-50 %	10-30 %	0-10 %
		✓			

Human Resource Perspective					
Time of absenteeism	16-24 h	11-15 h	6-10 h	1-5 h	0
			✓		
Number of complain	21-25	16-20	11-15	6-10	0-5
				✓	
Number of accident	8-9	6-7	4-5	2-3	0-1
				✓	
Score of communication between employees	1	2	3	4	5
				✓	
Score of communication between employees	1	2	3	4	5
and managers				✓	
Number of suggestion	0-3	4-7	8-11	12-15	16-19
				✓	
Number of training hours	0-3	4-7	8-11	12-15	16-19
			✓		

Financial Perspective					
Profitability	0-2x	2x-4x	4x-6x	6x-8x	8x-10x
			✓		

Customers Perspective					
The percentage of delivering on time	0-10 %	10-30 %	30-50 %	50-70 %	70-100 %
				✓	
The percentage of producing on time	0-10 %	10-30 %	30-50 %	50-70 %	70-100 %
				✓	
Number of complains	16-19	12-15	8-11	4-7	0-3
			✓		