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IMPLEMENTING LEAN PRODUCTION – APPLICATION OF LITTLE'S LAW

Michal Medonos[1], Marie Jurová[1]

[1] Faculty of Business and Management, Brno University of Technology, Kolejní 2906/4, 612 00 Brno, Czech Republic

Abstract

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This article is about implementing lean production in a company and problems with this process. Firstly it focuses on the definition of lean production. From literature review we find that there isn't uniform opinion on the process of implementing lean production. Every author focuses on usage of different framework and tools during this process. In the article, there is mentioned problem of evaluating the level of implementation of lean production in the companies too. Secondly article presents the opinion of the authors about the principles of implementation of lean production. It is mechanism based on variability and buffers in the production systems. Little's law is presented as a main tool that can help to better understand the process and manage the implementation in the right way. Finally there is shortly presented practical use of this law and mechanism in real company.

Keywords: lean production, cost of buffers, improving performance, company strategy, efficiency

INTRODUCTION

We are in the 21st century and benefits of implementing lean production are more than obvious. Companies can dramatically improve their performance by embracing the lean production approach (Yang *et al*., 2012). In 2008 Toyota surpassed General Motors in global car sales (Bunkley, 2009). Thanks to the great success of Toyota, its production system is famous worldwide and is often regarded as the gold standard of modern operations and supply chain management (e.g., Guinipero *et al*., 2005; Goldsby *et al*., 2006). That's why many other companies have tried to copy the Toyota Production System (TPS). Some of them were successful and they became members of a constantly growing group of lean companies. Others have failed and there are still a lot of companies that haven't tried implementing lean production. Maybe, because they don't know what the right approach is.

But why is that? Lean production was developed more than 50 years ago and its principles are now well known. Lots of people have studied Toyota and its production system. Many papers and books have been written. Lots of companies implemented lean production which consequently improved their performance. What did the unsuccessful companies do wrong? Finding an answer to this question could help companies find the right way of how to implement lean production and to prevent making wrong decisions during this process.

This is what we want to focus on in this article. Firstly, we would like to present literature review about today's main definitions of lean production and measuring the level of implementation. Then we would like to present our point of view on the definition of lean production and main ideas that we think companies should consider during the process of implementation. Lastly, we will be discussing our findings and potentials for future researches.

MATERIALS AND METHODS

In this research, secondary data collection from reputable scientific databases was used. Theories from the literature review were afterwards applied to the production of a real company Motorpal.

Literatue Review – Definitions

The popularity of this topic is seen on an enormous number of papers, which are connected with lean production. Firstly let's focus on

definitions of lean production. After studying papers we found that there are a few basic definitions, which are mentioned repeatedly: Lean production is an integrated socio-technical system whose main objective is to eliminate waste by concurrently reducing or minimizing supplier, customer, and internal variability (Shah and Ward, 2007); Lean production can be described as the elimination of waste (Liker, 2004); Lean production is a strategy or philosophy that promotes the use of practices, such as kanban, total quality management and just-in-time, to minimize waste and enhance firm performance (Womack *et al*., 1990) or lean production is a manufacturing strategy, which strives to minimize waste and thereby increase efficiency (Hofer *et al*., 2012). From these definitions, we understand that lean production is a system of tools, which are used to eliminate waste. And waste is a product of variability in the company. Another important thought is that, it is a strategy that influences the whole company. This definition sounds quite clear, but it is rather general. Explaining this definition in greater detail can be a problem. Every author understands this definition differently and focuses their research and papers in different ways. They are trying to describe and explain implementation of different parts or tools of a production system. Some say that the most critical factor for lean production adoption is the management of external relationships, rather than the internal operations of the company (Panizzolo, 1998). Others highlight the importance of reducing waste and that we must definitely focus on the identification and elimination of waste (Tuček and Dlabač, 2012). Liker sees implementing of lean production in focusing on four company dimensions, it is called the 4P model: philosophy, process, people and partners, and problem-solving (Liker, 2004; Liker and Meier, 2006). Another focus is, that the companies that want to move forward in adopting lean production, must manage variable supply, processing times and demand (Hopp and Spearman, 2004; de Treville and Antonakis, 2006).

Here we start to see the difference in opinions of the authors and if we go to more depth, the difference is bigger. Sometimes we find even contradictory opinions like that about cooperation between supplier and customer. Simpson and Power say that relational supplier-customer links have a positive influence on lean production adoption by the supplier (Simpson and Power, 2005). But research of Moyano-Fuentes *et al*. shows that the level of cooperation with suppliers doesn't have any significant influence on the intensity of lean production adoption (Moyano-Fuentes *et al*., 2012). And research of Hofer *et al*. confirms this with similar results, that the direct effect of external lean practices (Just In Time – JIT) on financial performance is statistically insignificant (Hofer *et al*., 2012). Another difference is even in the definition of lean production. Womack wrote that lean production is a strategy or philosophy that promotes the use of lean practices (Womack *et al*., 1990). Tuček and Dlabač answer to this definition that the methods and tools are not as important as functioning processes (Tuček and Dlabač, 2012). And Yang *et al*. add that companies overemphasize the technical aspects of the Toyota Production System, but ignore the human aspects and humanity management (Yang *et al*., 2012). This leads us to the idea, that there isn't a clear understanding of what lean production is or what is the most important for successful implementation of lean production.

Literature Review – Level of Lean Production

Managers of many companies say that they've successfully implemented lean production. But how can we prove it? How do we know that some factory is lean? In many papers the authors use, for evaluation of the level of lean production, some kind of survey. For example Hofer *et al*. based their research on methodology developed by Shah and Ward (2007). This formative scale comprises 41 questions which capture 10 lean production practices: supplier feedback, supplier JIT, supplier development, customer involvement, pull manufacturing, continuous flow manufacturing, setup time reduction, statistical process control, employee involvement and total productive maintenance. Other authors like Moyano-Feuntes *et al*. and Deflorin and Scherrer-Rathje conducted their own surveys, which were created on the basis of one of the known frameworks for implementing lean production. For example "Time frame for the lean leap" by Womack and Jones (1996), "Sequences in the implementation of lean production" by Åhlström (1998), "Lean manufacturing implementation" by Hobbs (2004) or "Hierarchical lean transformation framework" by Bicheno and Holweg (2009). All of these frameworks consist of a defined set of steps, which should lead the company to a successful implementation of lean production. The frameworks have some similar steps but there are some differences as well. Powell *et al*. made a comparison of these frameworks (Tab. I).

What all of these surveys have in common, irrespective of the basis on which the framework was made, is that the results are based on the answers from the people employed in the researched companies. The questionnaire is sent to the managers and they answer the questions about the level of implementation of the parts/tools of lean production. So the answers are very subjective depending on the self-criticism of the managers. The surveys could have problems with clarity and comparability of the answers from different managers. Then comparison of results between different companies can be questionable. Another problem connected with this measuring of leanness is that if we use this method, we haven't evaluated the benefits of this strategy, but only the level of usage of some tools. Formal use of some defined tools doesn't always mean that the company is lean. And on the other hand, company can be lean without using

I: *A comparison of lean implementation processes*

	Bicheno and Holweg (2009)	Hobbs (2004)	Womack and Jones (1996)	Ahlstrom (1998)
Initial education	X		X	
Establish strategic vision	X	X	X	
Organizational structure for change			X	X
Define and establish teams	X	X	X	X
Define performance goals	X		X	
Implement basic foundations of lean	X			
Define products	X	X	X	
Define processes	X	X	X	
Establish zero defect mentality	X			X
Ongoing training/learning	X		X	
Vertical information systems	X		X	X
Layout for flow	X	X		
Lean accounting	X		X	
Pull system	X	X		X
Continuous improvement	X	X	X	X

Source: Powell *et al*., 2013

these tools. For example Hofer *et al*. say that the exact mechanism through which lean production affects financial performance remain under researched (Hofer *et al*., 2012). So the company can use different ways how to achieve the benefits of lean production, then the strictly defined set of tools described that the Toyota and others used. Especially if we take into account, that the lean philosophy stems from automotive industry (Deflorin and Scherrer-Rathje, 2012), which is based on mass production and there are a lot of companies which are job-shop or craft production.

How to Begin

In the beginning it is important to make a strategic decision about implementing lean production. At this point, we could talk about change of the strategy on the top management level, but when the company is interested in lean production, we can expect that this decision has already been made. Therefore we will go further and we will focus on the beginning of the process of changes in the production. First of all we think that the company should pay attention to identifying the buffers in the system. All buffers cost money and from the point of view of the customers they don't have value added and customer isn't willing to pay for them. So we think that implementation of lean production is about reducing these excessive costs of buffers. Our experiences from the real company are that it is not easy to find them. It is because they are hidden in the system and many people can't "see" them or identify them as a buffer. It is because it is natural for conventional production systems to include these buffers (and for people, who are used to working with it too). It is important to find those buffers because they cover many types of inefficiencies in the system in the same way as water in the lake that hides the rocks at the bottom. If you reduce the buffers it will show you the inefficiency such as lowering water-level in a lake will show us the rocks.

Buffers, built to cover both external and internal variability, consume money which doesn't generate value. In the internal variability there is hidden the ineffectiveness of the system or how some authors call it "waste". For example if you don't have a stable process and you produce scrap pieces, then you have to keep buffer which will cover this. If you want to reduce this buffer, then you have to implement Total Quality Management (TQM) or other tool for improving quality. Or if you have some delay in deliveries of material, then you have to keep buffer to not stop production, and you can reduce this buffer for example by implementing JIT. But again there can be more other tools to reduce this buffer. In general buffers can have 3 major forms (Hopp and Spearman, 2008):

1. Inventory buffer.
2. Time buffer.
3. Capacity buffer.

Inventory buffer means that we keep extra material in the transformation process. This extra material can cover unstable process or other problems in the production. Time buffer is that we produce pieces in advance to cover potential delay in the production. Capacity buffer means that we keep free capacity which we can use in situation of unplanned problems. Creating these buffers is somehow natural, and conventional production systems are based on these buffers. Without them they collapse.

One of the main buffers defending the improvement of the production system is Work In Process (WIP). High level of WIP is a common problem in many companies. It is remnant of the old

production systems used in the 20th century. In many cases it is connected with the planning systems. One of the famous planning systems created in the 60's is Material Requirements Planning (MRP), which is surprisingly still the basis for planning processes in modern Enterprise Resource Planning (ERP) systems. MRP and other systems need for their proper working a high level of WIP. When they were created there wasn't such a big pressure on efficiency of production processes, so their inaccuracy and imperfection wasn't a problem. Times have changed and today for improving the performance it is a problem. Our experience showed that to reduce WIP, change in planning processes is needed. There are many ways how to realize this change. You can use some improved computer planning system, one of the top systems is Advanced Planning and Scheduling System (APS). Or you can use some kind of physical control system for reducing WIP on the shop floor such as kanban, CONWIP or other tools or combinations of these tools and planning systems.

Here, it is important to remember Little's law. This law (1) explains the relationship between WIP measured in number of pieces, throughput (TH) measured in number of pieces per time unit, and cycle time (CT) measured in time units most often in days (Hopp and Spearman, 2008):

$$WIP = TH \times CT. \quad (1)$$

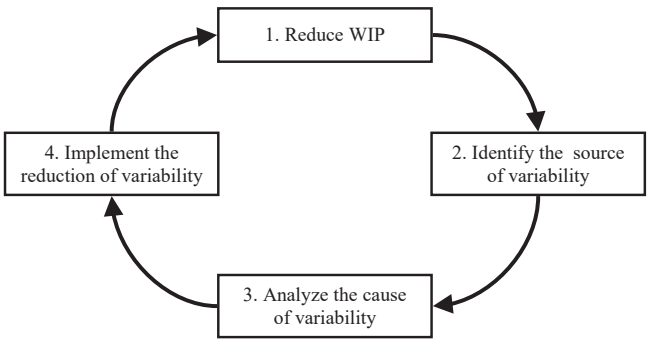
This formula came from queuing theory, when in 1961 John D.C. Little published his article about proof for the queuing formula (2):

$$L = \lambda W. \quad (2)$$

Here L represents the average number of items in a queuing system, λ stands for the average arrival rate of items to the system and W is the average waiting time of an item in the system. There is one big difference between these two formulas. It is throughput representing output in (1) and arrival rate representing input in (2) (Little, 2011). Our experience from real company showed us that this difference is really important. We can use (1) only in case that WIP meets special conditions, for example if there is a strict adherence to the First-In-First-Out (FIFO) system. Otherwise we should use input rate instead of throughput.

It is obvious from this law, that there is a direct correlation between the amount of WIP and production time. So it is good to analyze production times and look for potentials to reduce them. During this analysis it is important to remember that batch size dramatically influences the production times. Reduction of batch sizes in a production process can really shorten the production times and WIP. That is why one piece flow is considered as a top level of lean production.

Now we can see that to take control of WIP we have to focus on planning process, which is one of the most important processes in a production. This can help us with reducing of production times and WIP. When we reduce one of our buffers then we lose comfort of a safety "pillow" in the case that there occurs some variability in the system. In a conventional system there would be a buffer which would cover it and it is very likely that we wouldn't notice that there was some deviation in the system. But when we don't have this buffer, we can easily identify this deviation and the employees are naturally forced to solve it as fast as possible and to find the causes. This is a very crucial phase of the reducing of WIP. People and the system tend to build the buffers again, because it is easier to do it then to analyze the causes and change the system. We can recognize this situation in the moment, when the decreasing of WIP will stop or even worse, it will start to increase. To avoid this, it is time to use some tools of lean production for example like TPM in case of variability on the side of high failure of machinery or TQM in case of bad quality of production and other tools. To choose the right tool it is important to thoroughly analyze the reasons why we can't continue reducing the WIP and what the causes of variability are. When we are successful with the analysis and with implementation of the tool, we can see that the variability decreased and the system doesn't tend to build the buffers. In that case we can continue reducing the WIP. This cycle we should repeat again and again and we call it, in lean production terminology, continuous improvement (Fig. 1).



1: *The cycle of reduction of variability and WIP*
Source: Own work, 2015

RESULTS

We tested functionality of Little's law and reduction of WIP in real Czech production company Motorpal, a.s. We applied these principles in production of camshafts for injection pumps. This department is a typical jobshop production – there are many workplaces with different machines, around tens of types of camshafts are produced, and the sequence of workplaces differs based on the type of camshaft. Furthermore, there is no line, quite small batches, and setup times of some machines take up to a few hours. In the beginning, there were about 5 000 pieces of WIP in the production and it took 5 weeks on average to produce one batch. If you sumed all the operation times for one piece up, you wouldn't get more than a few minutes. Camshafts are one of the basic components for injection pumps. They are delivered straight to assembly line. Because of long production time, high WIP and other problems on the shopfloor they were the most problematic component. It happened many times that the assembly line was stopped due to missing camshafts.

The task was clear, to reduce WIP and prevent stopping the assembly line. We made a calculation of the potential reduction of WIP without negative influence on production flow of camshafts. We calculated that the potential without any changes in production (no application of TPM, SMED, 5S and other tools) is to decrease WIP to a half. The only changes in shopfloor management were the reduction of transport batches, and detailed planning and scheduling of the production (we used Excel without APS system). After one month of applying this new system, we reduced WIP to about 2 500 pieces and production time was 2.5 weeks. Thanks to this, we were able to build safety stock before assembly, so there was no stopping of the line due to missing camshafts.

The result was a 2.5-week reduction of production time only by change in the planning system and reduction of WIP. If we focused for example on setup times, we could save a few hours, maximum 1 or 2 days. It would probably take more time to implement and it could be expensive. From this point of view, it is better to start with reduction of WIP first.

This test confirmed the validity of Little's law in practice. After applying these changes in camshaft production, we applied it in the production of other parts with the same results. Based on that, we can assume the universal validity of this law and its principles. Another important result was that there is a big potential of reduction of WIP only with these principles. In every production, we were able to reduce WIP at least by half without applying other tools and without negative influence on production flow and deliveries to assembly. Moreover, we found possitive effects on the reliability of deliveries on time, saving capacity, and others. That is why we think that the first and the most important step in implementation of lean production should be reducing WIP.

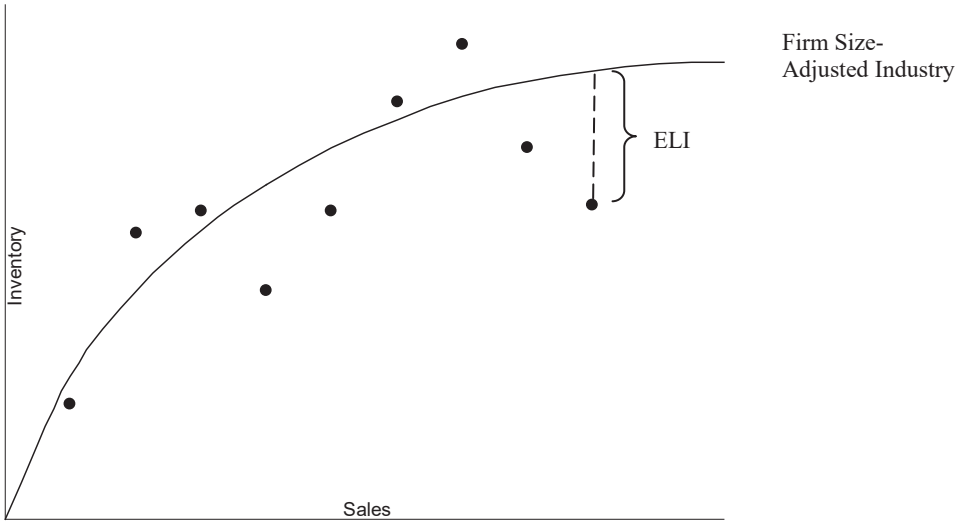
DISCUSSION

In the literature review we found that there are a lot of contradictions about definition of lean production and about the process of implementing it. So the question is "Do we know what we are trying to implement?" We think that many companies don't. A lot of authors and companies see the external signs of the system. They are trying to easily copy these signs by implementing some tools, but without deeper understanding of the philosophy hidden behind it and without knowing the reasons why Toyota and other successful companies did it that way.

If we want to be inspired by Toyota and implement lean production like they did, we think that it is more important to understand the situation in which they were before implementation. Understanding of this situation could show us the steps to implement lean production. Toyota and Japan weren't in an easy position after World War II. They had few resources, little money and big competitors on the markets. So they had to find the way how to beat the competitors with less money. This was their target in that time. They had to use their cash as effectively as possible. This is what we think is the philosophy behind lean production. If the company wants to be lean, it has to use working capital effectively. To do it, you have to turn the capital over as fast as possible. Money is effectively used if it circulates and generates more money. There is some amount of money needed in order for the production system to work properly. Lean production is a system that works with lower working capital than other conventional production systems.

This is thanks to the reducing of the size of buffers in the system and the costs of these buffers. Buffers are in the system to cover either the external variability or the internal variability of the system. External variability is generated by sources outside the company, the most frequently by the market and customers. For the company it is mostly hard to affect this variability. Internal variability is caused by random effects and the probability of the internal processes. This variability can company reduce.

These considerations lead us to the thought, like some other authors had (for example Tuček and Dlabač), that the tools which we use aren't important. Important is to improve the performance of the company. There are many ways of how to achieve this improvement and a lot of them can be successful. We think that common principle used in successful implementation of lean production is the reduction of buffers. It is not important which tools we use for this reduction, but if they work and generate required results. We don't say that tools like JIT, 5S, TPM and many others connected with lean production don't work, but first we have to know



2: *The sales-inventory relationship*
Source: Eroglu and Hofer, 2011

what our goal is. Then we can look for the way to achieve it and what tools to use.

We agree with Tuček and Dlabač that it is not possible to copy a production system literally "from one to another" and then wonder about its unsuccessful application and dysfunction. (Tuček and Dlabač, 2012). Every company needs a different approach to the process of implementation of lean production. There are many forces that can influence this process like an industry of the company, markets and company position, social and psychology aspects of the country and employees, and many others. So it is really more about the strategy and philosophy of a company but it is important not to forget why we do the changes and what our goals are.

We aren't sure that there is a universal framework how to implement lean production. We don't even think that this process has an end, when we can declare that the company has fully implemented lean production. There are more or less "lean" companies, but it is an endless process. Maybe because of this, the right definition is that lean production is a style of production management. Then we should focus on finding the modes of behavior and management style of people in lean companies, than finding the right tools or frameworks of implementation lean production.

In this paper we wrote about basic principles how we think that company can improve its performance through reducing the WIP. In our future research we would like to focus on finding tools, which can help managers to find the right way how to reduce WIP and to choose the right tools and steps, which will help to increase the performance of the company.

Another important thing connected with the lean production is measurement of implementation level. Since, as we mentioned, we don't think that the principle of the implementation of lean production is about implementation of the tools. And we don't think that it would be right to measure it as a level of using these tools. We expect that there would be some indicator, which could measure the level of leanness and the level of improving the production performance. Then we could compare different companies among themselves. Eroglu and Hofer used Empirical Leanness Indicator (ELI) for measuring inventory leanness (Eroglu and Hofer, 2011). This indicator measures a firm's deviation from size adjusted within-industry average inventory levels, which represents the level of inventory leanness of the company (Fig. 2).

We think that this could be the way to measure the stock buffer. The best indicator should be able to measure the size of all buffers. The question is how it should be constructed. In our future research we would like to focus on finding this indicator.

CONCLUSION

Lean production is a very popular philosophy of how to manage companies of all the branches of industry in the whole world. It is because the markets and the customers' demands rapidly changed in the last hundred years. And because there are big automotive companies whose performances amazingly increased after implementation of this production system. Lots of companies have followed these leaders, but still the mystery of successful implementation remains unknown. In this paper our goal was to analyze possible reasons. We used secondary data collection from the papers focused on lean production. We found that there is no clear definition what lean production is. And that there are many contradictions in the interpretation of what the main pillars of this system are. We think

this could be one of the reasons. We think, that another reason is, that there is no objective indicator of how to measure the level of implementation of lean production. That is why it is hard to evaluate which methodology works and which doesn't or which has a bigger benefit for the company than others. The last reason we discussed in this paper is that we think that lots of authors and managers confuse implementation of lean production with the implementation of a set of tools and they lose the focus on their target. We think that the target is to improve the performance through the reduction of the buffers in the system, especially the reduction of WIP. This reduces costs for the buffers and decreases requirements for working capital. We presented in this paper a really general point of view on this topic. Our goal wasn't to present the methodology for implementation of lean production. We wanted to present our main ideas and experiences from real company about lean production and possible ways for future researches about this topic.

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Contact information

Michal Medonos: medonos7@gmail.com
Marie Jurová: jurova@fbm.vutbr.cz