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**“**Increasing the Efficiency of "Gotek Northwest"'s Production Flow Using the SMED Tool**”**

Consulting project

Bachelor thesis by

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# Statement of substantive character of the course paper

I, Novikov Artyom, 4th year student of Graduate School of Management SPBU (faculty “International Management”), am confirming that my individual bachelor thesis on the topic of consulting project “Increasing the Efficiency of "Gotek Northwest"'s Production Flow Using the SMED Tool”, presented for public defense in June 2023 does not contain elements of plagiarism. All direct borrowings from printed and electronic sources, as well as from previously defended coursework and final qualifying works, candidate's and doctoral theses have corresponding links.

**Novikov Artyom** 30/05/2023

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# **Introduction**

Paper relevance and managerial value;

Gotek is one of the leading players in the Russian packaging market. The company is engaged in the development and production of packaging for large local and multinational companies operating in different business areas: from food manufacturers to companies providing a variety of services. The value of this work is due to the changing global trends in the packaging industry and trends in the introduction of lean tools and companies’ desire in the creation of their own production systems aimed at creating value for the customer. Due to covid-19 pandemic, increasing popularity of sustainability of the business and e-commerce development the packaging industry faced new global trends; demand for high variability and mass customization, increasing overall demand for packaging and its transportation features mainly due to e-commerce development, demand for flexible packaging, creating sustainable approach to packaging and rapid variability of customer desires ([Marinova V., 2021](#MarinovaV)). Moreover, companies pay a great attention to brand packaging which includes design trends, environmental requirements and opportunities for greater consumer awareness. In the production process companies lean toward the following trends: process automation, reduction of materials used, reuse of the same, naturally oriented design and construction, the ability to easily manipulate packaging throughout the logistics of packaging to the end user. As for sustainability, the new growing trend is for “smart” packaging, namely with a minimalist and simple design that minimizing the materials needed for production hence simplifies and cut costs for transportation. Augmented reality (AR) connects the packaging sector with new thinking and new lifestyles, showing that the industry is following the future trends ([Marinova V., 2021](#MarinovaV)).

One of the many definitions of lean production is to produce more efficiently using the resources and capabilities you have ([Womack et al., 1990](#Womack); [Eliyahu M. Goldratt, 2016](#Goldratt)). Today, in times of pandemics, economic crises, and the general trend toward de-globalization, lean thinking is one of the most effective solutions for business survival and prosperity. Over the past 25 years there has been a tremendous growth in the literature related to lean manufacturing. Research shows that the Lean concept is having a major impact on academics, professionals, and consultants ([Jasti, Kodali, 2014](#Jasti)). However, lean production is most adapted to developed countries and poorly adapted to developing countries, including Russia. Furthermore, lean research is more about a case study analysis rather than empirical researches and creation of systematic approaches, this is especially noticeable with one of the fundamental principles of lean but least studied - heijunka ([Boutbagha, Abbadi 2022](#Boutbagha)). That is why it is important to analyze different production systems of Russian companies and study their experience in implementing lean production tools.

Gotek responds to market challenges in a timely manner. The company has developed and is improving the platform for close interaction with the customer. The company focuses on shortening the cycle time of value creation; from customer request and co-design of packaging to its production and product delivery by pulling system (just-in-time). This company strategy is called the “fourth dimension”. The company explores hidden opportunities to provide the customer with added value at all stages: design, creation of solutions to the logistical challenges of packaging, production and delivery. Optimized packaging solutions help customers improve product margins - Gotek confirms it in practice. Gotek is engaged in in-depth research into all phases of packaging functionality, i.e. Gotek acts as an expert in creating packaging solutions, enabling customers to reduce R&D costs and create synergies that increase product quality and improve Gotek's competitive advantage. Moreover, the company created a packaging development lab, the 4D Lab. This solution allowed the company to reduce the development time from several weeks to a few days. The 4D lab allows customers to be present remotely during the development phase with a digital platform that has real-time capabilities to see the 3D model of the packaging and with Augmented Reality (AR) to see and test the finished product. Gotek offers companies the opportunity to reduce storage costs for packaging products by providing a just-in-time delivery system. The idea is that in this way the company does not take over the costs, but builds the production system in such a way that the production capacity corresponds to the demand, so as not to accumulate work-in-progress (one of the worst types of waste according to lean philosophy), which leads to even greater waste. Here come into play such concepts as production leveling (heijunka) and reduced batch sizes. These principles will be discussed further in details. In general terms, when a company builds its production system with small batch sizes, an increased number of changeovers is an unavoidable result, since several types of products/orders must be produced in one work shift and because different orders go through different process cycles, each requires different equipment. This is where the SMED (Single Minute Exchange of Die) method comes in. The point of the method is not to reduce changeover time simply for the sake of time reduction but to build a continuous flow of leveled production with small batch sizes. Thus, the SMED method is an inevitable and very important aspect not only of production, but also of the company's strategy as a whole, because it allows it to pursue its goals and bring value to the customer.

## Paper goal and objectives:

The goal is to developrecommendations to increase the efficiency of the Gotek Northwest SPO 1 line by using the SMED method.

Objectives:

* The theoretical foundation of the SMED methodology
	+ History of Lean Production. Basic principles
	+ SMED (Single Minute Exchange of Die) methodology
	+ Benchmarking analysis
* Collecting data. Analysis of current state of production system.
	+ Qualitative data. Conducting an interview with managers
	+ “Gemba walk”
	+ Collecting of qualitative data to analyze the current efficiency
* Practical application of the SMED method. Creating changeover maps for SPO production line.
* To assess the theoretical impact of SMED on OEE (Overall Equipment Effectiveness) indicator

## Managerial problem

Gotek has a very unique and complex technological process. It produces a huge variety of packages, they are distinguished in size, material, printed pictures, colors, etc. Moreover, the company works with customers on just-in-time delivery terms which forces them to produce in small batches which inevitably leads to high number of changeovers that consumes a lot of time hence the efficiency of the whole production flow is not as effective as it could be. Therefore, the company faces with the decreasing production volumes. The production line SPO 1, which is a target of the paper, is highly dependent on human factor. Taking into account the fact that SPO 1 can be an intermediate in the technological process, other production lines, which do not have human labor in them, are limited in their production capacity. Such a situation is called a bottleneck and inevitably leads to a drop in efficiency of the entire system. Additionally, bottlenecks lead to an unleveled flow, which means an increase in work in progress, downtime, overtime and defects. The company is facing the problem of downtime of downstream equipment due to the low performance of SPO 1, causing order delays. What is more, the SPO 1 is very old equipment, so it takes longer to readjust and the machine operators do not follow a standardized changeover plan, which leads to waste. The SMED system is the answer to these challenges, this system reduces the time for equipment changeover, which can compensate for problems caused by reliance on the human factor. The managers of Gotek gave me the task of analyzing the SPO 1 line according to SMED methodology, and to work on eliminating time losses during changeover.

# **Methodology**

As a basis of methodology I have chosen the “research onion” developed by [Saunders et al. in 2007](#Saunders). In the book “Research methods for business students” authors present research onion as a set of decisions you have to make in order develop a research methodology to conduct a study.



Figure 1. Research onion.

Source: [Mark Saunders, Philip Lewis and Adrian Thornhill 2011]

## Layer 1 – Research philosophy

The main research philosophy of this paper is pragmatism. Pragmatism highlights the importance of using the best tools possible to investigate phenomena. The main goal of pragmatism is to approach research from a practical perspective, where knowledge is not fixed, but instead is constantly being questioned and interpreted. For this reason, pragmatism includes an element of the researcher's involvement and subjectivity, especially when drawing conclusions from participants' responses and decisions. In other words, pragmatism is not committed to (or limited to) one particular philosophy. This paper is highly practical oriented and demands a high level of involvement in production processes of the company. Moreover, Gotek Northwest production system is very atypical and unique in terms of applying lean production tools. I did not find any case studies examining the SMED method in packaging companies, not only at Russian enterprises whose production system is similar to that of Gotek, but also at foreign ones.

## Layer 2 - Approach

There are two methods – **deductive** and **inductive**. Research approach is necessary in terms of forming a basis for decision making when selecting types of data collection and analysis. The **inductive** approach can be used when studying an unknown isolated community. Very little is known about this community, so a study must be conducted to gain information about the community, leading to the formation of theories. Inductive approach is closely connected with **qualitative** methods of data collection (textual, audio or visual data). **Deductive** approach takes a theory and never changes it, building further study unquestioningly following it. This approach deeply connects with **quantitative** methods (numerical data). For this study I have chosen inductive approach with the use of qualitative and quantitative data. This paper addresses unstructured interviews with managers and technologist of the company, visual data by shooting the changeover process on camera and “gemba walk” which is one of the most useful lean tools. Moreover, quantitative data of the previous and current time measurements of the changeover process is also used.

## Layer 3 – Methodological choice

This layer is about how many data types the paper uses (qualitative or quantitative). There are three options – mono, mixed and multi-method.

* Mono method implies that the paper uses either quantitative or qualitative data.
* Mixed method implies that the paper uses both qualitative and quantitative data.
* Multi method uses other approaches of collecting data such as thematic analysis and content analysis.[[1]](#footnote-1)

As explained earlier the paper uses mixed approach as quantitative and qualitative data is used.

## Layer 4 – Research strategy

I have chosen a case study research strategy. As described earlier, implementation of lean production tools is highly depending on studying the experience of other companies. Usually, the authors of books dedicated to lean production are managers or consultants of the companies where this concept is successfully implemented. They share their experience and create methodologies based on many cases.

This strategy is about an in-depth study of a single object, such as a person, group, or institution, or an event, phenomenon, or problem. In this type of research, the subject is analyzed to gain an in-depth understanding of problems in real-world settings. The goal here is to gain an in-depth understanding in the context of the study, rather than (necessarily) generalizing the findings. This strategy is tightly connected with qualitative method of collecting data and tends to be inductive.

## Layer 5 – Time horizon

The book describes two time horizons: **cross-sectional** and **longitudinal**. Cross-sectional captures the moment in history and describes it while longitudinal takes a longer scope and studies the subject throughout a long period of time. This paper examines the studied object in cross-sectional term.

**Layer 6 – Techniques and procedures**

This layer is about choosing a tools based on the previous decisions made considering philosophy, methods, strategy etc. The one should:

* Decide what data to collect and what data collection methods to will use (e.g. a survey? Or perhaps a one-on-one interview?)
* Decide how to sample the population (e.g., snowball sampling, random sampling, convenience sampling, etc.).
* Determine the type of data analysis to use to answer the research questions (e.g., content analysis or statistical analysis such as correlation).

Prepare the materials to use for the research (e.g., design survey or interview questions).

# Company description

Gotek JSC is one of the biggest players in the packaging industry in Russia. The Gotek Group is a multi-profile holding which main business is the development and production of packaging products. Over the past 20 years, the company has evolved from a regional player to one of the leaders of the Russian market. The total number of employees of Gotek Group is 2,172 employees. The company's customers are large, small and medium-sized local and foreign companies that operate in various industries from food, construction, pharmaceutical to the service industry. Some of the clients are: Nestlé, Mars, X5, Danone and many others. The company includes 3 business areas, namely:

* Gotek, Gotek Center and Gotek North-West are engaged in the design and production of corrugated board packaging.
* Gotek Print designs and manufactures offset printed packaging.
* Gotek Polypack develops the composition and manufactures flexible packaging materials with flexographic printing.

The company's financial results increased sharply in 2018, in 2017 Gotek carried a loss in net profit of 124.5 million rubles, but in 2018 the net profit was 1.5 million rubles, and in 2021 already 316.7 million rubles (a decrease of 1% compared to 2020)[[2]](#footnote-2). The main competitors of the company are “Ilim Group”, “YuzhUralKarton Factory”, “Smurfit Kappa” and “Remos Alfa”. Alexei Karpeshin, manager of production system development of Gotek Northwest, which is the object of the study, named two main competitors for this company - an international company, a leader in the European market Smurfit Kappa and a local manufacturer Remos Alfa. In a conversation with Alexei, I found out that the packaging market is changing a lot in the direction of high customization, hence the increased volume of nomenclature, the pulling system (just-in-time), i.e. customers often require delivery of a specific volume at a specific time and an overall increase in the volume of orders. The desire to gain a competitive advantage and to follow market trends, the company decided to enter the national project "Labor Productivity".

Moreover, the company approaches the challenges of the market strategically. Gotek is changing the way it interacts with customers by creating close communication at all stages of value creation, from prototype development to logistics solutions. “The market situation is changing, cost optimization is becoming an ever more stringent business requirement, the speed of life renewal is increasing, and production needs to respond quickly to these changes. So now every consumer of packaging needs a supplier who has expertise not only in production, but also in the use of the product.”, - Vladimir Chuikov[[3]](#footnote-3), Chairman of the Board of Directors of the Gotek Group of Companies. At this point, it's not enough to just produce packaging; companies need to create a product that will bring even more value to customers. According to Vladimir Chuikov, for multinational companies the old tender conditions are secondary compared to the supplier's philosophy and the solutions that the supplier is ready to offer in addition to the product or equipment. Hence the new global challenge is to become an expert, not just a supplier.

# History of Lean. Basic principles

 The concept of lean manufacturing first became widely known with “The Machine That Changed the World” and [“Lean Thinking” By James P. Womack](#Womack)[[4]](#footnote-4). These books are interesting from the standpoint of developing lean principles, but they do not show how these principles can be applied to other companies. [“The Toyota Way” by Jeffrey Liker](#liker)[[5]](#footnote-5) offered a more detailed description of the basic principles of lean and how to apply them. The book uses a pyramid model to show Toyota's approach. The base of the pyramid is a management that builds its decision making based on the long term, even if it has to incur financial expenses in the short term. The second layer relates to ensuring the right processes, namely the production flow should be leveled, be adjusted to the pulling system, there should be visual management to make problems immediately visible, and everything should be standardized. The next layer refers to relationships. The corporate culture of Toyota and every lean organization is built on mutual respect and growth when challenging tasks are set and results are achieved together. The apex of the pyramid refers to problem solving and continuous improvement when tools such as Kaizen and Genchi genbutsu are used.



Figure 2. The Toyota Way model according to Jeffrey Liker

Overall, Womack and Jones formulated 5 basic principles of the lean organization[[6]](#footnote-6):

1. Specify value from the standpoint of the end customer by product family.
2. Identify all the steps in the value stream for each product family, eliminating whenever possible those steps that do not create value.
3. Make the value-creating steps occur in tight sequence so the product will flow smoothly toward the customer.
4. As flow is introduced, let customers pull value from the next upstream activity.
5. As value is specified, value streams are identified, wasted steps are removed, and flow and pull are introduced, repeat this process again and continue it until a state of perfection is reached in which perfect value is created with no waste.



Figure 3. 5 principles of Lean Production.

Source: [Lean Enterprise Institute.]

When companies identified value for their customers and all the steps that create it, ones have to focus on creating flow and searching for processes that do not bring any value. According to Liker ([Liker, 2004](#liker)), organizations should focus on eliminating or at least reducing the following three M’s from their processes and the way of work:

* **Muda**, waste
* **Mura**, unevenness
* **Muri**, overburden

One of the founder of TPS – Taiichi Ono was an adept at fighting with unproductive waste (muda), that is, reducing any activity that consumes resources but does not add value to the end consumer. To do this, the first step is to identify the operations that add value and minimize cost for the rest of operations. Taiichi Ono identified seven main groups of waste ([Ohno, 1988, p. 42-43](#Ohno)). The eighth group was formulated by Jeffrey Liker. This type of waste has also become canonical for lean manufacturing. Here are main groups of waste:

1. Overproduction. Production of items for which there was no order leads to excess inventory and generates losses such as excess labor and storage space, as well as transportation costs.
2. Waiting. Workers who watch automated equipment work are idle waiting for the next operation, tools, parts, etc., or simply sitting idle due to missing parts, delays in machining, equipment downtime and lack of capacity.
3. Excessive transportation or relocation. Moving work in progress over long distances, creating transportation inefficiencies, and moving materials, parts, and finished goods to and from the warehouse.
4. Over-processing. Unnecessary operations in the machining of parts. Inefficient machining due to poor tool quality or poor design that leads to unnecessary movements and defects. Losses caused by excessive quality requirements.
5. Surplus Inventory. Excess raw materials, work in progress or finished goods increase lead times, cause product obsolescence, result in damaged finished goods, transportation and storage costs, and cause delays and procrastination. In addition, excess inventory prevents detection of problems such as production imbalances, delivery delays, defects, equipment downtime and long changeovers.
6. Excessive movement. All the unnecessary movements that employees have to do in the process of work: searching for what is needed, having to reach for tools, parts, etc. or to deal with their packing. This also includes walking.
7. Defects. Production of defective parts and correction of defects. Repairs, rework, waste, product replacement and inspection result in wasted time and effort.
8. Unrealized creative potential of employees. Loss of time, ideas, skills, opportunities to improve and gain experience due to inattentive employees who managers don't have time to listen to.

**Muri** - overloading of people or equipment. In a sense, it is the opposite of muda. Muri forces a machine or person to operate at its maximum capacity. Overloading people threatens their safety and causes quality problems. Overloading equipment leads to accidents and defects ([Liker, 2004](#liker)). **Mura** is the result of the first two M. At times there is more work in normally functioning production systems than specialists and equipment can handle, and sometimes there is not enough work. The cause of the unevenness is an improper schedule or fluctuating production volumes caused by internal problems, such as downtime, missing parts, or defects. Muda is the result of Mura. Uneven production levels cause the need to match the available resources (equipment, materials, people) to the maximum amount of production, even if in fact its average level is much lower ([Liker, 2004](#liker)).

When implementing lean production tools, every organization focuses specifically on reducing muda, without giving proper attention to mura. As Liker points out, this is a wrong approach because without an evenly balanced flow, any waste reduction is meaningless. The concept that requires a production flow leveling is called Heijunka. The realization of this principle is a condition for the elimination of mura, which, in turn, is necessary for the elimination of muri and muda. [Eliyahu M. Godratt's “The goal: A process of ongoing improvement”](#Goldratt) perfectly describes the process of creating a leveled production flow. One of the results of leveling is a reduction in batches and an increase in the number of models produced. Indeed, many tools are used in the leveling process, not only from the lean philosophy, but from the general principles of operations management, however, Goldratt, Liker, Womack and many other lean specialists point that SMED method is an essential tool in creating a leveled production flow which in turn is a necessary step to reduce other types of waste and create a lean organization.

## SMED method

Single Minute Exchange of Die is a process for changing over production equipment from one part number to another in as little time as possible. This tool was developed at Toyota to reduce the batch size of manufactured products between changeovers. High changeover times required working in large batches, which resulted in a huge amount of inventory, higher handling costs (moving, transporting, accounting, operating, maintaining warehouses, etc.), not to mention the capital frozen in that inventory. Shigeo Shingo, Toyota’s engineer, in 1950s-1960s developed a methodology which helped Toyota to reduce changeover time and produce in small batches. Later, he wrote [“A Revolution in Manufacturing: The SMED System”](#Ohno) which became a “bible” for each manager who wanted to implement this tool. This tool allows to get rid of several types of waste not just by reducing the changeover time itself and increasing the load of the adjuster, but precisely by reducing the batch size and the number of stocks. From the lean point of view, there is no point in reducing changeover time and continuing to work in large batches, it is a waste of time and money. The main goal of this tool is to reduce the batch size between changeovers as much as possible. The goal is achieved by increasing the number of changeovers by reducing their duration while keeping the time available for changeovers constant. Therefore, this method brings the following advantages: reduced work-in-progress which is a reduction of investment and production costs, less occupied space, less work that does not add value, reduction of the risk of injury, etc. In addition to reduced inventories, more changeovers lead to shorter lead times, i.e. faster release of investment and customer satisfaction. Shigeo Shingo based the tool on the fundamental division of changeover actions into internal and external.

* Internal changeover - part of the changeover operations, which are performed when the equipment to be adjusted is stopped.
* External changeover - part of the changeover operations, which are performed during the production of valid products on the equipment to be adjusted.

In the initial situation, the changeover process is usually not optimal (there is no distinction between external and internal work, preparatory time has large variations, there is no methodology for changeover, not to mention standards). This is a typical situation in average enterprises that have not used SMED. From this initial situation begins a five-step procedure:

1. Examination of the current situation. The whole changeover process is timed (from the end of production of the product "A" to the beginning of production of the product "B"), all actions are recorded in the smallest details (took, fastened, moved, etc.). It is recommended to shoot the current changeover process on video for the convenience of subsequent analysis
2. Separation of internal and external operations. In this step the analysis is performed: all recorded actions are classified into internal and external, as well as those that must be done before, during and after the stop of the equipment. This stage examines two important aspects:
	1. reevaluate the internal setup operations to check or see if some of them were considered erroneously as internal;
	2. and search for alternatives that allow internal setup to be carried out in whole or in part as external operations, with the machine working ([Jagdeep Singh et al., 2017](#Singh)).
3. Conversion of internal work to external work. Analysis continues, highlighting those actions that can be performed without stopping the equipment (pre-assembly, adjustment, warming up, preparation of tools, tooling, etc.)
4. Reduction of internal works. Development of solutions to eliminate corrections, adjustments, simplified fixtures, parallel work, etc. At this step it may be necessary to change the design of tooling and fixtures, which may require a significant investment
5. Reduction of external work. Development of solutions to improve logistics (delivery of equipment, fixtures, tools, etc.), improve maintenance, reduce travel, etc.

Thus, by a simple logical analysis, even if a company does not invest in design changes or fixtures (fasteners, etc.), it can find enormous potential for improvement in any changeover process. Even the simplest analysis, with maximum internal-to-external conversion and standardization of the result, can help significantly reduce changeover time and stabilize the process. Despite the existing myth that the implementation of lean requires absolutely no costs, this tool is by right the most costly, since a significant part of the potential for reducing changeover time is realized by changing the design (fixtures, fixtures, etc.), i.e. after investing certain funds. The result of the analysis and decisions made should be a changeover standard that clearly defines the sequence of operations, setup and startup parameters, the time needed and the means of implementation (tools, tooling, etc.). Of course, the changeover standard must be supported by managers, i.e. managers must make sure that nothing prevents them from following the standard and monitoring compliance with it. The results of the SMED work should be as follows:

* Standardized optimal sequence of actions for changeover, including preparatory work, direct change of tooling (tool).
* Standardized time of changeover.
* Standardized places and ways of tooling delivery and external operations performance.

Usually the company conducts several cycles of SMED application, such as in the case of the study object, to ensure that workers meet the standards and really spend standardized time, it is possible that the reanalysis may reveal additional solutions to improve.

## Benchmarking analysis

As mentioned above, many studies in the field of lean production are based on case studies. Since lean production is essentially an adaptation of TPS, experts study the experience of other companies to create a relatively systematic approach to the application of various lean tools. Therefore, in order to apply the SMED tool more effectively and to delve more deeply into the practical part of this work, it is necessary to carry out the benchmarking analysis.

One of the interesting case studies is done in a company in the Republic of Serbia called Trim Ltd operating in labeling industry ([Jovana Nikolić et al., 2022](#Nikolic)). The case is interesting in terms of assessment of the current state of changeover and of the result of implementing SMED. The article suggests OEE (Overall Equipment Effectiveness) indicator presented by Nakajima (1988) in the context of Total Quality Management as a key indicator on equipment/machine working characteristics. It measures the capability of the machine to produce a product unit of demanded quality within a defined term in order to secure customer loyalty ([Jovana Nikolić et al., 2022](#Nikolic)). The concept of OEE is a method serving for improvement of business performance, whereby the main focus is on achieving quality, productivity, and availability of equipment and reduction of all activities without values in the Lean production environment (Nelson Raja & Kannan, 2010). One of the main goals of OEE concept is the reduction or elimination of so-called six big losses (failure, setups, small stoppages, speed reduction, the impossibility of movement and discarding production). OEE represents a complex indicator obtained as a product of the following three factors (Gonzalez, 2017):

OEE = *Availability* \* *Performance* \* *Quality*

*Availability (A)* is a function of working time and loss of stoppage. It takes into account Equipment Failure (unplanned stops) and Setup and Adjustments (planned stops) from the Six Big Losses. It equals to relation between the time period in which the machine actually operates and the total time during which the machine should be in operation.

$$(A)=\frac{Operating Time}{Plan Production Time}$$

*Performance (P*) takes into account Idling and Minor Stops (small stops) and Reduced Speed (speed loss) from the Six Big Losses[[7]](#footnote-7). It is obtained relating the real capacity to the ideal capacity of the machine.

$$(P)=\frac{Net Operating Time}{Operating Time}$$

*Quality (Q)* It takes into account Process Defects (production rejects) and Reduced Yield (startup rejects) from the Six Big Losses*.* It is a ratio of Fully Productive Time and Net Operating Time.

$$(Q)=\frac{Fully Productive Time}{Net Operating Time}$$

OEE represents the ideal indicator for comparing the initial state of the machine performance and the state when some improvements are achieved in the case of the article.

# Empirical research results

## Description of “Gotek Northwest” case

Gotek Northwest manufactures corrugated cardboard packaging products. The factory creates blanks from materials provided by suppliers, process it and stores finished products. Three years ago, Gotek joined the national project "Increasing Labor Productivity. Together with the specialists of the Federal Center of Competences there was conducted work on the analysis of the stream of value creation and the application of methodologies on the implementation of lean production tools[[8]](#footnote-8). Visual management tools and the 5S system are successfully implemented and is improving in the production room. Visual management boards are also used in the main decision-making office. Management conducts systematic training of employees on the TPM (Total Productive Maintenance) and 5S system. Measures are taken to attract employees to Kaidzen, namely, employees are encouraged for suggestions to improve workplaces, methods of work, elimination of waste, etc. Moreover, because of the specifics of production, which will be discussed later, SMED tools are used to reduce changeover time. Now the plant is aimed at the full implementation of the TPM system and in the future to create its own production system.

I did a series of unstructured interviews with the director and deputy director of production system development, Alexei and Dmitry. It is these people who are engaged in the implementation of lean tools, are responsible for training workers and know the entire production process perfectly. Dmitry and Alexei used to work as ordinary operators on production lines, so they know well what problems workers face and what the production flow consists of. They also have access to performance indicators of each production line.

As there is no information about the production system of Gotek Northwest a series of unstructured interviews were conducted to gather general information about the current stage of implementation of lean tools, organizational structure, relationships with suppliers and customers, future plans and finally the production process. My research limitations were also discussed. The fact is that production system development managers deal directly with the workshop itself and are not integrated into the affairs of the procurement department, which directly communicate with the customers themselves, and into the logistics of the finished product warehouse. Therefore, my powers were limited only to the production workshop.

A “gemba walk” and discussion with the managers helped me to create a scheme of the production flow. The figure below shows the technological process steps, from materials to finished products (figure 4). Each production line, namely BHS corrugator, Ward 1, Ward 2, SPO 1, SPO 2, RDC, PRT, FSA 1, FSA 2 plays its unique role in creation of final product. Each line has several teams and one team leader, which is responsible for performance and execution of the plan of all the teams. The number of teams depends on the size of the machine and the volume of products produced. For example, BHS is the largest machine because all the materials go through it and it has 7 teams, at the same time, SPO 1 line responsible for creating folds on blanks and breaking a large sheet of packaging into several small hence this machine is smaller and requires 3 teams. On each line there is a hub with a visual management board, on which the goal for the month and for the shift is recorded, next to these values the team leader enters the actual data on the work performed and reports to the meeting, which is held once a week. These meetings discuss results, solve problems and set new goals and objectives. The meetings are attended by team leaders, technologists, managers for the development of the production system, the director of production and the head of the quality service. The main KPI of the efficiency of the production line and the entire production is the number of produced square meters of products as well as the number of orders completed by day, week, month and year. This KPI was chosen due to the wide variety of orders. Due to the fact that orders can differ in the size of packages, it would be impractical to measure efficiency in units over a certain period of time.



Figure 4. The technological process of Gotek Northwest

## Current state analysis

The complex specificity of Gotek Northwest production lies in a very large nomenclature, that is, customers order different packages not only in size, but also in the shape of the folds, in printed pictures and in colors. Moreover, materials can also differ, and at the same time, additional equipment configuration is required.

*“We work with a very large variety of products, we have thousands of types of packages and almost each of them requires equipment changeover. But despite this, the main tasks for us are to produce products with high quality and on time.”, - Dmitry, manager of the production system development.*

One day, having attended the training of workers on the TPM system and training on creating proposals for improvement, we went to the SPO 1 production line along with the workers and the manager who conducted the training, which is actually a “gemba walk”. SPO 1 is relatively small machine responsible for creating folds on blanks and breaking a large sheet of packaging into several small. However, the process of breaking a sheet is fully performed by a worker. This causes several problems that lead to a decrease in the efficiency of this machine: firstly, the worker gets tired, since this is a very laborious work, and can be quickly injured, which leads to additional costs, secondly, product quality deteriorates, thirdly, productivity decreases because the speed of the machine is artificially reduced so that the worker has time to break the sheets produced, and considering the following technological process machine, which uses an automatic breaker and does not need a human, this leads to the creation of the so-called bottleneck, which leads to uneven flow.

*“Yes, we are well aware that this is wrong, that there is a very heavy burden on the employee. Injuries can occur and even sometimes have occurred. Plus, quality problems… hence the overall efficiency of the machine falls. But, unfortunately, management does not yet plan to buy another SPO 2, there is an investment plan in far future, but it is not implemented soon.”*

Analysis of other machines showed that they are all independent of the human factor. The output power of the line depends solely on the power of the machine. The problem is aggravated by the fact that some orders can use SPO 1 as intermediate processing, i.e. other production lines depend on the employee who manually breaks the sheets of cardboard, this leads to the accumulation of work in progress before SPO 1, downtime of the following production lines and an increased percentage of scrap, since defects are visually inspected and some defective parts can be overlooked. One day when we were measuring the changeover of SPO 1, the technologist Andrei said that "*it often happens that the next machine in the process is idle because of the slow performance of SPO 1, today, for example, the next machine was idle for an hour and in the result the planning department had to cancel the order*." Therefore, the managers gave me the job of applying the SMED method on SPO 1 to compensate for the problems caused by the human factor and to give the machine more operating time, which will lead to improved efficiency. I was paired with a technologist with whom we will go through all five stages of the SMED methodology, find solutions to reduce the changeover time and standardize the results.

Managers shared with me a quantitative data describing the current state of changeover as well as standardized activities that have to be done by workers. As seen below (Table 1 and 2), 3 operators are working in parallel, each performs slightly different operations. That is why total changeover time is a time of the longest operation, not a sum of all the operations.

 *Table 1*

Initial changeover data when the stamp wasn’t used, with creasing dies installed

|  |  |  |  |
| --- | --- | --- | --- |
| **Performer/time to carry out operations** | **Actions performed** | **Total changeover time by the operator** | **Total changeover time** |
| **№1. Forging Machine Operator (Team leader)** | Remove breaking tools | Install breaking tools | Preparing the counter plate for installation and its installation | Idle running of the die | adjusting of the breaking section | Die-cutting stamp correction. Quality control of produced product |   | 1680 |
| Time to perform, sec | 120 | 180 | 420 | 300 | 120 | 540 | 1680 |
| **№2. Forging Machine Operator** | remove the die-cutting stamp  | Install the die-cutting stamp  | Preparing the counter plate for installation and its installation | Idle running of the die | adjusting the crucible press | Die-cutting stamp correction. Quality control of produced product |   |
| Time to perform, sec | 120 | 120 | 480 | 300 | 120 | 540 | 1680 |
| **№3. Forging Machine Operator** | Remove the front waste removal bar | Install the front waste removal bar | Setting up the receiving table. Placement of the workpiece on the infeed conveyor | Preparing the counter plate for installation and its installation | Idle running of the die | adjusting the pack formation section | Die-cutting stamp correction. Quality control of produced product |   |
| Time to perform, sec | 60 | 60 | 120 | 480 | 300 | 120 | 540 | 1680 |

Table 2

Initial changeover data when the stamp was used

|  |  |  |  |
| --- | --- | --- | --- |
| **Performer/time to carry out operations** | **Actions performed** | **Total changeover time by performer** | **Total changeover time** |
| **№1. Forging Machine Operator (Team leader)** | filling in order data | Remove breaking tools | Install breaking tools | adjusting of the breaking section | Die-cutting stamp correction. Quality control of produced product |   | 840 |
| Time to perform, sec | 60 | 120 | 180 | 120 | 360 | 840 |
| **№2. Forging Machine Operator** | Setting up the receiving table. Placement of the workpiece on the infeed conveyor | remove the punching mold | Install the punching mold | adjusting of the breaking section | Die-cutting stamp correction. Quality control of produced product |   |
| Time to perform, sec | 120 | 120 | 120 | 120 | 360 | 840 |
| **№3. Forging Machine Operator** | Remove the front waste removal bar | Install the front exit bar | Cleaning of technological waste | Preparation of pallets, corners, re-laying | Fitting the stack forming section | Die-cutting stamp correction. Quality control of produced product |  |
| Time to perform, sec | 60 | 60 | 120 | 120 | 120 | 360 | 840 |

In total, four initial states of the machine are distinguished before changeover:

* Changeover when the stamp was used
* Changeover when the stamp wasn’t used
* Changeover when the stamp was used, with creasing dies installed
* Changeover when the stamp wasn’t used, with creasing dies installed

In the case of SPO 1 we considered a changeover when the stamp wasn’t used, with creasing dies installed and when the stamp was used because these are the most frequently performed changeover and the most time-consuming. Moreover, they include all the actions that are required for other types of changeovers and all the improvements will work on other types as well.

## The 1st step of SMED method. Examination of the current situation.

Together with the technologist and the SPO 1 team leader we conducted an analysis of the current changeover process by timing all the actions performed by operators, shooting video of changeover works and filling all the information into the special form. In total we have captured 4 changeovers that are divided into two types – the 1st changeover (the stamp was not used, with creasing dies installed) and the 2nd changeover (the stamp was used). During changeovers 3 operators were working, each of us was following the actions of one operator. Below are the changeover forms of two of the workers for each type of the changeover. For technical reasons, managers were unable to share video of the 1st operator with me, so his actions are not included in the changeover tables, but we were able to get video footage from the video cameras in the shop, from which the current changeover maps (for each changeover) can be compiled.

Table 3

Actions of the 3rd operator during the 1st changeover (the stamp was not used, with creasing dies installed)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| № | Action  | Type of operation | Time, sec |   |  |
| 1 | remove the counter plate | internal | 67 | 00:00-01:07 |  |
| 2 | waiting | internal | 12 | 01:07-01:19 |  |
| 3 | Remove the breaking tools | internal | 79 | 01:20-02:39 |
| 4 | Install the breaking tools | internal | 90 | 02:39 - 04:11 |
| 5 | Walking, waiting | internal | 36 | 04:11 - 04:47 |
| 6 | adjusting the breaking section | internal | 64 | 04:47 - 05:51 |
| 7 | Walking, waiting  | internal | 49 | 05:51 - 06:40 |
| 8 | Helping to prepare the counter plate for installation and its installation | internal | 57 | 06:40 - 07:37 |
| 9 | removal of stamps from the counter plate | internal | 58 | 07:37 - 08:39 |
| 10 | Idle running of the die (it has to be 300 sec), preparing for the next changeover  | internal | 244 | 08:39 - 12:43 |
| 11 | Waiting while other worker is adjusting the crucible press | internal  | 153 | 12:43 - 15:16 |
| 12 | Decides to help to adjust the crucible press  | internal | 126 | 15:16 - 17:22 |
| 13 | Die-cutting stamp correction. Quality control of produced product | internal | 1224 | 17:22 - 37:46 |  |
|  |  |  |  | 37:46 min | Total  |

Table 4

Actions of the 2nd operator during the 1st changeover (the stamp was not used, with creasing dies installed)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| № | Action  | Type of operation | Time, sec |   |  |
| 1 | install the counter plate | Internal | 37 | 01:22 - 01:59 |  |
| 2 | Preparing the punching mold for installation and its installation | internal | 180 | 01:59 - 04:59 |  |
| 3 | Waiting  | internal | 68 | 04:59 - 06:07 |  |
| 4 | adjusting the pack formation section  | internal | 16 | 06:07 - 06:23 |  |
| 5 | Waiting  | internal | 18 | 06:23 - 06:41 |  |
| 6 | Preparing the counter plate for installation and its installation | internal | 153 | 06:41 - 09:14 |  |
| 7 | Idle running | internal | 488 | 09:14 - 17:22 |  |
| 8 | Die-cutting stamp correction. Quality control of produced product | internal | 1224  | 17:22 - 37:46 |  |
|  |  |  |  | 37:46 min | Total  |

Table 5

Actions of the 2nd operator during the 2nd changeover (the stamp was used)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| № | Action  | Type of operation | Time, sec |   |  |
| 1 | remove the punching mold | internal | 116 | 00:00 - 01:56 |  |
| 2 | Waiting  |   | 22 | 01:56 - 02:18 |  |
| 3 | install the punching mold | internal | 85 | 02:18 - 03:43 |  |
| 4 | Install the breaking tools, delegating the work to another worker | internal | 25 | 03:43 - 04:08 |  |
| 5 | adjusting the machine | internal | 82 | 04:08 - 05:30 |  |
| 6 | Help to solve the defect with the breaking tools | internal | 90 | 05:30 - 07:00 |  |
| 7 | Waiting  | internal | 66 | 07:00 - 08:06 |  |
| 8 | setup of the receiving table | internal | 192 | 08:06 - 11:18 |  |
| 9 | Die-cutting stamp correction. Quality control of produced product | internal | 1970 | 11:18 - 44:08 |  |
|  |  |  |  | 44:08 min | Total |

Table 6

Actions of the 3nd operator during the 2nd changeover (the stamp was used)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| № | Action  | Type of operation | Time, sec |   |
| 1 | Waiting  | internal | 60 | 00:00 - 01:00 |
| 2 | Filling order data into the computer | internal | 175 | 01:00 - 03:55 |
| 3 | Waiting  | internal | 84 | 03:55 - 05:19 |
| 4 | setup of the receiving table | internal | 49 | 05:19 - 06:08 |
| 5 | adjust the die-cutting stamp | internal | 84 | 06:28 - 07:52 |
| 6 | setup of the receiving table | internal | 78 | 07:52 - 09:10 |
| 7 | adjusting the pack formation section | internal | 58 | 09:10 - 10:08 |
| 8 | Cleaning of technological waste | internal | 70 | 10:08 - 11:18 |
| 9 | Die-cutting stamp correction. Quality control of produced product | internal  | 1970 | 11:18 - 44:08 |
|  |  |  |  | 44:08 min | Total |

Firstly, all the actions were performed while the machine was turned off so all the actions refers to an internal type. Secondly, as it can be seen from the tables, in average changeovers took 41 minutes which is 13 minutes more than the data the managers provided (see table 1 and 2). Moreover, by observing the workers and analyzing the video footage, it became clear that the workers were not following the standards and a certain sequence of actions that had been set. During the 1st changeover, for example, after the worker removed the punching mold he handed over the installation task to the first operator and began the action that the third operator had originally planned to perform. Hence, the operator took 12 seconds to coordinate the next actions with other workers. Additionally, the last step of changeover takes up most of the total time – 54% and 74% respectively. This due to the poor condition of the machine and the need to produce a small batch of product in order to monitor the quality of the packaging. If defects are found, the machine has to be stopped again, the crucible press has to be retracted and adjusted so that there are no defects. The problem is exacerbated by the fact that the initial cardboard blanks often do not have the same moisture characteristics, which leads to the fact that it is necessary to run test batches because the workers never know how the machine will behave. This problem is one of the biggest in the plant because the moisture depends on the materials that the suppliers supply and the seasonality. Dmitriy, production system development manager, said that suppliers produce materials with inconsistent moisture content due to imperfect production technology, so Gotek only works with those that produce materials with a minimum moisture content variation of 1%-2%. In addition, the BHS machine that processes raw materials into sheets of cardboard has a special module that can temporarily equalize the moisture, but it doesn't completely eliminate the problem. Seasonality lies in the fact that at different times of the year the raw material is exposed to different temperatures and humidities. For example, in summer it is very hot and humid, and in winter it is dry and cold and this greatly affects the carton blank that goes through the SPO. All of these factors make it impossible to create a standard for the last stage of changeover.

Thus, based on the tables of actions of workers and measured time, as well as video from cameras in the shop, it is possible to build current changeover maps (Table 7 and Table 8).

Table 7

The current changeover map of the 1st changeover (the stamp was not used, with creasing dies installed)



Table 8

The current changeover map of the 2nd changeover (the stamp was used)



## The 2nd step of SMED method. Separation of internal and external operations.

It is important to notice that some activities that help to prepare workers for the changeover are done while the previous order is producing, i.e. management created a special wagon that carriers all the necessary breakout and cutting stamps therefore workers without spending much time can easily take them and install into the machine. However, because of uncoordinated actions among workers they do these actions during the changeover and idle running hence spend time for walking. Idle running of the machine is a “checkpoint” reaching which workers must wait a certain amount of time. Idle running must last at least 5 minutes in order to “warm-up” all the machine’s mechanisms. Therefore, we can consider idle running as an external work during which workers can perform other useful activities. It is also important to organize the changeover work so that 3 workers at the same time come to this "checkpoint" spending a minimum amount of time and performing coordinated, standardized actions and move some useful actions to the period of idle running (figure 5).



Figure 5. A changeover process

## The 3rd step of SMED method. Conversion of internal work to external work.

Through dialogue with the Gotek technologist and observation, we found out that the initial changeover map that the managers provided and the current changeover maps have actions that can be carried over to the idle period of the machine. These actions apply to both the current changeover and preparatory actions for the next one:

* Receiving table setup, placement of the cardboard on the infeed conveyor. Currently, this action can be found in the initial changeover maps ([Table 1](#Table1) and [Table 2](#Table2)) and in the current ones ([Table 7](#Table7) and [Table 8](#Table8)). The receiving table is needed only when die-cutting stamp correction is started. Therefore, if this action is performed during idle running, it can save about 175 seconds, which is 7.18% of the total changeover time in average.
* Preparation of tooling for the next order (delivery of the die from the wagon and back, installation of the die in the frame, installation of the seasoning sheet, installation of the front waste removal bar). In the case of the 1st changeover ([Table 7](#Table7)) these actions were done during the idle running, however, due to the lack of experience of one of the workers, the process of setting the seasoning sheet was delayed, so that the idle time lasted 488 seconds instead of 300 seconds as it should have been. The problem is that these preparatory actions are not included in the standard changeover and the workers themselves take the initiative not to lose more time on the next changeover, but their movements are chaotic and uncoordinated, which leads to a loss of time. The solution is to put these actions into the standard and train the workers (this will be discussed later in the paper). This can save 188 seconds which is 8.4% of changeover time in average. In the case of the 2nd changeover ([Table 8](#Table8)) because it does not need idle running, preparatory work is done by the 1st operator which included delivery of the die from the wagon and back and installation of the die in the frame. By the time the operator has performed these actions the die-cutting stamp correction had begun and he had to participate.
* Preparation of the zone at the product output. This action involves preparing the trays for the finished product.
* Cleaning. Cleaning is part of the 5S system and allows workers to keep the workspace clean, which reduces time searching for items and increases comfort.

Therefore, these actions can be performed while the machine is idling in the case of the first type of changeover or they can be added to the duties for one of the workers in the second type. To further analyze the changeover, a spaghetti diagram must be drawn to identify the movement patterns of workers during the changeover and to reduce undesirable actions in the internal work. It will also help delegate identified external work and build less time-consuming changeover maps.

## The 4th step of the SMED method. Reduction of internal works.

An analysis of the recorded video and video from CCTV cameras in the shop allows to build a spaghetti diagram that shows the movement of operators during the changeover. Below is the spaghetti diagram of the 1st and 2nd types of changeover (Figure 6 and 7), where:

1 – the finished product output zone;

2 – the section where the breaking tools are installed;

3 – the section with a counter plate, where the punching mold is installed;

4 – the machine control panel;

5 – the receiving table, infeed conveyor;

6 – the breaking section adjustment area;

7 – the computer with order data;

8 – the storage space for stamps;

9 – the platform for the installation of the punching mold;

10 – the carriage on which the stamps are stored;

Orange – the 3rd operator

Green – the 2nd operator

Black – the 1st operator



Figure 6. The current spaghetti diagram of the 1st changeover



Figure 7. The current spaghetti diagram of the 2nd changeover

The diagrams show that the movements of workers are chaotic and uncoordinated. Many sections are approached by several workers, which increases the time to move and harmonize actions. The following pattern of behavior has also been observed: when the first operator finishes work in his section and waits for the second operator to complete his task, he comes up with an activity that takes a longer time than the second operator needed to finish his task. The second operator, who is already free, notices that the first one is performing a new task therefore comes up with an activity that again takes more time, and so on. This creates a snowball effect that leads to lost time and delays. During the first changeover, this pattern was observed during the idle time of the machine when the 3rd operator started preparing the stamps for the next order, the 2nd operator started setting up the counter plate and due to inexperience took a long time to lay out the seasoning sheet, noticing this 3rd operator wasted time moving around, talking and checking the stamps in the storage area. In the case of the 2nd changeover, the 2nd operator, having completed his tasks and waiting for the other operators, went to help the workers to another nearby machine, wasting 66 seconds in the process ([Table 8](#Table8)).

The changeover analysis also showed that the main working sections are 2, 3, 9, 6 and 5. In sections 3 and 9, workers set up the punching mold, prepare the counterplate, and adjust the die cutting stamp. in sections 2 and 6, workers replace the breaking tools and correct the stack forming zone. in section 5, workers set up the receiving table and form the cardboard stacks for the entry into the machine. These areas are the most important for the beginning of the idle run and the last phase of changeover, and therefore the most time-consuming. It has also been observed that 2 workers can handle all the tasks, if they are experienced enough. The third worker is mainly involved in assisting the others, performing minor actions and preparing the stamps for the next order. In the second changeover, for example, due to the lack of idle running, the first operator mainly performed preparatory actions for the next changeover and only joined the others in the last die-cutting correction step.

Additionally, with the help of current changeover maps, it is possible to calculate how much time workers spend at each section. In the first case, sections 1, 2, 6, and 7 took 330 seconds of working time. This includes 36 seconds of walking to section 6 and working there for 64 seconds, 170 seconds to install the breaking tools, and 60 seconds to work with the computer. Sections 3, 4, 5, 8, 9 and 10 took 353 seconds. Which includes setting up the counter plate with the punching mold in 257 seconds, transferring the used stamps to the wagon in 80 seconds, and setting up the receiving table in 16 seconds. Thus, taking into account the weaknesses of the current working system, the identified destructive patterns of behavior and the time spent on work in each section, it is possible to build a new changeover map (Table 9) and a spaghetti diagram of the 1st changeover (Figure 8).



Figure 8. The new spaghetti diagram of the 1st changeover

In this case the workspace is divided into two zones: yellow and green. Each consumes about the same amount of time:

* Orange works in the yellow zone, wastes no time going from 8 to 10, eventually comes to section 3 to start the die-cutting stamp adjustments. Performs preparatory actions for the next order (during idle time) only in this zone.
* Green works in the green zone, does not waste time going to the computer, helps carry stamps from 8 to 10, and spends most of his time working on the counter plate and the punching mold, additionally does preparatory work only in this zone.
* Black acts as a coordinator and controls the quality of the work done in sections 2 and 3, prepares the machine for idling, and helps with sections 5 and 7. During the idle run, he makes sure that the workers finish the preparatory actions within the required 300 seconds.

As a result, the following changeover map can be constructed:

Table 9

The new changeover map of the 1st changeover



In this version of the changeover map, the second and the third operators perform the essential actions for replacing the breaking tools and the punching mold, while the first operator supervises the process, assists the second operator and starts the machine for idle running. During the idle running, workers prepare the receiving table, output area and make preparations for the next changeover. The average values of the 1st and the 2nd changeover as well as CCTV cameras were taken as the basis of time for each operation. The new changeover map allows to complete changeover in 1846 seconds which is 17% less compared with the current changeover time. This is due to allocation of particular zones to workers which minimize time consumed for walking, appointment of a clear leader that will control the process and coordinate actions, and transfer of some internal actions to the external ones.

As for the second changeover, based on the analysis it is also possible to build a new spaghetti diagram (Figure 9) and changeover map (Table 10), but because in this type of work there is no idle time, i.e. preparatory actions will be performed directly during the changeover, time reduction will be less.



Figure 9. The new spaghetti diagram of the 2nd changeover

Similar to the previous type of changeover, the workspace is divided into two zones: yellow and green. Each consumes about the same amount of time:

* Orange works in the yellow zone, wastes no time going from 8 to 10, eventually comes to section 4 to start the die-cutting adjustments. Does not perform any preparatory actions.
* Green works in the green zone, does not waste time going to the computer, spends most of his time working on the counter plate, the punching mold and receiving table
* Black bring stamps from the wagon and back, helps Green with sections 3 and 9, prepares the counter plate for the next changeover. Right before the die-cutting stamp adjustments controls the quality of the work done, helps others if needed and coordinate next actions.

Therefore, the following changeover map can be constructed:

Table 10

The new changeover map of the 2nd changeover



As a references for time measurements were taken measurements from [Table 8](#Table8), video from CCTV cameras and the initial changeover maps ([Table 2](#Table2)). However, through a dialogue with the technologist some changes were made, namely:

* The 1st action of the 1st operator: “Brings stamps from the wagon, helps to install the punching mold”. 120 seconds were deducted because this is the time it took the worker to bring the wagon from another location to the SPO 1 line, usually the wagon is already brought to the beginning of the changeover.
* The 3rd action of the 2nd operator: “setup of the receiving table”. As with the first changeover, the setup of the receiving table can easily be done in 120 seconds. Sometimes hitches and defects occur, which increase the time to complete the job.
* The 1st action of the 3rd operator: “Filling order data into the computer”. The technologist stated that 120 seconds should be enough time to enter the data into the computer. Usually the time increases because of downtime and lack of coordination.

In general, this changeover map is similar to the previous one except it does not have the idle running which limits the possibilities to transfer some internal actions to external ones. Basically, the 1st operator acts as a coordinator and team leader, his duties include preparatory works, assisting others if needed and coordination of workers before the die-cutting stamp correction. This changeover map allows operators to complete all the tasks in 2504 seconds which is 5.43% less compared to the current changeover process ([Table 8](#Table8)).

Additional important factors in improving the quality and speed of changeover are the personal abilities of the operators and the complexity of the work in some sections. The most difficult operations are performed in sections 3, 4 and 9, as the installation of the counter plate, the punching mold and the machine control requires high skill and experience on the part of the operator. In addition, the team leader must have not only the experience, but also the authority to coordinate the actions of the others, so the first operator (team leader) must be the link between others. Working in the yellow zone does not require much technical knowledge and skills, it is enough training and proficiency to do the work in sections 1, 2, 6, and 7 in a quality and timely manner, so this zone can be assigned to a less experienced worker, a beginner. Therefore, the recommendation would be to assess the qualifications of workers and, based on the results, assemble balanced teams that will meet the standard of changeover.

The paper does not include the analysis of the last stage of changeover, because it is not only the most time-consuming, but also the most unpredictable and strongly depends on the complexity of products, personal capabilities of workers and many other factors. In order to significantly reduce the time spent on this stage it is necessary either to overhaul the machine or to buy a new one, but this requires a significant financial investment and a long and deep calculation of financial feasibility and risks. The middle managers I have worked with don't have the authority to make such changes.

## The 5th step of the SMED method. Reduction of external works.

Reduction of external works includes development of solutions to improve logistics (delivery of equipment, fixtures, tools, etc.), improve maintenance, reduce travel, etc. As for the technical part of the external actions, they are quite simple and straightforward and do not require any special tools, fasteners, etc. During the implementation of the 5S system at Gotech Northwest, all equipment was sorted into specific locations and labelled, so that pallets for the output area, materials for the preparation of the counter plate and the mobile wagon dedicated to transporting dies are in a designated place and labelled so that workers do not waste time looking for them. Moreover, currently Gotek Northwest holds seminars and trains workers in the TPM (Total Productive Maintenance) system. The main goal of TPM is to reduce downtime, reduce equipment wear and tear, improve product quality, motivate employees and increase productivity in general. Thus, the introduction of this system in itself is already a step towards reducing external activities during changeover.

## Assessment of the impact of the proposed recommendations on the OEE indicator

OEE indicator consists of 3 variables: Availability, Performance and Quality. Availability takes into account unplanned stops (such as equipment failures and material shortages) and planned stops (such as changeovers). Performance takes into account anything that causes the manufacturing process to run at less than the maximum possible speed when it is running (including both Slow Cycles and Small Stops). Quality accounts for manufactured parts that do not meet quality standards. To calculate OEE before and after SMED, Gotek management shared the following data concerning SPO 1 line:

* Planned production time per month
* Operating time per month
* Time consumed by changeovers per moth
* The ideal rate of production per shift
* Shift length
* Monthly average actual production speed
* Average reject rate

Taking into account the data listed above, the current OEE can be calculated (Table 11):

Table 11

Overall Equipment Effectiveness (Before the SMED implementation)

|  |  |  |
| --- | --- | --- |
| Production data |  |  |
| Planned Production Time for the month | 556.39 hours |  |
| Operating time for the month | 416.8 hours |  |
| Time consumed by changeovers for the month (included in operating time for the month) | 102 hours |  |
| The ideal rate of production per shift  | 40000 pieces |  |
| Shift length | 12 hours – 30 min lunch – 25 min daily maintenance = 11.08 hours |  |
| Monthly average actual production speed  | 3108 pieces per hour |  |
| Average reject rate | 2% |  |
| OEE variable  | Calculation | Result |
| Availability  | Operating time for the month / Planned Production Time for the month | 74.91% |
| Performance | Monthly average actual production speed / (the ideal rate of production per shift / shift length) | 86.09% |
| Quality | 100% - average reject rate | 98% |
| **OEE** | Availability x Performance x Quality | **63.2%** |

As it can be seen from the table 11, OEE indicator before SMED equals to 63.2% which is typical for many manufacturing companies (world class is 85%). Availability has the lowest score of all which means that availability loss, which includes time loss for changeover, is the highest.

As it was described in [step 4](#step4), the introduction of new changeover maps for the 1st ([Table 9](#newmap1)) and the 2nd  ([Table 10](#newmap2)) changeover allowed to reduce the time loss by 17% and 5.43%, respectively. To precisely calculate the OEE after the proposed recommendations for changeover it is necessary to test them in a real environment in the shop, but unfortunately, at the time of writing the paper Gotek management does not provide such an opportunity, so it will be reasonable to calculate the theoretical OEE using the available data. Taking into account that the ratio of the first type of changeover to the second type is 20% to 80%, the time consumed by changeovers for the month will be

$102×(100\%-\frac{2×17\%+8×5.43\%}{10})$ = 94.1 hours

Therefore, 7.9 hours are saved and now will be included in operating time.

It is important to note that the time spent on changeovers does not affect the Performance indicator, as Performance loss only includes factors that prevent the machine from producing at its highest possible speed. Reduced changeover time allows the machine to produce more in a certain amount of time, but does not affect its speed.

Table 12

Overall Equipment Effectiveness (After the SMED implementation)

|  |  |  |
| --- | --- | --- |
| Production data |  |  |
| Planned Production Time for the month | 556.39 hours |  |
| Operating time for the month | 424.7 hours |  |
| Time consumed by changeovers for the month (included in operating time for the month) | 94.1 hours |  |
| The ideal rate of production per shift  | 40000 pieces |  |
| Shift length | 12 hours – 30 min lunch – 25 min daily maintenance = 11.08 hours |  |
| Monthly average actual production speed  | 3108 pieces per hour |  |
| Average reject rate | 2% |  |
| OEE variable  | Calculation | Result |
| Availability  | Operating time for the month / Planned Production Time for the month | 76.33% |
| Performance | Monthly average actual production speed / (the ideal rate of production per shift / shift length) | 86.09% |
| Quality | 100% - average reject rate | 98% |
| **OEE** | Availability x Performance x Quality | **64.39%** |

After the suggested recommendations OEE indicator has become 64.39% which is 1.19% higher than the OEE before SMED. Taking into account the constant work on improving the working environment, improving the efficiency of employees, implementing 5S and TPM systems in Gotek Northwest, an improvement of 1.19% is a relatively successful indicator of the feasibility of the proposed recommendations. It is also worth considering that OEE is not a universal measure of equipment performance, as it does not relate to a company's real business goals and is useless if considered in isolation from the whole system. The main objective of SMED is not to improve some KPIs, but to create a levelled flow of value creation. [Eliyahu Goldratt's book "The Goal"](#Goldratt) describes the principle of “Theory of Constraints”, which is to maintain a constant rhythm of production and lower risks of constraints in the system in order to prevent all production from choking. This theory looks at the production system as a single organism with its "organs" dependent on each other. OEE, on the contrary, is focused on local optimization of each working cell, but the goal is to optimize the entire production system. The Theory of Constraints is used by manufacturers to identify their production bottlenecks and then work to improve and eventually eliminate them. Not all resources in a plant are potential bottlenecks, so only resources that are (or have potential to become) constraints to production should be closely monitored and optimized for the company to achieve its real manufacturing goals. If the organization focuses on “fixing” work centers with the lowest OEE numbers, it might be under optimizing the overall macro manufacturing process. Therefore, in order to implement the recommendations effectively, an in-depth analysis of the entire production system must be carried out. The SMED done in this paper is only a small step towards creating a leveled production flow. Fortunately, Gotek Northwest has very qualified professionals who are motivated to implement lean tools and create their own lean production system.

# Conclusion

Gotek Northwest is facing global changes in the packaging market, which is prompting the company to create an efficient production system in order to produce more, better quality and on time with the internal resources it has at its disposal. Fortunately, Gotek meets the challenges of the market and implements lean production tools that will create a big competitive advantage for the company in the future. Gotek Northwest has very complex productions system that produces huge variety of products that need different equipment on the production lines. The SPO 1 production line is a bottleneck and slows down the entire production flow due to the high number of changeovers, human error and wear and tear on the equipment. The SMED analysis revealed the following problems:

* Operators work chaotically, uncoordinated and do not follow a set algorithm of actions
* In the initial version of the changeover map, there are actions that are performed during the machine stop, thereby slowing down the changeover
* The initial changeover maps do not take into account the real time of tasks in the working sections, which results in an uneven workforce

In general, it was possible to meet all the objectives of the paper:

* The theoretical aspect of the SMED tool and the principles of lean production in general was studied
* Qualitative and quantitative data were collected, and it was possible to visit the manufacturing plant personally during the changeover of the production line SPO 1,
* The collected data made it possible to practically apply the SMED, i.e. to go through all 5 steps of this tool
* The new changeover maps were made and at the end a theoretical assessment of the proposed recommendations on the OEE indicator was carried out.

During the SMED analysis the work has been done on transferring some internal actions to external ones, on analyzing and creating a new algorithm of actions for each operator to reduce the impact of destructive behavior patterns and on reassessing the initial time spent by each work section. As a result, the SMED conducted in this paper allowed to develop a set of recommendations that led to creation of new changeover maps that can save 7.9 hours of operating time, which is a step towards eliminating the bottlenecks in the production system. After calculating the theoretical impact of SMED on changeover time, the OEE increased by 1.19% to 64.39%, which is a relatively good result, considering the work already done by Gotek management in implementing lean tools. As a result, the goal of the paper was achieved - to develop recommendations to improve the efficiency of the SPO 1 production line with the help of the SMED tool.

Of course, in order to do SMED most effectively, testing in a real environment and further analysis is necessary. And in general, creation of a levelled production flow that will allow the company to produce at lower costs, with high quality and on time, i.e. meet all of the company's business objectives, will require analysis of the entire system - from procurement department to warehouse logistics. Gotek therefore needs to continue to work on implementing lean production tools, creating its corporate culture based on lean principles, and constantly improving its production system.

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