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IMPLEMENTATION OF LEAN CONCEPT FOR FAST FOOD INDUSTRY PRODUCTION PROCESS IMPROVEMENT USING SIX SIGMA AND TRIZ METHODS

KULUSÄÄSTLIKU MÕTLEMISE RAKENDAMINE KIIRTOIDUTÖÖSTUSE TOOTMISPROTSESSI PARANDAMISEL KASUTADES SIX SIGMA JA TRIZ MEETODEID

MASTER THESIS

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PREFACE

The thesis topic was provided by the Department of Mechanical and Industrial Engineering of Tallinn University of Technology.

I would like thank my supervisor Eduard Ševtšenko and Margus Müür for guiding me in my work and helping with coping with challenges

I would like express my gratefulness to professor Kristo Karjust, Head of Department of Mechanical and Industrial Engineering of Tallinn University of Technology, for guiding me through my education in Tallinn University of Technology.

This thesis provided an overview of implementation of Lean Manufacturing, TRIZ problem solving methodology and Six Sigma in Fast Food industry and demonstrated its capabilities on case study using various software tools and techniques

Keywords: Lean Manufacturing, TRIZ, Six Sigma, 5S, Lean Fast Food

List of abbreviations and symbols

VSM	Value Stream Mapping
BPR	Business Process Redesign
BPI	Business Process Improvement
LM	Lean Manufacturing
TRIZ	Theoria Resheneya Isobretatelskikh Zadach
OPEX	Operational Expenses
NSE	National Stock Exchange
GM	General Motors
UK	United Kingdom
USA	United States of America
SMED	Single Minute Exchange of Die
TPM	Total Productive Maintenance
FMEA	Failure Mode and Effect Analysis
DEA	Data Envelopment Analysis
VA	Value Adding
DMAIC	Define Measure Analyse Improve Control

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INTRODUCTION

Rapid growth and development of market is creating urgent need of companies in decreasing negative business environmental impacts by improving their functional strength and acquiring better social benefits. Thereby company leaders focus more on finding and implementation of various optimization frameworks, quality improvement systems such as sustainable manufacturing, lean manufacturing, six sigma and other approaches and technologies. All mentioned approaches can be used for achievement of more efficient production if correct optimization tools were implemented within appropriate framework. Implementation of those tools has already shown its effectiveness in big companies by improving quality of product, productivity, employers' safety and health along with customer satisfaction, however smaller companies are not focusing much on it.

Fast food industry is one of the most popular industries nowadays and is widely spread over the world. According to the statistics total worth of Fast Food industries is around 525 billion euros. This number is growing rapidly over time resulting in rapid increase of the demand. Thereby many fast food companies face the need of implementation of optimization tools in order to be able to fulfil demand and avoid need of huge investments and trade-offs. Although there are numerous huge fast food companies that own huge revenues and are able to easily implement desired systems and innovations, there are also companies and fast food shops that are much smaller and have dramatically less resources to bring innovations and increase their capacity. Those shops can be found all over big cities, particularly in Tallinn they are in shopping malls, corners of streets, airports, schools, gas stations and even in some hospitals.

As mentioned previously demand for Fast Food is increasing rapidly, however it is not stable only on long term basis, however it is also very dynamic on a short-term period. According to the data gathered from one of local Fast Food shops demand on their product is varying dramatically depending on the part of the day. It was observed that the number of customers that buy their product is low in the mornings but increases rapidly during lunch times. Then drops for several hours and rises again drastically in the evenings. The problem occurs during such rush hours and the issue is that capacity of the shop becomes not sufficient for meeting the demand resulting in creation of bigger queues

increasing waiting time for customers up to 5 times more than planned. This in its turn is believed to decrease interest of customers and result in customer numbers decline what in its turn in decline of company revenue. It would definitely be possible to increase capacity of the shop by increasing number of equipment and number of employees, however considering those solutions we come to the second issue which is related to the financial and spatial limitations of the shops. Most of those shops that are within the focus of this work have very limited space that needs to be used not only for operation but also for storage. Total revenue of those shops is usually also quite limited for implementing high end technologies that would improve their capacity.

The formation of lean production as a concept of enterprise management began in the first half of the twentieth century.

F. Taylor, A. Fayol, G. Ford and G. Emerson laid the foundations of the classical school of management. In subsequent years, it was developed by many Japanese researchers: T. Ono, M. Imai, S. Shingo, J. Monden, as well as famous American and European scientists, such as E. Deming, J. Wumek, D. Jones, J. Liker, J. Michael.

At the same time, despite a large number of scientific papers, the provisions put forward by them, implementation mechanisms and tools need to be specified and developed in relation to the processes occurring in the Estonian industry.

The object of research is the business processes of an industrial enterprise, Fast Food shop.

Subject of research - methods and tools for assessing and improving the efficiency of enterprise business processes.

Focus of the work will be to help those companies to have smoother production/process flow, decrease scrap, decrease production times and other valuable parameters that directly affect wellbeing of the companies' financial and operational status.

The purpose of the thesis is to develop a set of measures to improve business processes and assess the economic efficiency of its implementation using the example of Fast Food shop. Aim of the work is to perform extensive literature review of the most effective techniques for optimization and provide tools for their best implementation within the small fast food shops. Aim is to decrease waiting time of the customers during rush hours by 40% in order to

get competitive advantage in the market thereby increase customer flow. Work is to be performed using data from one of the local fast food shops that resembles situation of most popular fast food types.

In order to complete the task, the list of following is required:

- study the theoretical and methodological aspects of the concept of lean manufacturing;
- analyze the experience of implementing lean manufacturing in Estonia and abroad;
- identify and summarize the criteria for evaluating the effectiveness of business processes;
- analyze approaches to improving business processes;
- assess the effectiveness of business processes of Fast Food company using the lean manufacturing tool;
- develop measures to improve business processes.

Therefore, work is planned to be carried out in a systematic way. Following steps are to be implemented:

- Type of the data required for the work will be defined.
- Data will be gathered from shop based both on experience of owner and practical observations
- Digital discrete clone will be created, processes and value stream mapped, KPIs to be defined
- Digital model is to be analyzed.
- Data comparison of current and proposed situation.

The dissertation research is based on the use of methods of system analysis, deduction and induction, analysis and synthesis, as well as the graphical method and observation. The use of these methods allows us to study the problems of efficient use of the potential of industrial enterprises, to objectively perceive the essential features of the concept of lean manufacturing, tools and methods for its implementation.

The hypothesis of the thesis is the assumption that the implementation of the concept of Lean Manufacturing, TRIZ problem solving methodology and Six Sigma based on the rational use of resources and optimization of industrial processes in the industrial sector will be a fundamental factor in the development and growth of competitiveness of Fast Food enterprise and a prerequisite for intensive modernization of key industries.

Practical novelty is as follows: the author developed a set of measures to improve business processes of Fast Food company and assess economic efficiency based on the results of its implementation. The practical significance of the research results lies in their further use in solving specific problems of increasing the efficiency of production processes at the mentioned organization.

The work consists of introduction, three chapters, conclusion, bibliography.

1. THEORETICAL AND METHODOLOGICAL ASPECTS

1.1 The essence of the concept of Lean Manufacturing

After World War II, significant changes occurred in manufacturing processes around the world. Growing consumer demand for high-quality, cheaper products required expanding the range, lowering prices and shortening delivery times. The answer to these requirements in the automotive industry was the creation of the concept of lean manufacturing, the founder of which was the Japanese company Toyota. Created "based on" the Toyota Production System (TPS– Toyota Production System), the term lean manufacturing was coined in the 1980s by the MIT (Massachusetts Institute of Technology) research team led by Dr. James Womack, at a time when the group was preparing to write the book "The Machine that Changed the World] [1].

The founder of the production system of Toyota company is considered the famous outstanding Japanese businessman Tahiti Ono. In his book, "The Production System of Toyota moving away from mass production", he reveals in detail the basic philosophy and principles of the company, which allowed it to take a leading position in the world. As a basis, he takes the main thoughts and ideas of three managers of the twentieth century - Sakichi Toyoda, Kiichiro Toyoda and Henry Ford [2-3].

Further study of the Toyota production system was done by consultant, engineer and professor Shigeo Shingo. Working closely with Tahiti Ono, he created and described a quick equipment changeover system called SMED. His efforts resulted in creation of "The study of the production system of Toyota from the point of view of the organization of production", which became a wonderful addition to the book of Tahiti Ono. In this book he reveals in details the features of the basic tools and methods of the production system, most of which are his merit. Based on these works, modern experts complement and improve the principles of TPS. Scientist Jeffrey C. Liker in his book "Toyota Tao: 14 principles of management of the world's leading company" describes in detail the basic principles of the company, giving relevant examples [4]. Brian Maskell and Bruce Baggaley, in their work called "Practice of Lean Accounting" explain the subtleties of changing financial activities in enterprises that introduce lean manufacturing. They describe a phased plan for transforming a financial system

into a lean one in accordance with the stages of introducing a lean manufacturing system throughout the firm (Figure 1) [5].

Lean manufacturing is a management concept focused on creating attractive value for the consumer by creating a continuous stream of value creation and continuous improvement of all organization processes through personnel involvement and elimination of all types of losses [6]. The production system is one of the main elements in the economic activity of any enterprise. If this system is created on the basis of the concept of lean manufacturing, then it will allow the company to achieve significant success in constantly changing market conditions, take a leading position among competitors and win the trust of consumers. Therefore, at present, it becomes necessary to study the nature and characteristics of the implementation of lean production in enterprises.

The concept of "lean manufacturing" is designed to solve some of the vital problems of enterprises: to minimize losses while achieving maximum productivity. Lean manufacturing ideas help improve product quality and reduce production costs without increasing investment [7]. As a result of the organization of such a production process while ensuring the high quality of manufactured products, production losses and costs are reduced, which leads to the efficient use of available financial, labor, material and information resources.

Lean manufacturing considers the concept of “product value” from the perspective of a customer [8]. The value of a product is related to its usefulness, and usefulness is the ability of a product to satisfy one or more human needs. The basis of Lean Production is the creation of the value of a product or service for the end user. The purpose of production processes is the value preferences of people, and the basis of the production system here is also people. In the concept under consideration, the optimization process occurs due to the systematic elimination of losses - muda. Muda is a Japanese word for activities that consume resources, but do not create value (literally translated as “waste”, “loss”). In previous systems, the costs of such storage were passed on to the consumer. In lean manufacturing, losses of this kind (indirect costs) are excluded [9].

So, following what was mentioned above, the main purpose of LM can described as removal of waste from production system [10]. Waste can be described as anything that does not add value to the end product. Lean

manufacturing aims to provide the product that precisely meets requirements of the client, thereby minimizing all non-value adding operations. Quality assurance can serve as an example of such a process as it does not add any value to the product itself and only checks whether product can be delivered to the customer or no. Toyota has specified the number of wastes that can be considered for both production and business lines. Those are called 7 Wastes of Lean and are listed below:

Waiting – employer waiting for other people, tools, servicing, input material, etc. and equipment waiting for employers, service, other equipment, etc.

Overproduction – when company produces good exceeding demand thereby not being able to transfer them to customers

Inappropriate processing – excessive number of unnecessary processes and processes that do not add any value

Transport – relocation of products, people or equipment over large distances

Excess motions – existence of movements of people or equipment that do not add any value

Work-In-Process – excessive inventory process that creates additional handling, additional space and additional price

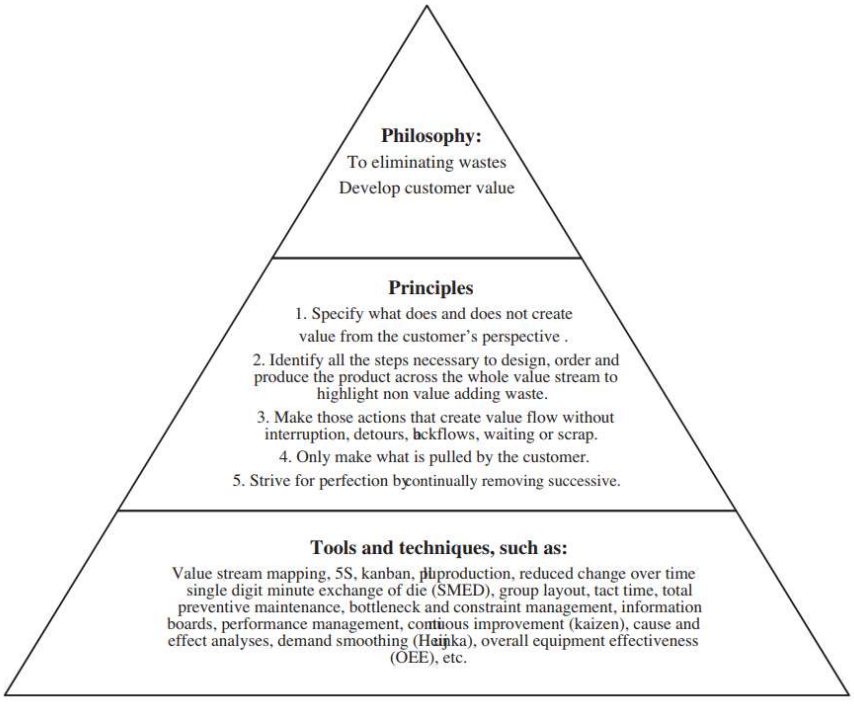

Figure 1. Three levels of lean [5]

Defective products – products considered as scrap, returned from customers, rework or dissatisfaction of clients.

Manufacturing companies use variety of LM instruments and techniques to reach their objectives. Those include: 5S, SMED (Single Minute Die Exchange), Poka Yoke, TPM (Total Productive Maintenance), etc. [11-12].

1.2 Principles and methods of Lean Manufacturing

Lean manufacturing includes five basic principles (tools), using which the company can achieve significant results [7]:

Determining the value (usefulness) of a particular product (service) from the customer perspective. An organization can take many actions that are not important to the consumer. Only when the organization knows exactly what the consumer needs, it can determine which processes are focused on providing the consumer with value and which are not.

Drawing up an accurate flow diagram of the creation of these values in the enterprise. Actions in the processes must be arranged in such a way that there is no waiting, downtime or other losses between operations. This may require redesigning processes or applying new technologies. All processes should consist of activities that add value to the product.

Elimination of losses so that the value is continuously created along the stream. To optimize the work and identify losses, it is necessary to describe in detail all the actions from the moment of receiving the order to the delivery of products to the consumer. Due to this, potential opportunities for process improvement can be identified.

Creating a stream that allows to pull value to the client. The organization should produce only those products, and in such quantities that are necessary for the final consumer.

Continuous improvement by eliminating unnecessary actions. The implementation of a lean manufacturing system cannot be a one-time event. When embarking on the introduction of this system, it is necessary to constantly improve work by searching and eliminating losses.

To implement lean manufacturing, it is needed to understand the principles of this concept. Despite their simplicity, the implementation of these principles requires considerable effort from the enterprise.

Within the framework of the concept of lean manufacturing, there are many methods. The most famous are the following [7]:

1) 5S is an improvement methodology that is part of the Kaizen approach. Allows to reduce losses associated with poor organization of the workplace;

2) Kaizen - an approach for managing an organization based on continuous quality improvement. In this approach, employees regularly and actively work to improve their activities [13-14].

3) Just-in-Time (just in time) - an approach to production management based on consumer demand. Allows to produce products in the right quantity at the right time [15];

4) SMED (Single Minute Exchange of Die) - a system that allows to reduce the time loss associated with the installation of blanks [16];

5) Kanban - a system for regulating the flow of materials and goods within the organization and beyond - with suppliers and customers. Allows to reduce losses associated with stocks and overproduction;

6) Andon - a visual feedback system in the workplace. It enables all employees to see the state of production, warns when help is needed and allows operators to stop the production process in case of problems;

7) Standardization of work - is an element of the Kaizen approach. Allows you to document processes, due to which the basis for improving activities is created;

8) Poka - Yoke - a method for modeling errors and their prevention in production processes. Allows to reduce the losses connected with defects in production;

9) Quality control tools - histogram, stratification, Pareto chart, scatter chart, Ishikawa diagram, checklist, control charts;

10) Quality management tools - affinity diagram, link diagram, tree diagram, matrix diagram, network diagram, priority matrix, PDPC diagram;

11) Quality analysis and design tools - FMEA analysis, quality house, method 5 why, etc.

Many of these approaches and tools can be used separately, but in the concept of lean manufacturing, their combination gives more significant results.

The combination of techniques, tools and approaches supports and strengthens each other, due to this the Lean system itself becomes more flexible.

Lean can be described as group of principles that create mindset focused on identification and elimination of non-value adding steps for customers, time wastes, employee productivity reduction, customer satisfaction decrease, etc. for constant improvement of processes [17]. It can be implemented both in manufacturing and service companies. There are five main principles of Lean that support its implementation:

1) Value specification
2) Value stream mapping
3) Flow
4) Pulled
5) Perfection

The first principle analyses customer point of view and determines what is the real value of service or product for customer. Second principle is focused on identification of business processes from initial design of product till the delivery according to value stream to find non-value adding processes. Third principle is used to eliminate any processes that create interruptions in the process flow. Fourth principle is about providing products and services that are desired by customers. Fifth principle strives for continuous improvement until perfection is reached [18, 12].

1.3 Lean Manufacturing drivers and tools

1.3.1 Lean Manufacturing drivers

More extensive literature review on Lean Manufacturing will result in number of LM drivers that can be used for optimization purposes and are listed below

1. **Production scheduling.** Involves development of processes until they reach continuous flow that will support achievement of standardized products manufacturing
2. **Effective utilization of resources.** Can be obtained by effective allocation and monitoring of resources used in the system
3. **Effective inventory management.** Can be obtained by implementation of Kanban principles and 'just -in-time' methodologies

4. **Control of product flow.** Indicates implementation of forecasting approaches and monitoring of take time. Average time spent for production of one unit
5. **Reduction of cycle times.** Can be obtained by decreasing non-value adding activities and avoiding bottlenecks by adopting Poka Yoke
6. **Safety improvement initiatives.** Refers to implementation of safety equipment and maintaining tidiness in production area increasing employer safety
7. **Reduction of setup time.** Involves standardization of used jigs and fixtures, existence of checklists for quick guiding and consistent setups along with detailed manuals for changeovers
8. **Quality product design.** Involves implementation of equipment and systems that can detect scraps and present solutions by elimination of root causes
9. **Aligned distribution management.** Can be obtained by implementation of shared distribution facilities and optimization approaches for transportation systems
10. **Effective strategies for marketing management.** Involves implementation of forecasting approaches and performing relevant promotion for creating pull systems
11. **Standardize product development approaches.** Is obtainable by standardization of parts and integration of design for manufacturing as vital part of early product/system design
12. **5S.** Means successful housekeeping, standardization and effective sustainability of them.
13. **Value stream mapping.** Involves mapping of currently used processes, finding out non-value adding activities and delivering suggestions on development of future state activities map
14. **Waste analysis.** Can be obtained by classification of wastes that result in creation of non-value-added activities.
15. **Total quality management.** Involves implementation of innovative quality practices and commitment of top management and strategic planning for all processes used in production.
16. **Total productive maintenance.** Involves maintenance techniques and strategies that will not obstruct smooth flow of processes.

17. **Cellular manufacturing.** Involves grouping and mapping of alike processes for development of product families and systematical preparation of work cells
18. **Technology management.** Involves implementation of advanced technologies that can decrease lead times and increase product quality.
19. **Standardization of work.** Is achieved by the alignment of process operations and implementation of standard procedures.
20. **Process focus.** Can be obtained by monitoring of changing demand and standardization of processes for optimization of both product and process.
21. **Continues improvement approach.** Involves implementation of Kaizen and uninterrupted diagnosis of the activities that can end up with non-value addition
22. **Visual management.** Explains activity visualization that will detect wastes by creating visual information systems and aids.
23. **Appropriate supplier evaluation strategies.** Analyzing suppliers' performance, comparative costs and achieving 'just-in-time' deliveries
24. **Mapping the delivery performance.** Initialization of required measures for obtaining customers' desired delivery times.
25. **Supplier development.** Involves training of suppliers and creating long-term cooperation.
26. **Identifying the requirements of customers.** Having better understanding of customer demand and designing products accordingly.
27. **Monitoring feedback from customers.** Establishment of effective feedback loop between customer and company for quick and adequate responding to them complains and recommendations.
28. **Adequate workforce evaluation strategies.** Establishment of effective programs for employees' performance measurements and increase of motivation.
29. **Workforce training and education system.** Development of effective training programs and education of employees better understanding and implementation of LM activities.
30. **Employee proficiency.** Improvement of workforce multi-functionality for better adoption by assigning various work programs.
31. **Workforce empowerment and involvement.** Involvement of employees in implementation and planning of lean activities [19].

1.3.2. Lean Manufacturing tools

Tools mentioned below can lead companies to achievement of more competitive advantage for their customers and stakeholders. Those tools are focused on reduction of costs and increase of revenue. Lean is the way companies can survive and succeed in such a big market with a lot of competitors. Implementation of Lean Manufacturing tools will assist companies to reach their targets and increase productivity.

Standard work has been developed in fifties and covers formalized and executed rules and operational procedures. Aim of this tool is to establish certain procedures executed in a predefined way which has been considered as the most optimal. It will eliminate any improvisation from employees during manufacturing process leading to sustainable and constant performance.

Standard work has following benefits:

1) Variability reduction – more stable and measurable work process.
2) Cost reduction – elimination of all inefficient activities that result in wastes.
3) Quality improvement – as operations are executed in the same way, probability of defects decreases
4) Worker involvement – employees are less blamed for the errors as they are dependent on the system. This in its turn result in more honest employees about opportunities for improvements.
5) Continuous improvement – it results in easier, faster and more efficient operations [20].

Value Stream Mapping is a method that describes material flow starting from raw material till the final version of the product [20]. It can be stated that the main focus of lean is VSM considering it as a very important step for development of lean systems such as business planning and communication tool. Those two-play crucial rule in driving company towards lean environment [21].

The aim of the lean manufacturing is to meet customer demand fully without sacrificing quality and implementing the most efficient and economical methods available for production. Lean manufacturing can be implemented in 2 ways. The first method is determination of waste its minimization in production process and elimination of the ones that have direct impact on production flow.

Second method however aims to make production process as smoother as possible. Value stream mapping is a tool that helps to visualize processes and define ones that need to be whether improved or eliminated.

Value stream mapping is graphical tool that does not include very detailed information about a production process. Instead of that, current and future state maps are being created where all the necessary data is to be presented such as cycle time, lead time and TAKT time. VSM is essentially an approach where all the processes times are measured and mapped accordingly. Then current and future state maps are modelled into a simulation software and numerous analysis performed results of which will provide the best future state map, which in its turn will be later transferred to shop floor. Such simulation will decrease chances of problems occurring during actual implementation. Moreover, increased number of iterations will guarantee the best solution implemented.

There are several stages of VSM that are mentioned below:

1. Selection of Product Family: Mapping of processes related to certain group of products, product family is advised. A product family is a group of products that undergo similar processes which are performed by the same machinery
2. Drawing Current State Map: After certain product family has been selected AS-IS state or current state is mapped. Below prerequisites before mapping of AS-IS state are mentioned:
    - Cycle time, Changeover time, Uptime
    - Inventory
    - Customer requirement
    - Supply schedule
    - Sequence of operation
    - Number of workers on each operation
    - Number of working hours, shifts and breaks
3. Analysis of current state map: AS-IS map should be carefully analyzed for waste, bottleneck processes, congestion points. Seven wastes mentioned chapter 1.1.2 should be considered during analysis, they should be detected and prioritized accordingly.
4. Eliminate wastes and draw future state map: If any wastes found, they should be eliminated according to the prioritization made. Updated process should be more continuous and pull rather than push.

5. Simulate future state map: After processes has been optimized, it is required to map TO-BE or future state map. TO-BE process should be loaded to simulation software and simulated using various iterations until most favorable process has been obtained for implementation
6. Implementation: Selected TO-BE process later needs to be presented to top management where it will further be approved for implementation [10].
7. 5S created in Japan by Sakichi Toyora, Taiichi Ohno and Kishiro Toyoda in 1960, is a lean tool that aim achievement of highly organizational working environment by keeping shop floor tidy and organized. This is sequential method and consists of 5 steps that are described below:
   - Seiri (Sort) – Getting rid of everything that is not related to work. Working space should have only things that are required for performing work.
   - Seiton (Set in order)– Everything in workspace should have dedicated place for them that are visually marked for quicker sorting and finding when required to avoid time waste for searching.
   - Seizo (Shine) – Workspace should always be kept clean what in its turn will minimize risk of accidents and help product inspection
   - Seiketsu (Standardize) – Standards should be developed and followed for performing first 3 S's.
   - Shitsuke (Sustain) – This step includes development of method of controlling fulfillment of previous steps. Periodic audits can be performed for control. This step requires discipline and focus.
   - 5S brings various benefits to company one of which is minimizing waste of time and space. It also improves quality, security and hygiene [20].

Visual Management is considered as basis of several other Lean tools including 5S. Its main purpose is to implement quick and easy means of communication. There are several descriptions of this tool such as "self-ordering, self-explaining, self-regulating and self-improving work environment where what is supposed to happen on time, every time, because of visual devices" and "communication without words nor voice". Below are different types of Visual Management:

1) Informative boards

2) Space delimitations
3) Andons
4) Work instructions

The purpose of this tool is to make employees create better work environment and reduce errors or any other means of waste.

Kanban is a tool used to assist companies struggling with overproduction. It is implemented to delivery only necessary things and only when necessary. It was developed by Ohno on production lines of Toyota. Kanban can be translated from Japanese as card and is a visual input system to trigger just-in-time delivery systems. The idea of this tool is to update stocks of the company only when required by exchanging signals with suppliers, usually using cards.

Line balancing is a task allocation procedure to evenly distribute quantity of work. Two main values that should be considered are takt tie and cycle time. Takt time describes frequency with which product needs to be produced while cycle time show amount of time required for performing certain operation. Due to the fact that various operations have different cycle times frequency of the system equals to the slowest time among all cycle times in the system which is called bottleneck. It is required to evenly distribute amount work over all workstations to make all cycle time equal. It should also be noted that efficiency of the line increase when mentioned metrics are as close as possible [20].

1.4 Methodology for assessing the effectiveness of the implementation of Lean Manufacturing

Assessment of changed performance of company resulted in implementation of Lean is very important to find out its advantages. Wide variety of models and techniques has been created to measure the performance of Lean and most of the researchers used productivity or operational efficiency to evaluate manufacturing leanness. It should be noted that proper selection of metrics and implementation method is vital.

On one side some researches implemented VSM to measure the effectiveness by analyzing costs, time and output values, however skipping evaluation of effectiveness in comparison with company aims. In contrast there were also researches who prioritized equipment effectiveness but failed to measure overall performance. Besides those there were also attempts to use

structural equation modelling to create relation between various lean tools and production performance. Some researchers stated that the most effective way of performance measurement is using VSM, qualitative and quantitative metrics along with graphical methods, while others stated that market evaluation, financial, non-financial and cost measures would instead cover all areas of analysis.

Different surveys have been carried out to receive valuable data for finding the most effective method. Most of the responds presented myriad indicators and checklist used to evaluate current state of the company and ideal state and comparison of those will show effectiveness of implemented tools.

Differently from qualitative surveys it was discovered that quantitative metrics and models provide better leanness score. Using this fact researches developed further tools for efficiency measurements. Those methods include:

1) Data Envelopment Analysis (DEA)
2) Fuzzy logic algorithms
3) Measurement of organizational profit using VA method by defining and analyzing various performance indicators [22].

The third method is proposed to be implemented in a following way:

1) Definition of key performance indicators.
2) Measurement and analysis of current state of company.
3) Measurement and analysis of future state of company.
4) Comparison

In order to be able to assess effect of changes implemented it is required to have some metrics to work with. Thereby in the first step key performance indicators will be formulated according to the purpose of the work.

Secondly it is important to analyze current state of the company to have clear image of situation. Current state analysis will act as reference point which will provide hints on most problematic areas. Moreover, data obtained from those analysis will later be used to compare the results.

Implementation of proposed solutions will be performed after current state has been analyzed and new parameters evolved. It is crucial to redo all the measurements made in second step and record updated information.

In fourth step data obtained from current and future state of the company will be compared based on predefined key performance indicators. This comparison will assess effectiveness of Lean Manufacturing implementation.

1.5 Theory of Inventive Problem Solving

Triz is a systematic approach for understanding and solving problems in a creative way developed by soviet scientist Genrich Altshuller in 1946 in the patent office in Baku, Azerbaijan. He wanted to discover standard ways of solving problems [23]. Genrich had studied 200000 patents and found out discovered that if details are eliminated most of the solutions implemented and only one fifth of them were innovative [24]. According to his research he has grouped all solutions into following levels (Figure 2):

1. Level 1 (Simple solutions) – 32% of all patents
2. Level 2 (Improvements) –Improvements resulted from personal experience. Formed 45% of all patents
3. Level 3 (An Innovation Inside of Studied Area) – Slight improvement of existing system. Formed 18% of all patents
4. Level 4 (An Innovation Outside of Studied Area) – Improvements and advances of existing patents. Included 4% of all patents
5. Level 5 (Extraordinary) – Solutions that created new knowledge. Included 1% of all patents

Levels	Selecting a task	Choosing the Concept of Research	Data Collection	Researching for Opinion	Finding Intellectual Solutions	Finding Practical Application
	A	B	C	D	E	F
1	Using an existing task	Using the concept of an existing research	Using existing datas	Using existing solutions	Using a prepared design	Producing a current design
2	Choosing one of many tasks	Choosing one of the research concepts amongs several concepts	Collecting datas from the many sources	Choosing one of the many opinions	Choosing one of the many desings	Producing altered version of an existing design
3	Changing the original task	Changing the research concept in accordance with the new task	Changing the the collected data in accordance with the new task	Changing he current solution	Changing the existing design	Producing new design
4	Finding a new task	Finding the concept of new research	Collecting new datas according to a new task	Finding a new solution	Developing new design	Using a new way of design
5	Find a new problem	Find a new problem	Collect new data according to new problem	Finding out the new concept(in principle)	Developing new structural concepts	Changing system that is applied the new concept

Figure 2 Creative process diagram [24]

TRIZ is the abbreviation of its original name in Russian „Theoria Resheneya Isobretatelskikh Zadach." When translated in English it becomes „Theory of inventive Problem Solving"and acronym that stands for it becomes TIPS. The benefit of this method is that it shows that overcoming contradictions is possible methodically. TRIZ has 3 fundamental principles shown below:

1. The perfect design is goal
2. Contradiction assist in problem solving
3. Process of innovation possible to be configured as systematic

In described context problems can be solved using model shown in Figure 2. The main purpose of TRIZ method is to find prefect solution or perfection. TRIZ depends on four basic paradigms that are mentioned below:

1. Contradictions
2. Perfection
3. Functionality
4. Utilization of resources

Besides that, Genrich Altshuller described four-step process for solving problems:

1. Describing problems
2. Matching and comparison general problem with TRIZ problems
3. Finding TRIZ solutions
4. Development of ideal solution to the problem

Engineering parameters of TRIZ

Around 3 million patents have been investigated, categorized, explained and grouped into 39 engineering parameters by Genrich using TRIZ. Those parameters have been created for both stationary and moving objects, the ones that are moving themselves or by application of external force. Those parameters are mentioned below according to literature:

1. Weight of moving object
2. Weight of stationary object
3. Length of moving object
4. Length of stationary object
5. Area of moving object:
6. Area of stationary object
7. Volume of moving object
8. Volume of stationary object
9. Speed
10. Force
11. Stress or pressure
12. Shape: The external contours, appearance of a system.
13. Stability of the object's composition

14. Strength
15. Duration of action by a moving object
16. Duration of action by a stationary object
17. Temperature: The thermal condition of the object or system.
18. Illumination intensity: Light flux per unit area, also any other illumination characteristics of the system
19. Use of energy by moving object
20. Use of energy by stationary object
21. Power: The time rate at which work is performed. The rate of use of energy.
22. Loss of Energy
23. Loss of substance
24. Loss of Information
25. Loss of Time
26. Quantity of substance/the matter
27. Reliability: A system's ability to perform its intended functions in predictable ways and conditions
28. Measurement accuracy
29. Manufacturing precision
30. External harm affects the object: Susceptibility of a system to externally generated harmful effects.
31. Object-generated harmful factors
32. Ease of manufacture
33. Ease of operation: Simplicity
34. Ease of repair
35. Adaptability or versatility
36. Device complexity
37. Difficulty of detecting and measuring
38. Extent of automation
39. Productivity

Those parameters are very helpful in finding a solution to existing issue by using TRIZ matrix where user can match parameter that he wants to optimize with the parameter that is creating conflict, after which matrix will lead user to one of forty principles mentioned below to provide some ideas.

40 Principles of TRIZ

Below 40 principled developed by Altshuller. They are used to provide user new ideas relying on previously implemented solutions by other scientists, engineers, etc.

1. Segmentation
2. Taking out
3. Local quality
4. Asymmetry
5. Merging
6. Universality
7. "Nested doll"
8. Anti-weight
9. Preliminary anti-action
10. Preliminary action
11. Beforehand cushioning
12. Equipotentiality
13. 'The other way around'
14. Spheroidality - Curvature
15. Dynamics
16. Partial or excessive actions
17. Another dimension
18. Mechanical vibration
19. Periodic action
20. Continuity of useful action
21. Skipping
22. "Blessing in disguise" or "Turn Lemons into Lemonade"
23. Feedback
24. 'Intermediary'
25. Self-service
26. Copying
27. Cheap short-living objects
29. Pneumatics and hydraulics
30. Flexible shells and thin films
31. Porous materials
32. Color changes
33. Homogeneity

34. Discarding and recovering
35. Parameter changes
36. Phase transitions
37. Thermal expansion
38. Strong oxidants
39. Inert atmosphere
40. Composite materials [24].

1.6 Lean Manufacturing Experience in Food industry

The penetration of LEAN into other industries took much longer, but now these principles are becoming the standard for enterprises around the world. This section considers how ideas that come from the automotive industry begin to be used in the food industry, since the use of LEAN contributes to the creation of competitive advantages, which are of particular value in the food industry.

Standards play a very important role in food safety. And food safety, in turn, begins with people. The main objective is staff training and the introduction of a food safety culture. Continuous improvement begins with leaders and ends with the creation of a positive production culture, in which, through joint efforts, any violations are analyzed and their root causes are eliminated. Nevertheless, when re-evaluating production efficiency, it is necessary to consider the relevant food safety standards that define requirements that may create some difficulties for production managers. There is a second level of requirements set by many retailers and product manufacturers in addition to these certification standards, which are interpreted as the minimum acceptance.

Meanwhile, the market requires innovation. Consumers need more and more diverse products, which require manufacturers to expand the range and, as a result, more and more frequent change of products on the production line.

Food industry enterprises need to find a middle ground between flexibility and production efficiency. With the release of long-established products for slowly growing market segments, the emphasis on these factors is becoming increasingly important. As a result of globalization, many manufacturers entered the competition for a competitive price, producing low-cost products by changing product formulations, using cheaper ingredients, reducing packaging costs or labor costs.

Outside of the food industry, a revolutionary increase in labor productivity was achieved using lean manufacturing principles. This reduced the number of errors, with their usually difficult to predict cost and raised the standard of product quality to a new level. No manufacturer with low costs can hope to compensate for their competitive shortcomings only by reducing wages. They need to increase production efficiency. Finished product prices are declining in contrary to rising costs of raw materials and labor costs. Large companies optimize costs by acquiring supplier companies. Inefficient enterprises find themselves in a particularly difficult situation.

In the food industry, there is some tension between the production staff and the maintenance team. These relationships are more often characterized by the term rivalry than cooperation. The goal of personnel directly involved in the production is to reduce losses and meet planned targets. The technical staff is guided by a quality management system and focuses on critical control points.

The task of leaders is to overcome these differences, create a positive culture of continuous improvement. This means that these leaders must understand how to change people's behavior.

Changes are ongoing. Innovative companies have long used change as a competitive advantage. A comprehensive study of published annual reports issued by food industry companies using the LEAN concept for their shareholders provides several examples. The benefits of the LEAN concept for food companies have never been publicly discussed. There is only one exception to this "corporate silence conspiracy." Arla Foods is a dairy producer with its own dairy farms and ranking sixth in the world ranking. It owns the world's largest fresh milk processing plant in Aylesbury, UK, where LEAN principles are fully implemented.

The 2010 report indicated that the company’s increased production of dairy products in Denmark and the United Kingdom was 15–30% without additional investment. Encouraged by the success, the company accelerated the implementation of LEAN in all its enterprises. In 2011, Arla Foods achieved additional savings of € 53 million by increasing output without expanding production capacity. In 2012, the company announced plans to save € 270 million over three years by investing in its own LEAN programs. The changes were aimed at improvements in the areas of production, procurement and organizational activities. In 2013, against the backdrop of a slowdown in major

markets and fierce competition, the company shared its plans for further efficiency gains, explaining how their OPEX (Improving Operating Activities) program is being implemented. In 2008, Nestlé launched the Long-Term Product Development Program (NCE), based on a combination of LEAN and TPM principles. A 2012 Nestle report stated that the NCE program provided the company € 1.23 billion in savings, or 1.6% of total sales. A lesson for competitors is the fact that the world's largest producer and supplier of food products has developed, implemented and adapted the NCE program aimed at providing additional savings.

In 2012, The Times newspaper published a case study of the work Nestle did in planning its new bottled water plant in Waterswallows in Buxton, UK. The company began by creating a "Value Stream Map" (LEAN methodology), and then applied kaizen principles to analyze the sources of losses. The plant was built using LEAN principles based on this new understanding of losses. This made it possible to achieve the following improvements: a more compact work area was created, a more efficient warehouse on the territory, the level of worker safety was improved due to the separation of the work area and the work area of forklifts and the change in the position of the storage and repair area of pallets.

The 2013 Nestle report no longer referred to NCE [25].

It is important to bring this system to the entire staff of the company as well as constantly and in different ways deal with losses to improve everything that happens in the processes.

1.7 Software

Arena simulation software.

Arena is a discrete simulation software that provides modelling and simulation capabilities to the companies and users. Its purpose to analyze various changes within companies resulted by complex changes within supply chain, manufacturing, processes, logistics, distribution and warehousing along with service systems. It is very flexible software and has wide variety of models to be used for creating discrete twins of processes.

Arena can be used for thorough analysis in following cases:

1. Analysis of any type of manufacturing system considering also material-handling components
2. Analysis of customer management systems and complicated customer service
3. Global supply chain analysis that ha warehousing, transportation and logistics systems
4. Forecasting system performance formed on such important metrics as costs, cycle times, output and utilizations
5. Identification such kind of bottlenecks as queues and over-utilization of resources
6. Planning of material, staff and equipment requirements.

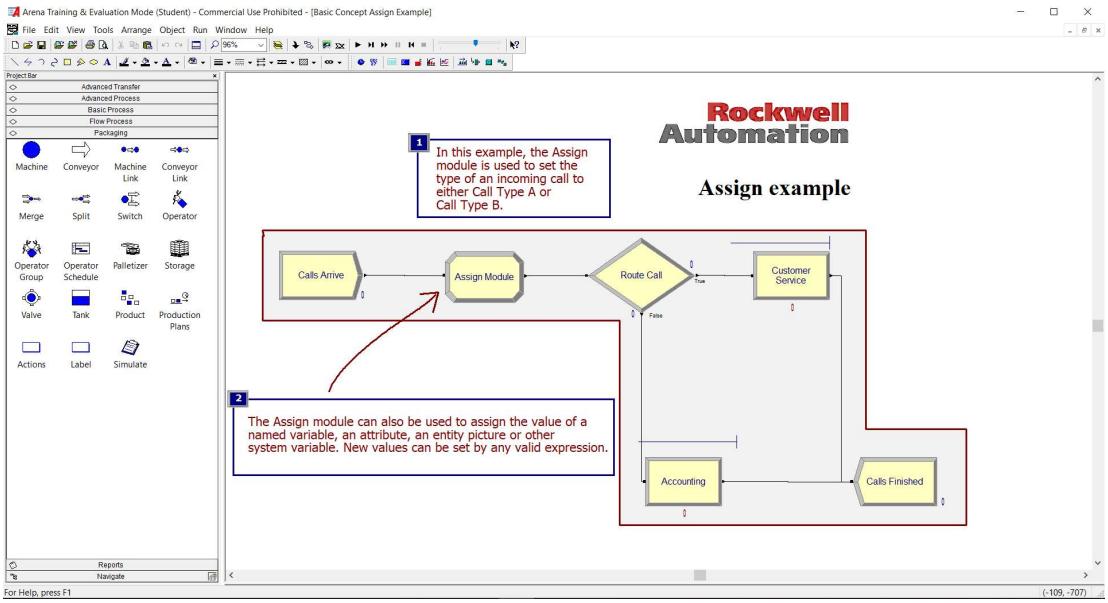

Figure 3 Arena simulation software

Arena simulation software is mainly presented for business and manufacturing process consultants and analysts along with industrial and system engineers. Generally, it is generally used as business analysis and productivity tool.

People who are using this software are expected to have some basic knowledge of systems and terms used in the software. They also have interest in improvement of their system productivity both from manufacturing and

business point of view and responsibility to evaluate changes that are planned to be implemented.

Arena software designers are providing online support and number of libraries to overcome challenges and help their customers to have better control over the program.

ARIS Express.

ARIS Express is free lightweight business process modelling tool developed by Software AG. It offers not only standard modelling functionalities but also additional highlights especially for Business Process Management beginners. It has **smart design** that helps users to create models of company quicker and easier on a spreadsheet view. The model is being generated automatically and can be easily changed avoid need of users to focus on standards and rules of correct object placements. ARIS Express (Figure 4.) has very helpful mini toolbar that accelerates modelling process even more by enabling quick and direct access to related objects when object is created.

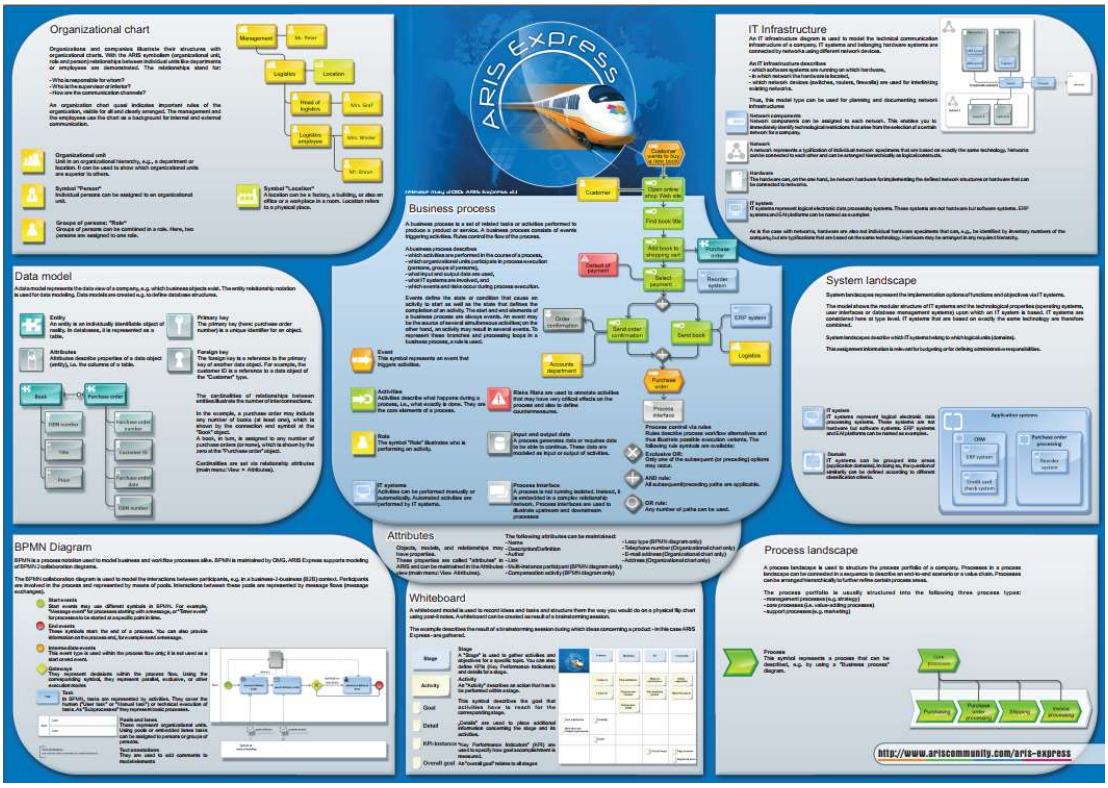

Figure 4. Aris express poster [26]

Proven ARIS method and industry standards lie as a baseline for ARIS Express. It is very intuitive software and instant results are obtained with the help of latest improvements in modelling assistances. Express should not be considered as limited or demo version as it is free modeling software that can serve as replacement for other drawing tools [26].

2. IMPROVING BUSINESS PROCESSES IN THE FAST FOOD SECTOR

2.1 The concept and essence of business processes

There are various descriptions and terms for describing business process. One of them describe process as number of activities that are put together in a such a way that value was generated for a customer (Figure 5.).

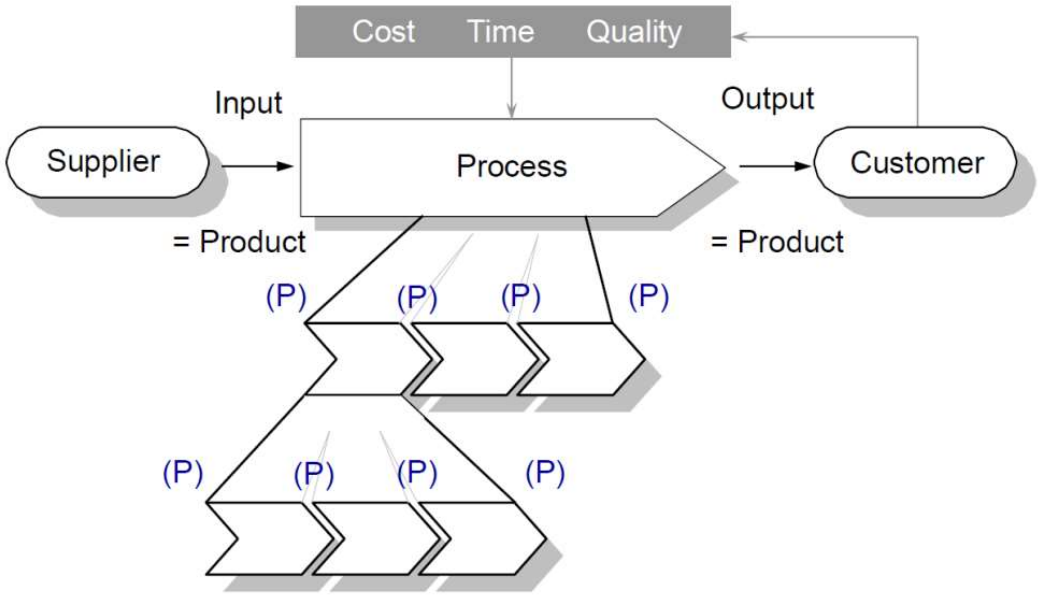

Figure 5 Pattern of Process Thinking [27]

Value generation is supposed to be one of the key roles processes. They should convert inputs obtained from suppliers to something valuable for the customers. Displayed patter is so-called "Pattern of Process thinking" and clearly represents both internal relations (if analyzed vertically) and supply chain (if analyzed horizontally) [27].

Business process can be considered as key property of any company. It plays the vital role in well beingness of the company and have direct impact on organization's products and services along with their success in the market. Business processes describe all vital parts within the company including jobs, tasks, responsibilities thereby organizing flow of the work of each employee. Processes link existing systems, information and resources inside and all over

the company. This is the reason why company may malfunction when any mistake occurs. Processes help company to adjust to new requirements and changes that dramatically increase over the time. They affect not only total revenue of the company but also formulate cost profile of the company.

Business process is quite complicated term that consist represents set of other terms. Events for instance are considered as part of business process. Theoretically they are considered to be things that happen but do not have any duration. However, events may result in creation of activities. For instance, arrival of equipment from supplier side can be considered as an event, however verification process of that equipment will be considered as activity.

If activity is not a complicated task and can be described as single unit of work then it is classified as task. For instance, if an employee is just checking equipment when it is arrived, then this operation is simple, thereby can be classified as task.

Besides events and activities processes also include decision points. That means that any step in the work flow requires decision to be made then this step is called decision point and it is considered that this step may affect further flow of the process.

Another compound of business process is actor. Actors of processes are not only humans, organizations but also physical objects such as documentation, materials, equipment, etc.

It should not be forgotten that all processes have certain ending which are called outcomes and are considered as part of business process as well. Depending on the result and value brought to actors, outcomes can be classified as both positive and negative.

One of the actors of processes have special role. Those actors are the ones who are consuming the products and services of a company and are called customers. Their interests should be specially reviewed as customers are the main actors who define attractiveness level of products and services in the market.

It does not matter whether company is governmental organization, non-profit organization nor enterprise, managing number of processes is obligation of any of those [28].

2.2 Efficiency as the main characteristic of enterprise business processes

It is quite intuitive to assume that processes are vital for company's wellbeing. However quite often it is possible to see lack of focus on their importance. Thereby it is crucial to establish systematic approach to processes in order to be able to adequately analyze their efficiency and utilize them with full potential.

Business process can also be defined as main part of company infrastructure. Correctly defined and managed processes bring company myriad advantages:

- It helps organization to quickly determine existing trends in the market and implement those in products.
- It helps to distinguish target groups and reach them in the most efficient way.
- Implementation of support processes will be done easier to increase manufacturing efficiency.
- Assessment of value-adding processes and decision making on whether to outsource or perform internally.
- Better cooperation with partners who add value to the company

In order to achieve competitive advantage, it is not enough to have well documented structure of the processes, it is more important to create such a structure that would lead company to achieve its targets in terms of cost, time and quality [29].

Business processes can be grouped into several categories and each of them affect company efficiency in a different way.

The first group of processes are called core processes and refer to primary activities of company. Processes that fall into this group are responsible for efficiency of production of goods or services that customers pay for.

The second group is called support processes and include activities that play supportive role in realization of core activities. Such activities are responsible for efficiency of infrastructure, labor, procurement and development of technology.

Some researchers also add management processes to the list of process categories. This group of processes aim to increase competitive efficiency by assessing competitors in the market and evaluate their capabilities [28].

2.3 Approaches to improving business processes

Business process improvement strategies are in center of attention of most of the companies. It is struggling for them to find quick solutions for immediate issues [30].

Effectiveness and efficiency of the organizations are heavily dependent on the level of processes and their management thereby creating a need of analyzing wide number of business decisions. If process management was previously used in quality assurance, no it is becoming more and more important and being implemented all over the company reaching all areas of organization. The reason behind that approach is due to the fact that management of flow of the processes is simpler. In order to reach the perfection in performance and sustainable improvement of business process number of procedures, systems, tools and methods are now presented by process management. All those are aimed to fulfil strategic goals of the company [31].

Number of approaches exist to perform business process improvement. In general, it is possible to divide business process improvement into two parts that are business process redesign (BPR) and business process improvement (BPI). The difference between those two are in a degree of change made into the system where BPR would mean radical changes whereas BPI would mean incremental approach. BPR and BPI are considered to be long term solutions while there is also another approach named "quick hits" which has different degree of change from previously mentioned ones and is focused on short term improvements, around a few months [32].

Along with approaches also number of other methods are proposed for business process proposed. Benchmarking is one the proposed solutions for business process improvement. This method focuses on continuous analysis of more successful companies in order to implement their ideas and practices. Implementation of benchmarking can result in significant cycle time and cost decreases and improve company efficiency to be able to compete in market. This method was developed in Japan and later active used in USA leading

numerous American companies to success. Benchmarking consist of five following steps:

1) Planning
2) Analysis
3) Integration
4) Action
5) Maturity

Six-Sigma is another method that has purpose to find and eliminate wastes such as defects, failure causes, defects, etc. Six sigma concentrates on outputs mostly the part which is the most valuable for customers. There are various models to perform Six Sigma and one of them is called DMAIC that consists of following phases:

1) Define
2) Measure
3) Analyse
4) Improve
5) Control

It is also possible to merge Six Sigma with Lean Manufacturing that will result in a methodology called Lean Six Sigma. While the main focus of Lean is optimization of process flow, Six Sigma will improve design and decrease variation. One key point that should also be noted is that Lean Six Sigma is more advantageous and can be implemented in all sectors.

Lean Thinking has been developed by Toyota Company. Despite it is quite old methodology it is still effective as it has been changed and modified a lot since its development. The main purpose of lean is to improve workflow thereby reduce costs and wastes. Lean can be separated into 5 phases which are:

1) Sort
2) Straighten
3) Scrub
4) Systematize
5) Sustain

Implementation of lean should result in continuous flow of processes without any interruptions. Lean is used both in manufacturing and service industries. Kaizen is a method that is focused on small improvements generated by all workers of organization. Kaizen has been developed in Japan after Second

World War and can be translated from Japanese as continuous improvement. Kaizen aims gradual, steady improvement along with generation of more value and less waste [33].

3. EVALUATION AND IMPROVING THE EFFICIENCY OF BUSINESS PROCESSES

3.1. General characteristics of the enterprise and problem definition

The Fast Food company that has been chosen for studies is a small enterprise. There is one employee who is responsible for serving customers and owner supports employee with all the required supplies. Shop offers 11 types of edible products and 16 types of drinks. 7 of mentioned foods are the most popular and around 150 products from this family of products is being sold on average every day.

The issue that company has faced is huge increase of orders during rush hours resulting in long queues where customers usually need to wait for the fast food product for around 15-16 minutes when it usually takes only around 3 minutes to prepare one. Moreover, company is planning to increase its sales thereby facing need of capacity increase to be able to fulfill demand.

Shop has very limited space and divided into two areas: storage area and production area. Production area is equipped with marmite, toaster, grill, fryer, microwave oven, water tap, freezer, refrigerator, cashbox and coffee machine. As it was recently opened and premise was not previously functioning as fast food shop amount of electricity supply is also limited which does not allow using equipment with their full capacity or adding new equipment. Another issue that also appear is confusion of orders during rush hour times which also add negative effect on customer satisfaction besides long waiting times. Below list of limitations and problems is presented:

- Long queues during rush hours
- Confusion of orders and their order
- Limited electricity supply
- Limited space
- Limited financial capacity

To identify root causes practical observations will be done and data collected. After processes of product preparation will be mapped using Aris Express software, then digital model created in Arena simulation software for further analysis. After analysis has been made Lean manufacturing and TRIZ

method to be implemented to identify possible solutions and create proposed model of processes. After simulation of new model has been done, results will be analyzed and evaluated.

3.2. Analysis of property and financial position of the enterprise

Company owns small shop that is divided into two parts. One part is used for storage purposes and the second part is devoted to production. As employee is not responsible for storage area and all the main processes happen in production area the first part will be eliminated from analysis.

Below layout of the production area is presented. As it can be noticed total area of the production area is 11.2 square meters. The shop is followed by the following equipment (Figure 6.):

1) Refrigerator - used from keeping cold drinks.
2) Freezer – used to store products that are used in production often.
3) Water tap – used for washing dishes or hands.
4) Microwave oven – used to warm up or unfrozen products if needed.
5) Fryer – used to produce fried potatoes.
6) Grill – used to cook meat.
7) Toaster – used to cook bread, tortilla.
8) Marmite – used to store cooked meat and keep it warm.
9) Cashbox – used to perform payments and store receipts.
10) Coffee machine – used to serve hot drinks.

Company sells 200 products per day. As it was mentioned previously biggest portion of those sales are made up by one product family 150 of which is being sold on average every day. Average price of a product from that product family is 4 euros. The rest of the products however have average price of 2 euros.

$$Daily\ revenue = Price\ of\ product \times Number\ of\ products\ sold \quad (3.1)$$

$$Monthly\ revenue = Daily\ revenue \times 3 \quad (3.2)$$

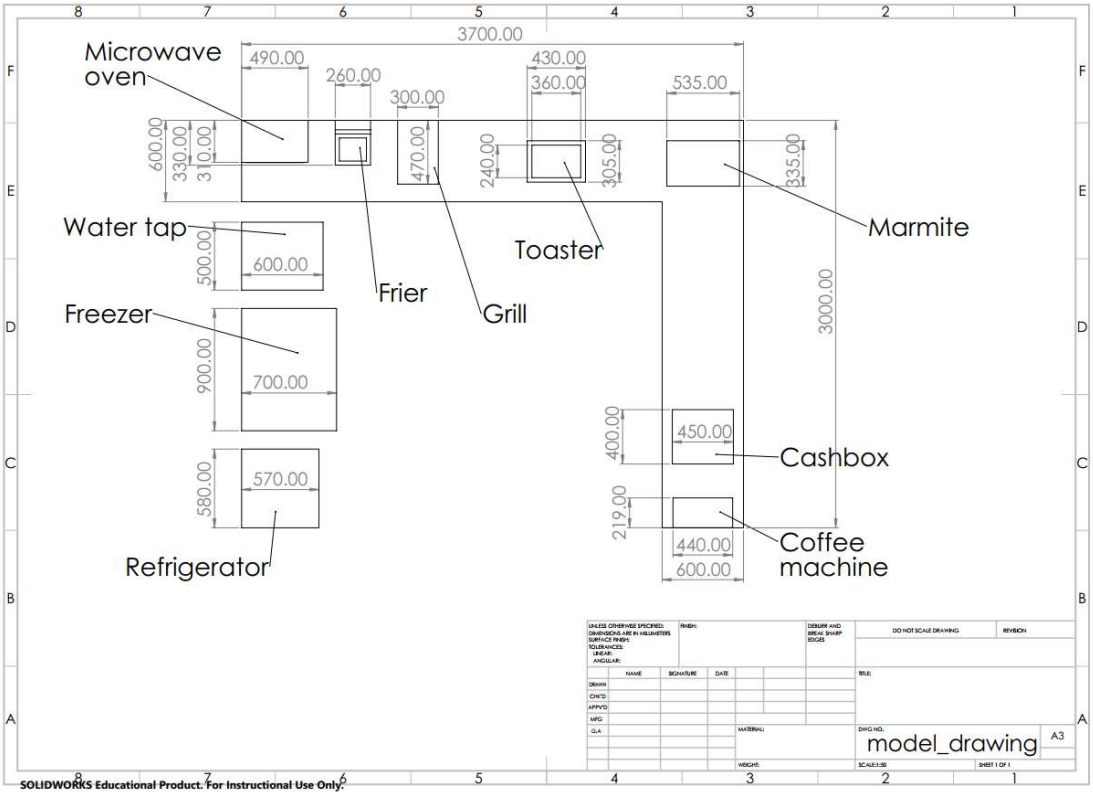

Figure 6 Layout of Fast Food shop

Using equations 3.1 and 3.2 it is calculated that total monthly revenue from main product family is 18000 euros and from secondary products is 3000 euros meaning that total monthly revenue of the company is 21000 euros.

Considering the fact that only main product family be considered, analyzed and improved further calculations will not include products of secondary importance.

3.3. Implementation of lean manufacturing conception at the selected Fast Food Shop as a tool to reduce losses and increase the efficiency of the enterprise

Practical part of the work will be performed according to following scheme (see Figure7).

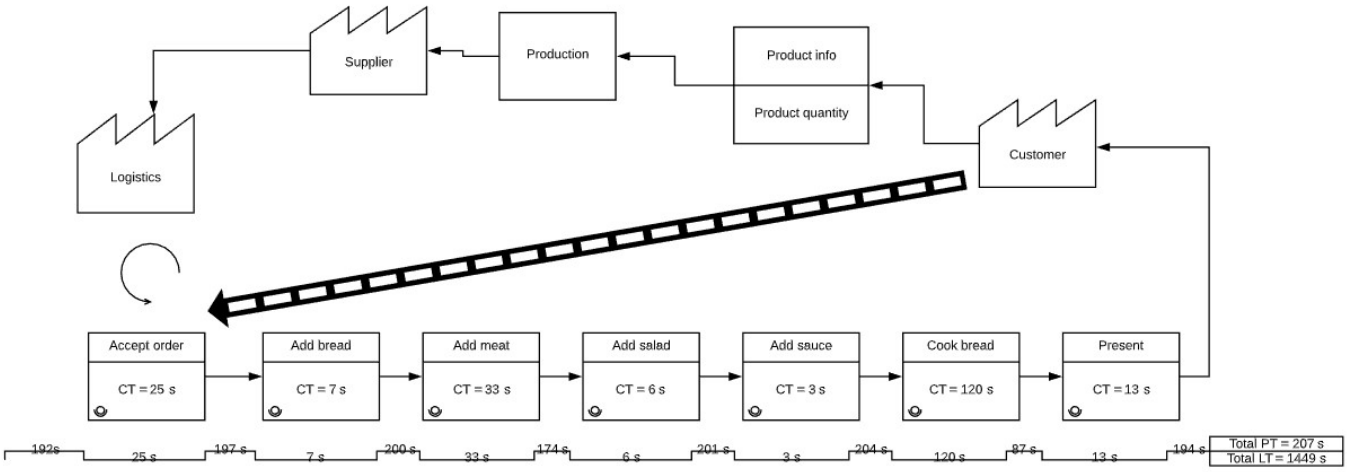

Figure 7 Process flow of Fast Food company improvement

Implementation will be divided into 5 steps according to DMAIC (Define Measure Analyze Improve Control) model provided to us from Six Sigma.

3.3.1 Define

In define step value stream map, processes map of production process will be presented along with times of the processes that will be used later.

Value stream mapping

Below value stream map of the company is presented. It is clear from the map that customer manually makes an order. According to the amount of orders employee manually informs supplier whether any supplies are required. All the material is being supplied to employee and those are waiting until customer approaches and order is made. After order has been made there is a list of other processes that happen until product is served customer.

Business Process mapping

To identify root causes of the issue practical observations has been made in order to obtained more detailed information about happening processes. In total whole business process map has been divided into 4 levels (Figure 8).

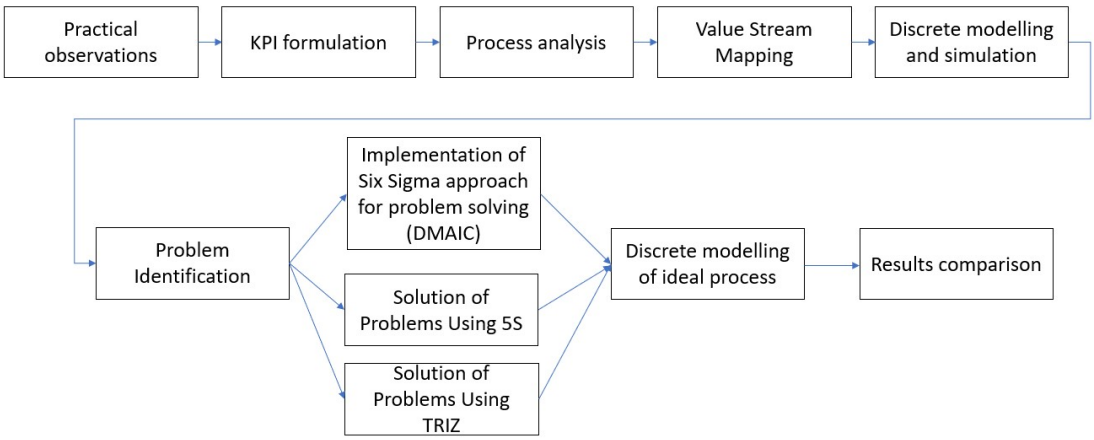

Figure 8 AS-IS Value Stream Map of Fast Food shop

As it was observed the first level of the company can be separated into 4 processes as following (Figure 9):

1) Purchasing – buying required amount of raw materials and equipment
2) Marketing – advertisement activities, mainly over social media
3) Production – refers to preparation of products
4) Logistics – transportation of bought materials, etc.

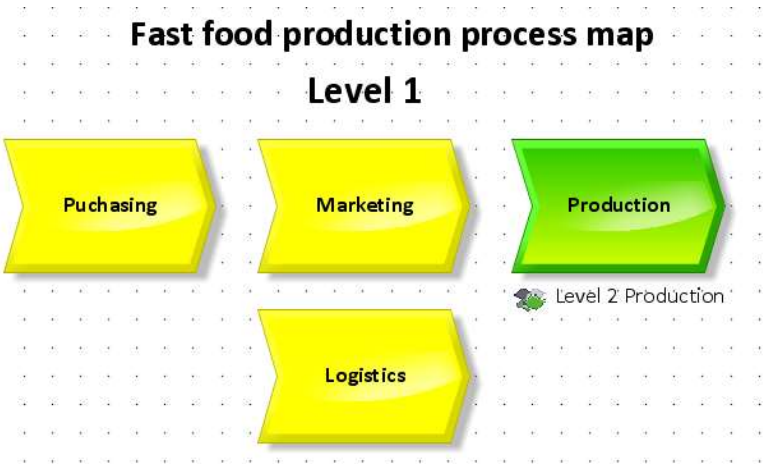

Figure 9 Level 1 process map

As it can be seen from the figure only Production process is considered as value adding and will be analyzed in more detailed way.

On the second level process map we divide processes into 4 groups as well (Figure 10).

1) Cut vegetables – refers to preparation of vegetables for employee to add into final product later
2) Prepare sauce – refers to creation of special mixture that will be added to final product
3) Prepare meat – refers to cooking meat that will later be added to the product
4) Combine all ingredients – refers to product preparation process.

As we can see from the second level process map only "Combine all ingredients" process is considered as value adding process and will be analyzed in more details. The rest of the activities are not done by employee thereby they do not affect product preparation time.

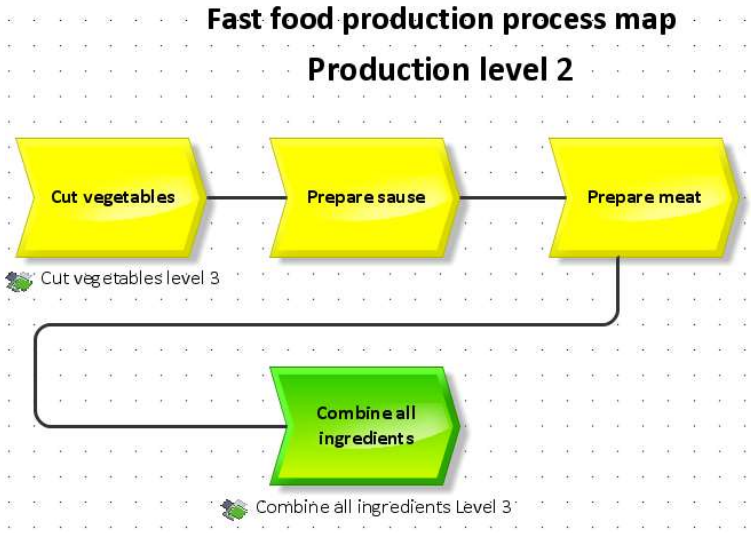

Figure 10 Level 2 process map

Third level process mapping provides more detailed picture of what employee is doing and what preparation time of one product consists of.

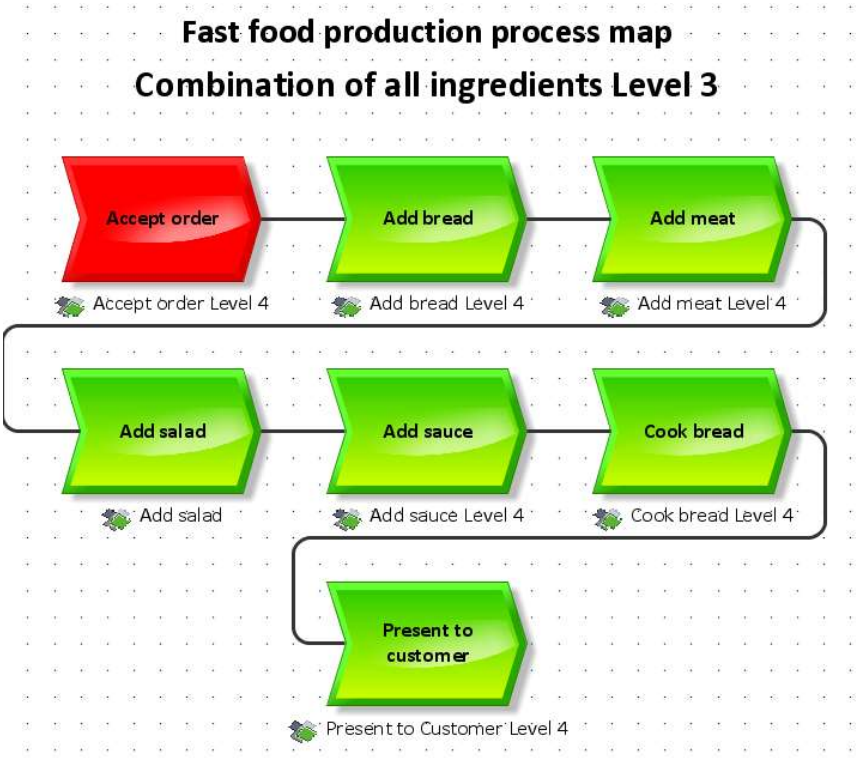

Figure 11 Level 3 process map

1) Accept order – Employee needs to ask customer details of order, calculate total price, ask preferred method of payment, accept payment and print receipt
2) Add bread – in this activity employee first needs to put on gloves and approach for bread which is located on the other side of the room and bring it back to the preparation area.

Figure 12 Location of marmite and bread

3) Add meat – in this process employee is responsible to get the meat out of the marmite, cut it in smaller pieces and add to the bread
4) Add salad – Employee is supplied with salad which is next to cutting area. He needs to take food forceps to take salad and add it to the product. Action is performed several times until required amount is obtained
5) Add sauce – there are several bottles filled with sauce next to cutting area. Employee needs to grab one of those, check whether it is ready to apply sauce and apply it. As it was observed, in some cases when there is small amount of sauce employee needs to shake it while turning it upside down to be able to add sauce

Figure 13 Cutting area

6) Cook bread – bread also so called "lavash" which is used is not fully cooked, thereby it needs to be put in toaster after all ingredients are in. At this stage it stays for 2 minutes and needs to be rotated 4 times to be evenly cooked from all sides.
7) Present to customer – in this process employee is responsible for packing the product. It goes into one small paper bag and later to bigger paper bag with paper tissue. After it is in employee ties bag with stapler and gives it to customer.

Further mapping of the processes on fourth level divided all the processes in 6 value adding processes, 6 non-value adding activities and 21 required processes.

Process times

In order to be able to have more realistic simulation important processes has been re-classified and their times has been measured as followed to be implemented later in analysis phase:

Table 1 Process parameters

Process name	Process time
Accept order	15 seconds
Put on gloves	10 seconds
Take bread	33 seconds
Add meat	7 seconds
Add salad	6 seconds
Add sauce	3 seconds
Toaster	120 seconds
Present to customer	13 seconds

3.3.2 Measure

In this part performance of the process flow will be measured and bottlenecks found. Three key performance indicators will be considered. Those are:

1) Time required for preparation of one product.
2) Maximum time spent in the queue for 10 orders in a row.
3) Maximum number of products that can be created in 30 minutes.

First process times has been added to Microsoft Excel and graph has been created.

Process name	Process time in seconds
accept order	15
put on gloves	10
take bread	7
add meat	33
add vegetables	6
add sause	3
toaster	120
present to customer	13
sum	207

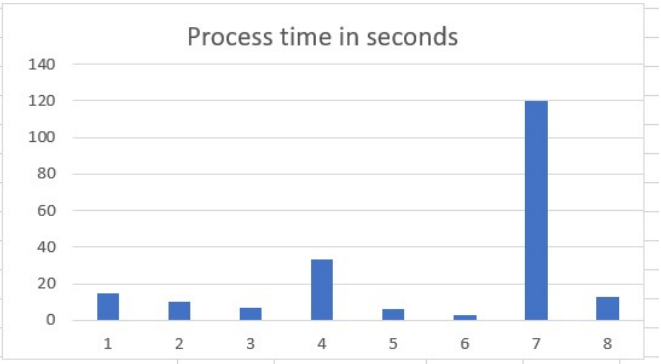

Figure 14 Process times visualization

Result of the bar graph clearly showed that two steps of the production process can result in creation of the bottleneck. Those are adding meat and toaster processes.

In order to analyze the process digital clone of the system has been created in Arena simulation as shown below.

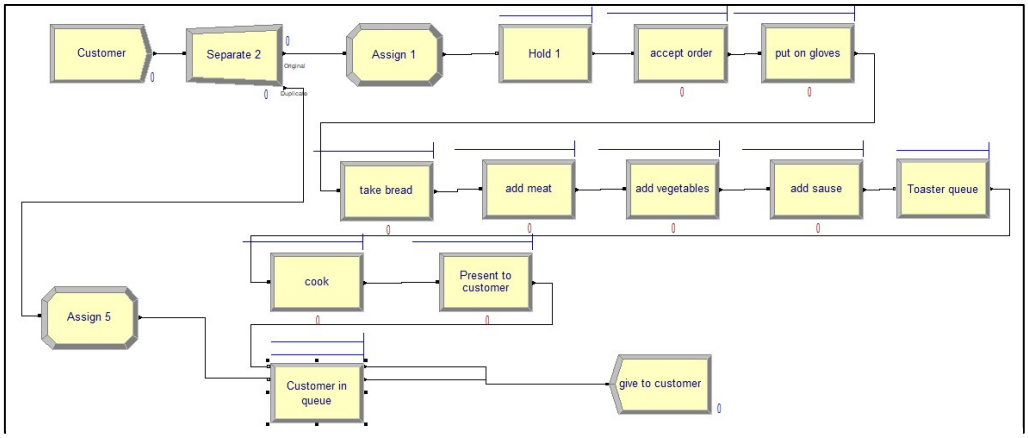

Figure 15 AS-IS simulation in Arena

From the measured data and simulation results following results has been obtained:

1. Time required for preparation of one product: 207 seconds
2. Maximum time spent in the queue: 936 seconds
3. Maximum number of orders finished in 1800 seconds: 19

As can be seen from the results, during rush hours long queues occur due to imbalanced production process. Process times add up with each order changing to waiting time for other customers who ordered later. We can also see that only

19 products have been prepared during 30 minutes what in its turn shows current capacity of the company.

3.3.3 Analyze

In order to decrease waste, in our case it is non-value adding times of some processes new solutions will be provided and control over the process will be increased. In order to find the solutions, we will approach TRIZ 40 principles that will provide clues on possible improvements. Reviewing of those principles resulting in the selection of the following principles:

- Principle 1 – Segmentation. Make bread cooking process separate and independent from the rest. If bread cooking process will be separated from the nominal process order it will remove the bottleneck and decrease queue significantly. The reason why it is believed that separation of this process valid is that during preparation time employee should not be involved and process can be done independently.
- Principle 10 – Preliminary action. Prepare cut meat before rush hour times to spend less time on preparation. Experience of company representatives has already shown that demand change is quite predictable. Meaning that it is possible to prepare some raw material before rush hours. In our case this process will be meat preparation. As one of the bottleneck processes is cutting meat and it can not be supplied in small pieces as it can loose its quality, employee can cut it prior to rush hours what will in its turn decrease process time too.
- Principle 13 - The other way round. As it was proposed previously bread cooking process should be made independent, however in our process flow this process is the last one in preparation of the product. To make this separation possible it is proposed to reverse preparation steps and start with cooking bread to make it ready before other ingredients are prepared.
- Principle 19 – Periodic action. Instead of selling with same price continuously, offer cheaper prices before rush hours to spread demand over bigger range of time. As we know there are various target groups who buy fast food products. Some of them are employees of other companies and organizations and are dependent on various criteria including their lunch time. However there are also people who are not

that dependent and can be motivated to buy before or after rush hours. This solution will not only decrease queues but also keep number of orders.

- Principle 25 – Self Service. As it was mentioned previously process of ordering is completely non value adding process and should be eliminated. Making ordering and payment process fully automated is also expected to provide huge impact to the process parameters.

Next thing that is proposed to improve is the general layout of the production area. Observations and measurements showed excessive amount of unnecessary movements of employee. More ergonomic line would significantly decrease unnecessary movements and result in faster operation cycle.

3.3.4 Improve

In this step all previously mentioned proposals will be implemented and new analysis made to see improvements.

Decrease of product preparation time. According to our analysis, all the processes start from taking bread and continues by adding ingredients to it. In order to be able to separate bread cooking process from the production process it is required to add intermediate location where all the ingredients will be placed while bread is being cooked. However in order to achieve minimum process time, transportation of combined ingredients should take minimum amount of time. To avoid any wastes it is proposed to use plate equivalent of size of applied ingredients. In our case length of applied ingredients range between 15-18 cm and width 6-7 cm. Ingredients will be filled into this plate in reverse order and then transferred to prepared bread by turning it upside down.

Decrease of overall cycle time per product. Overall cycle time of preparation of one product also includes acceptance of orders. It is already quite time consuming process however it becomes even more time wasting due to the reason that employee needs to take of gloves for accepting the order and then put them on back again what may double the time. Self service was proposed previously to eliminate those wastes. In our case company is able to implement self-ordering system that would significantly decrease time required for accepting the order and start preparing product immediately.

There are several ways of implementation of this proposal.

Online ordering. Company can implement online ordering systems that will provide chance to customers to order and perform payments via online. This way customers will have an opportunity to receive estimated time of preparation, thereby they will need to wait for delivery and can arrive to spot of

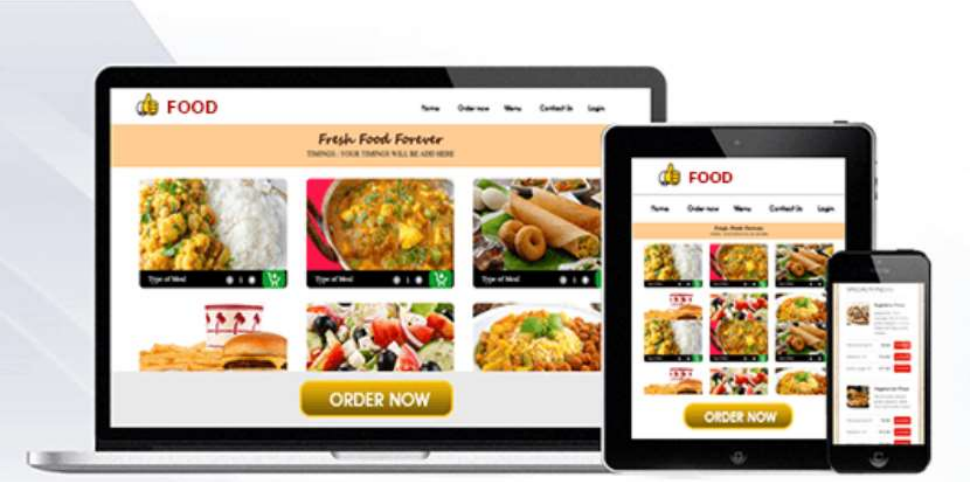

Figure 16 Online food ordering system [36]

delivery on shown time.

1) **On site self-ordering system.** Those systems are more comfortable to be used, however they are more expensive and larger.

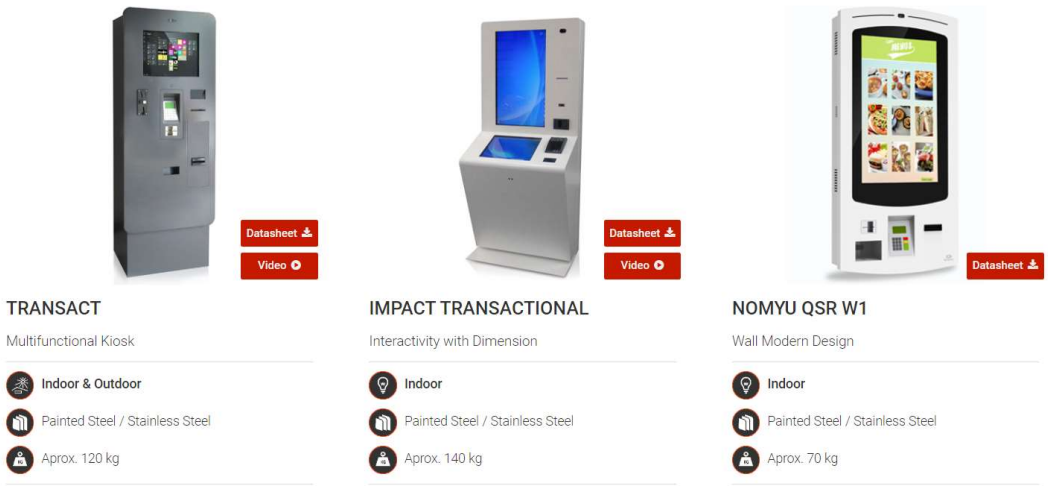

Figure 17 On site ordering systems examples [37]

2) **Online self-ordering on site.** This solution is expected to give the biggest advantage over other solutions implemented. There are various proposals in the market that allow connection of payment

systems to operational systems. It is possible to have external sensor touch screen attached to the outside of the shop where users will be able not only make their orders but also proceed to payment. This will be doubled system of online ordering, however the only difference will be that this system will be connected to POS terminal for performing payments.

Preliminary action. In order to make some preliminary actions it is first required to forecast demand. According to the information taken from company we can see the following graph of demand (Figure 18):

Figure 18 Demand change over time

It is obvious from the graph that sudden increases in a demand appear during 11:00 and in the evenings around 18:00. This means that employee can prepare to those raises in the demand by preparing required amount of meat to decrease amount of time spent preparation during rush hours.

Periodic action. Demand change analysis has already shown low and high demand times. This provides clear understanding of which times of the demand change can be used to shift the demand. According to the graph times around 14:00 can be aimed for demand increase using various pricing strategies.

More ergonomic line. Below proposed layout of the shop is presented (Figure 19). Distances between operating stations has been minimized. With new proposed layout employee will no longer need to move around the shop in order to complete order.

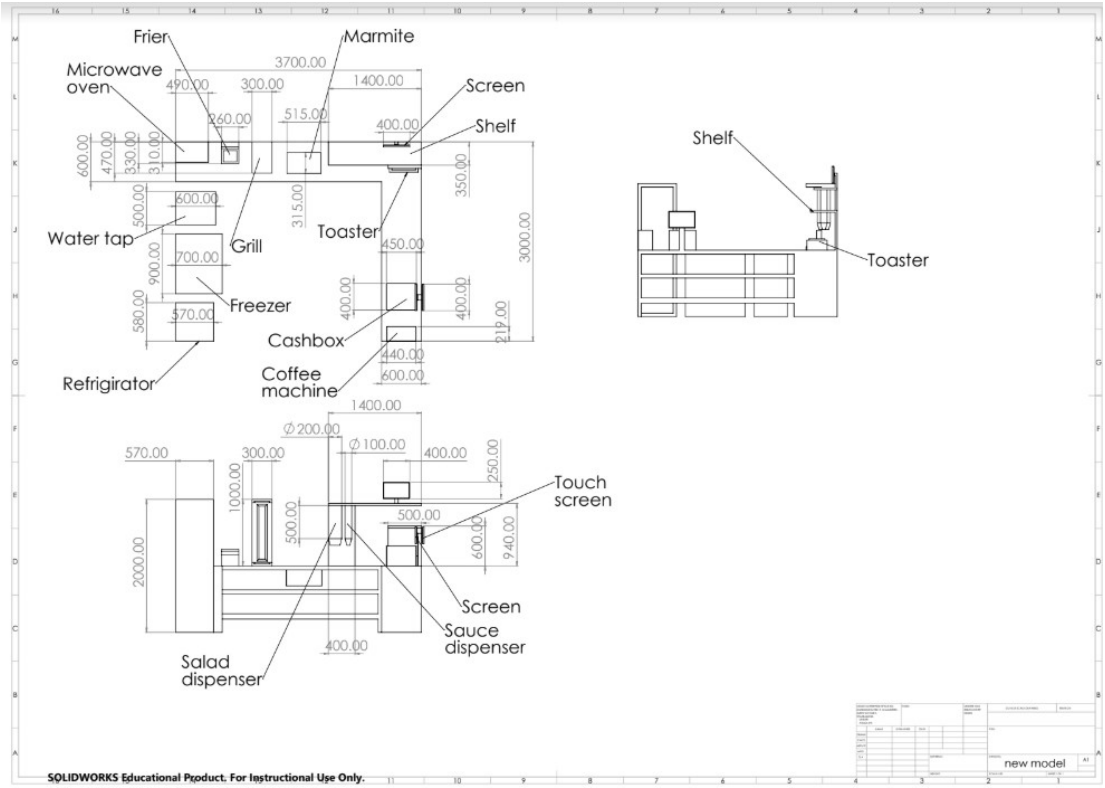

Figure 19 Proposed layout for the Fast Food shop

Below are changes proposed:

1) Lower marmite and change cap of marmite to sliding one. It will decrease time required for reaching the meat and adding it to product.

2) Move marmite next to the grill. This will ease process of adding meat to marmite and in case if another performing this task, no conflicts in the movements will be observed

3) Switch from ordinary salad dishes and sauce bottles to salad and sauce dispensing mechanisms. This way employee will not need any other tool to add salad in product. This will increase supply volume and decrease need of regular refilling. Place them as close as possible to marmite in order to decrease travelling waste.

Figure 20 Example of mechanism to be used for salad dispensing [34]

4) Place toaster in the end of the line. This needs to be done according to process queue.

5) Bring breads to toaster by creating shelf over toaster. Employee needs to able to easily reach bread in order not to waste any time.

6) Add screens in the most comfortable places for both employee and customers to place and track order.

Implementation in Arena simulation. Below simulation of production process has been updated and presented with following changes:

- As orders will be placed by customers along with payments, employee will no longer need to put off gloves and put them on again.
- Cooking process has been modified as parallel process and no longer creates any queues.

- Adding meat process has been speeded up as employee no longer needs to cut it.

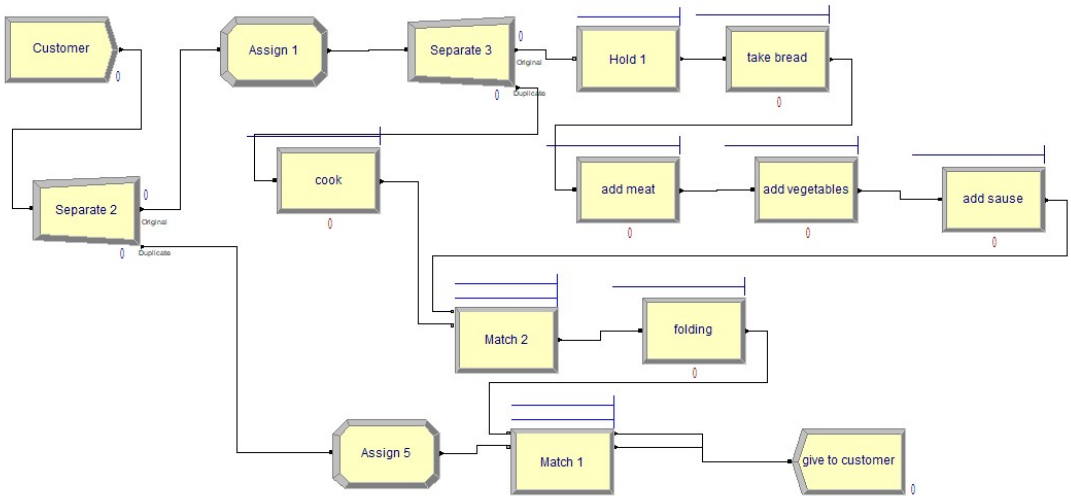

Figure 21 TO-BE process map analysis in Arena

Results of simulation are as shown below:

1. Time required for preparation of one product: 28 seconds
2. Maximum time spent in the queue of 10 orders: 324 seconds
3. Maximum number of orders finished in 1800 seconds: 116

By reviewing updated results of simulation it is obvious that capacity of shop increased by nearly 6 times. It is assumed that this improvement will lead to sales increase of 30 percent due to competitive advantage. Sudden increase of shop capacity also creates huge opportunities for the shop to increase its sales using various ways.

3.3.5 Control

After proposed results are implemented it is required to track performance of company and build up statistics for further improvements. By implementing online ordering and tracking of orders it is becomes possible to create digital database where all the required data will be stored. More accurate data on demand change, time spent on preparation of orders and other important information can be collected and saved in Excel format. This further can be imported in Arena simulation software to get more accurate data and achieve more realistic forecasts. Moreover, using various tools

provided by Excel it will also be possible to automate some of the operations and control the system accordingly.

4 Conclusion

Extensive literature review has been performed. All used methodologies and tools rely on previous experiences and literature that has been analyzed. Data used for simulation was taken from real observations. Moreover, all the company representatives who participate in production flow were interviewed and their challenges were asked directly from them. It should also be noted that information received from people were questioned and verified before used in thesis.

As a result of this analysis, it was revealed that the enterprise has a real opportunity to increase the efficiency of production processes by implementing comprehensive lean manufacturing tools proposed by the author; 86 percent improvement on preparation time of one product, 65 percent decrease in maximum time spent in queue by customer, around 500 percent increase of capacity.

Sudden improvement of results is related to the fact that processes were not continuous previously and most of process were waiting for couple of other processes. That in its turn was increasing cycle time of one product preparation and waste time was adding up for other customers in the queue which in its turn was resulting in long lasting queues.

Bread cooking, meat adding and accepting orders were identified as the most wasteful processes as they whether had long processing times or were not adding value for the customer.

Bread cooking was considered wasteful as its process time was around 120 seconds while the rest were around 15. New proposed approached made this operation be performed in parallel and require only around 20 seconds.

Meat adding process added waste due to the fact that employee had to perform cutting before adding meat. As it was proposed to prepare cut meat beforehand before rush hours, time required for cutting meat was eliminated therefore cycle time decreased up to 7 seconds.

Accepting order was identified as waste as it was not adding any value to the customer, therefore time spent for this operation has to be eliminated. Self-ordering and online ordering systems has been proposed that totally eliminated processes related to this activity.

There was also time waste related to ergonomics of the workspace, employee was required to use additional equipment for performing tasks or needed to look for the ingredients. Implementation of more ergonomic line decreased those wastes as well. Moreover, observations showed that in some cases there were mistakes made by employee with completing orders, therefor visual management system has been implemented to minimize those mistakes.

The reason why final result of total cycle time significantly decreases due to

- elimination of order accepting process and related activities with it
- removal of time required for cooking bread (tortilla) as it was performed in parallel
- decrease of time required for adding meat
- minimization of time waste that resulted due to bad ergonomics of the line

One of the alternative approaches that can be used for reaching maximum efficiency is switching to Industry 4.0 and involving automated systems to do all the tasks. Robots and industrial solutions proved to be much faster than humans thereby may result in even more decrease of time waste.

Economical effect is expressed in the reduction of time costs, as well as labor costs for unit production, which can be a significant part the cost of manufactured products. Lean manufacturing activities are currently partially implemented at the enterprise, in the future it is planned to track the results of their implementation. Thus, the study fully confirmed relevance of the thesis topic and confirmed hypothesis that the implementation of the concept of Lean Manufacturing, Six Sigma and TRIZ problem solving method can result in rational use of resources and optimization of production processes in the Fast Food sector with using innovative management mechanisms and tools. It will be a fundamental factor in development and growth of competitive advantage over other competitors in the market.

Summary

Rapid growth and development of market is creating urgent need of companies in decreasing negative business environmental impacts by improving their functional strength and acquiring better social benefits, thereby company leaders focus more on finding and implementation of various optimization frameworks, quality improvement systems such as sustainable manufacturing, lean manufacturing, six sigma and other approaches and technologies. Fast Food company was taken as a case study to implement and improve its processes. Lean Manufacturing was used as a main tool for analysis and problem identification with the help of discrete modelling and process mapping. Six Sigma was used to create improvement cycle. TRIZ problem solving methodology and 5S was used to propose improvements.

Implementation of proposed changes lead to 86 percent improvement on preparation time of one product, 65 percent decrease in maximum time spent in queue by customer, around 500 percent increase of capacity.

Economical effect is expressed in the reduction of time costs, as well as labor costs for unit production, which can be a significant part the cost of manufactured products. Lean manufacturing activities are currently partially implemented at the enterprise, in the future it is planned to track the results of their implementation.

Thus, the study fully confirmed relevance of the thesis topic.

KOKKUVÕTE

Turu kiire kasv ja areng tekitavad ettevõtetele kiireloomulise vajaduse vähendada negatiivset ärimõju keskkonnale, parandades nende funktsionaalset tugevust ja sotsiaalseid eeliseid. Seeläbi keskenduvad ettevõtete juhid rohkem erinevate optimeerimisraamistike leidmisele ja juurutamisele, kvaliteedi parandamise süsteemidele nagu säästev tootmine, kulusäästlik tootmine, Six Sigma ja muud lähenemisviisid ja tehnoloogiad. Antud töös vaadeldi juhtumianalüüsis kiirtoidufirma protsesse ning nende rakendamise ja parendamist. Diskreetse modelleerimise ja protsesside kaardistamise abil kasutati analüüsi ja probleemide tuvastamise peamise tööriistana kulusäästliku mõtlemise lähenemist. Parandustsükli loomiseks kasutati kuut Sigmat. Paranduste tegemiseks kasutati TRIZi probleemide lahendamise metoodikat ja 5S-i.

Kavandatud muudatuste elluviimine parandab ühe toote valmistamisaega 86 protsenti, kliendi järjekorras kulutatud maksimaalne aeg väheneb 65 protsenti ja mahutavus suureneb umbes 500 protsenti.

Majanduslik mõju väljendub nii ajakulude kui ka ühiktootmise tööjõukulude vähenemises, mis võib moodustada olulise osa valmistatud toodete maksumusest. Kulusäästlikku tootmist rakendatakse ettevõttes praegu osaliselt, tulevikus on kavas jälgida selle rakendamise tulemusi.

Seega kinnitas uuring lõputöö teema asjakohasust.

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