

USING VALUE STREAM MAP AND PROCESS MAPPING FOR VIZUALIZATION RECOVERY BOILER OS-5 PRODUCTION

1. Introduction

Nowadays, companies are faced with the most crucial problem seeking off to reduce the production cycle with minimum effort costs. Firstly to even talk about the possibility of shortening the cycle companies should characterize it and get to know all of its components, and locate any errors that might occur. The best way for achieving this goal is to use some form of analysis of production cycle and extend it by adding a process map. To choose proper methods enterprises should consider their current practical and financial capacity. One of the optimal and easy analyzes that allows to create an accurate map of the production cycle and estimate non value – added time is the value stream map (VSM) also known as Big Picture Analysis (BPA). In addition to BPA companies may also consider creating a map of key processes implemented in the company (process mapping). The value stream map was created by a big company (Toyota) and is still used mostly by the big corporations but it is not so popular in smaller enterprises circles. Many companies are specializing in creating the VSM for other enterprises but it is of course associated with extra cost. Small companies do not have financial resources to hire an outsourcing company to prepare the VSM for them so they do not use that analysis at all. VSM and process mapping will allow enterprises to detect any disruption occurring during the production cycle and help with making decisions about how to eliminate them, and show how that elimination will change the length of production cycle. VSM can also help small companies to improve customer service by understanding what processes are not bringing any value to the final good and hence the customer. After identification of wasteful activities companies can eliminate them, which will bring future benefits. Also VSM can be used in variable production but only after grouping similar parts of each manufacturing product and after that creating general maps for each group, so that way the company can always follow what is happening during the production cycle. The paper is structured of 4 section: introduction, literature review of the VSM, methodology – practical use of both methods in section 3 on the example of the production of recovery boiler and last section – conclusion. The article gives a methodology how the companies can use the VSM and process mapping to understand and improve the production cycle by themselves. It also gives a new approach because it suggest connecting BPA and process mapping methods.

2. Literature review

First example of a map mostly similar to VSM or BPA comes from a 1918 book called *Installing Efficiency Methods* by Ch. E. Knoeppel [3] and it presents materials and

information flows occurring in companies during production cycle but it does not use the icons it just contains arrows and very schematic designation. VSM was then used at Toyota company and is now a widely used tool in many enterprises. First symbols from value stream map were mention in 1993 by Y. Monden in *Toyota Production System* book [5] and shortly after, Toyota company created full value stream map for their own production cycle and created the set of questions to help getting more specific information about the processes. In 2005 the Nissan company also used the BPA method and published it in a book called *The Nissan Production Way* [6] but it does not contains anything new it is. In 2007 series of articles of a related topic appeared in *Factory Management* magazine and every article was also based on the Toyota example and using that example the case studies were designed. Than the latest and most simple version of something similar to BPA was created by M. Aoki in *All about car plants* book but it is only available in Japanese. Another point of view in which the VSM can be helpful is to improve leadership in the company. Emiliani and Stec [11] wrote an article about this problem and showed that the map can be used not only for characterizing the production processes but also for business processes which can be useful for the management. VSM can also be used to map service industry [11] and the article gives a full instruction on how to do it on the example of Enrolment Centre at the university. Most of the articles published about VSM are very similar to each other and describe what is the method, than show the example maps and propose some improvements to help reduce the length of production cycle. The improvement depends on the case study and it could be introduction of Total Productive Maintenance tool [10], using the RFID technology in the supply chain [12] or using lean philosophy to shorten the production cycle [15]. First article [10] is very general on how to actually implement it in the company and it does not give a full instruction on how to create the VSM map. Second one [12] also does not focus enough attention on the map but in details presents how to use the RFID application. The third one [15] gives the reader the idea what should be shortened like reduce set up time, process defect and basically reduce the production lead time and how the VSM map should look like after. In February 2014 appeared an article [13] which is actually a literature review from the past 15 years about VSM, describing 57 other articles and classifying them into 11 categories each with different problem with BPA such as creating maps lacking information about making changes in the processes, maps that are missing integration between processes or maps that cannot be created because of too flexible production. The article is very helpful from the scientific point of view but it is not very practical for the companies wanting to use that method. In Poland

most articles published about BPA are written by J. Czerska [9] and to understand the whole process of creating VSM according to the author it is best to use many sources. Each source includes different information and it is missing full step by step tutorial of how to actually implement it in the company. Average company with no proper knowledge of BPA can have difficulties with understanding the creation process of it. None of the articles about VSM combines both analyzes the VSM and the process mapping which joined together can be more effective and most of the articles give a very general point of view on the matter.

BPA is created based on the presentation of flows occurring in the company presented on a piece of paper in the form of map. Best way to build Big Picture map is to use sticky notes that are going to be placed on a large sheet of paper. Then, after the final map has been created, VSM can be transformed and saved as a computer file using for example Microsoft Visio software. BPA helps to increase customer satisfaction, reduce the number of defects and damaged products by locating where they are forming and also reduce production costs. BPA also facilitates the selection and implementation of new techniques in the enterprise through a detailed indication of the places that need improvements and / or changes.

BPA consists of five stages that must be carefully carried out to ensure appropriate determination of the production cycle duration:

- I. Customer requirements – what can the enterprise do to fulfill customer needs, identification of customer expectation.
- II. Flow of information – that allow to define the terms of cooperation with suppliers and clients.
- III. Material flows – the detailed course of operations occurring in the company, how the entire order process looks like.
- IV. The combination of material flows and information flows – that influence the production flow on material requirements planning.
- V. Supplement of analysis – define the total production cycle time and the value-added time and determine what are the components of value-added time.

3. Methodology – case study – production process of recovery boiler

In order to conduct the Big Picture analysis the company should answer a set of specific questions relating to customer requirements, and material and information flows as well as the connections between them. Answers to these questions are presented in five stages that were described in section 2. Then, in accordance with the information contained in the presented analysis stages, schematic map was created. After finishing VSM, the company can create process maps for all the processes mentioned in VSM. For the purpose of this article, one process was selected: „submit order” and taken under closer look to design the process map for it. The process maps can be made for any processes from the value stream map that the company chooses and considers important. They will help to better understand and see which actions are unnecessary, whether all the

documentation during the process are needed, how the information flow looks like and which action can be eliminated. Best way to choose which processes are not needed is to analyze which are bringing some values to customers and which are not. Companies do not have to improve every single process if they consider that the process is working correctly and fluently they can leave it as it is.

Data contained in the article come from the company producing industrial water and steam boilers and other components for the energy industry (e.g. superheaters, water heaters, membrane walls, reducing stations, separators, collectors, compensators etc.). It is a small company employing 128 people including 60 manufacturing workers. The maps were created after the measurement, observation and familiarizing with the technological documentation of one chosen product in this case the recovery boiler OS5. Manufacturing process was generalized because the original technological process is reserved. The amounts of materials and execution times were given by the company and summed up showing final execution time of each process. The industrial boilers are made only for special order whereas other smaller products are manufactured in mass production. In between the mass production the company is manufacturing the special order boilers. Also every production of boiler uses the same manufacturing processes but in a different order with the same materials in different dimensions and types, so it is not a typical unit production.

Step 1. Customer expectation

1. What product will be analyzed?

We analyze the recovery boiler OS5.

2. What are the required delivery dates and what is the required amount of delivery?

The company must provide boiler within 3 to 4 months. Required amount: 1.

3. Is there a large variety of manufactured products?

Yes, each boiler is unique and they are made according to the contract.

4. Are all the products delivered to the customer on time?

Yes, all products are delivered on time. The company does not accept infeasible orders.

5. How many deliveries of industrial boilers the company should deliver in a year?

5 to 6 boilers within the year but every boiler is a different.

6. How are the products protected during transportation?

The product requires adequate protection during transport, but the boiler itself is not packaged. It is too big to be packed.

7. Does the customer has a supply of the product?

No. These are single products made for special order.

8. Are there any damaged delivery or complaints about the products?

No. The boiler must not be delivered if it has some drawbacks also the product cannot be shipped to the client if it did not pass all the required tests.

Step 2. Information flows

1. How many orders are rejected during the year?

Approximately 5 orders per year.

2. What department or which person receives information about placing an order?

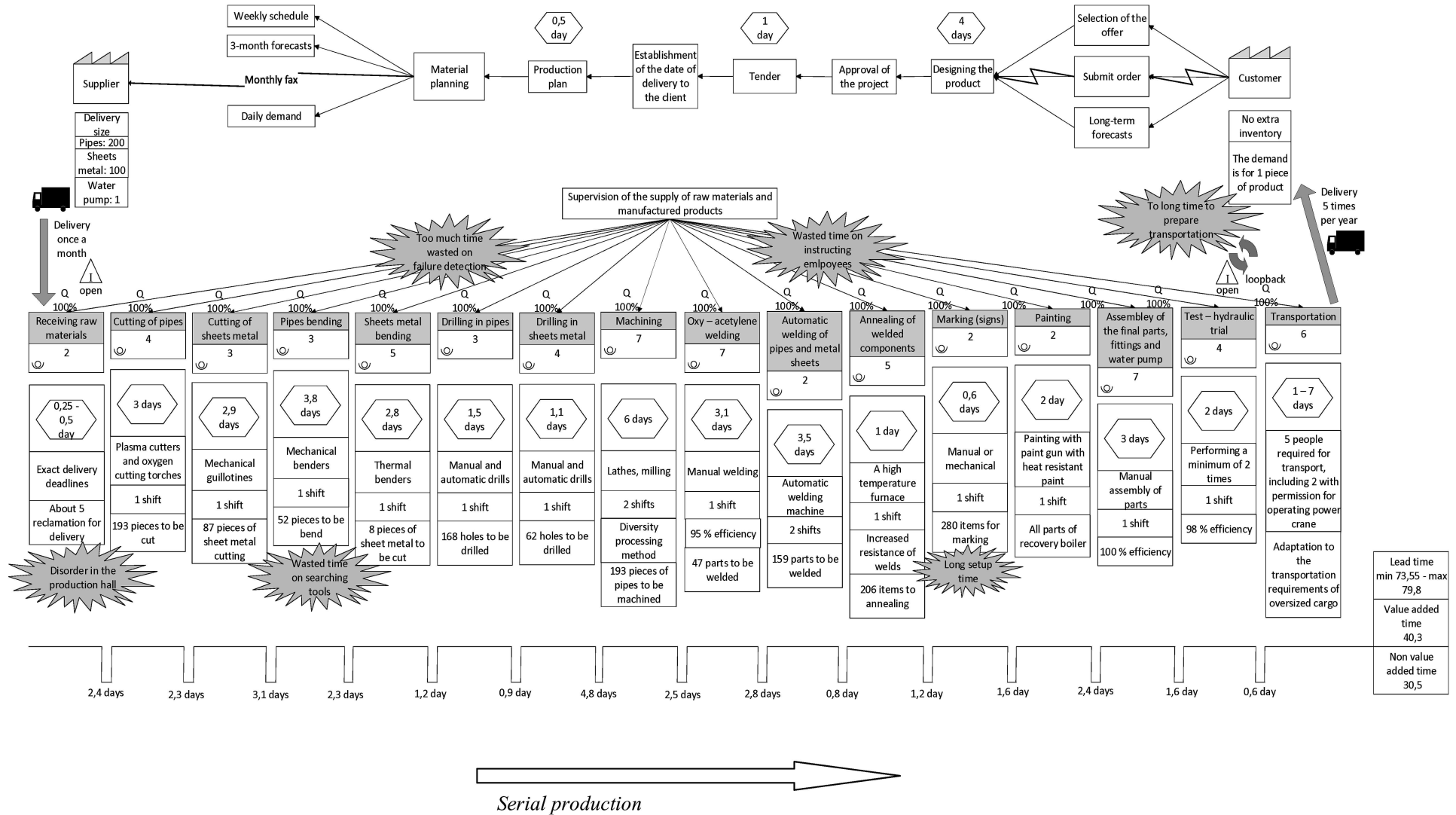


Figure 1. Value stream map (Big Picture)

No intermediate stocks because next process begins when all pieces of material had been finished processed.
 Employees work 8 hours per shift of which they are allowed 30 minutes breaks therefore working shift in minutes is $7,5 \times 60 \text{ min.} = 450 \text{ min.}$

Goal: visualize the production cycle and determining the production lead time, value added and non value added time

Chairman of the company.

3. What is the waiting period to process this information?

4 days plus 1 day for auction.

4. How does the order process look like?

First, the information about the order reaches the Chairman, who after the acceptance transmit it to the team of engineers, who design the boiler. Then, further information, or final design of the boiler is transferred again to the Chairman, who must again accept it. After that the project is turned to the work managers. In the last phase the project is transmitted to the manufacturing department. The offer can be accepted only if the company has won the tender.

5. Does the company cancel any supply deliveries?

No.

6. What is the amount of raw materials needed to manufacture the product?

Indicative amount (without screws, nails, caps, etc.): 200 units of various diameters metal pipes (types of metal pipes: K10,K18,10H2M,15HM,16), 100 units of sheet metal (types of metal: 13JS,18JS,H18JS,H25N20S2,St36K in size sheet: 1000x2000, 1250x2500,1500x3000 mm), 1 pump and 1 can of paint. The company orders pipes and sheets metal in units because this is how the suppliers sell this kind of materials. Also when designing the boiler the company sets demand for materials in units.

Step 3 Physical flows

1. How many products the company produces in a year?

The company produces 5 to 6 boilers during the year. Companies currently are not able to produce more boilers because of the length of the production cycle.

2. How many different semi – finished goods have to be manufactured to assembly the complete product?

16 parts of semi – finished goods.

3. Are all the products delivered on time?

Yes, the term of delivery is predetermined and cannot be changed.

4. What is the frequency of the supply of raw materials?

1 time a month.

5. How are the raw materials packed?

Raw materials are supplied in containers or in the case of tubes and sheets without packaging.

6. How long does a delivery take?

From day 7 to a maximum of 1 month.

7. How many suppliers now have the company?

currently about 6 suppliers.

Questions about the internal processes in the company

1. What are the main elements of the manufacturing process?

Providing material, bending and cutting of sheet metal and pipes, drilling, machining, welding, annealing, studded signs, painting, assembly, testing the boiler, transporting to the customer.

2. How long does the production cycle take (minimum and maximum length)?

Minimum duration of the production cycle lasts 73,55 days and a maximum of 79,8 days.

3. Where are the operation of storage?

On the production floor.

4. In which moments does a quality control occur?

Quality control is performed after every manufactured item. The quality control department is responsible for the control. Errors are corrected up to date.

5. Is there re-processing of the product during manufacturing?

Yes the boiler is constantly re-processed until all the parts are assembled.

6. What are the execution times of the individual elements?

- cutting sheet metal and pipes – also it depends on the pipe diameter and the sheet thickness (from 3 min. to 25min.) – for cutting pipes average time is 7 min. times 193 units ($7 \times 193 = 1351$ min. ≈ 3 days) and for cutting metal sheets average time is 15 min. times 87 units ($15 \times 87 = 1305$ min = 2,9 days),

- bending sheet metal and pipes – it depends on the pipe diameter and the thickness of the metal sheet (10 sec. to 3h) – for bending pipes average time is 33 min. times 52 units ($33 \times 52 = 1716$ min. $\approx 3,8$ days) and for bending metal sheets average time is 157 min. times 8 units ($157 \times 8 = 1256$ min. $\approx 2,8$ days),

- drilling in pipes and metal sheets – average time for drilling in pipes is 4 min. times 168 holes ($4 \times 168 = 672$ min. $\approx 1,5$ days) and for drilling in metal sheets is 8 min. ($8 \times 62 = 496 \approx 1,1$ days),

- machining (lathe, borer, planning machines, milling machines, grinder etc.) (from 3 min. to 30 min.) – average time of all processes is 28 min. times 193 parts and it is done in 2 shifts that way it takes less days ($28 \times 193 = 5404$ min. ≈ 12 days divided into 2 shift is 6 days),

- oxy – acetylene welding (from 10min. to 30 min.) – average time for pipes and metal sheets welding is 30 min. times 47 parts ($30 \times 47 = 1410$ min. $\approx 3,1$ days),

- automatic welding (from 10min. to 30 min.) – average time is 20 min. times 159 parts done in 2 shifts ($20 \times 159 = 3180$ min. ≈ 7 days divided into 2 shifts is 3,5 days),

- annealing – average time for this process it 2 min. times 206 parts ($2 \times 206 = 412$ min. ≈ 1 day),

- marking sings (from 10 sec. to 1 min.) – average time is 1 min. times 280 units ($1 \times 280 = 280$ min. $\approx 0,6$ day),

- painting of all processed parts – 2 days because of the drying process,

- assembly of the final parts, fittings and water pump – average assembly time of the final product takes 3 days,

- test – hydraulic trial – to carry out the test the company needs 2 days.

7. What types of inspection are carried out?

Visual inspection, leak test, inspection of welds, spatter control, ground control elements.

8. How much time is used in workstation during the day?

7.5 hours. People working on gantries – 4h.

9. How many people operate the workstation and whether this number is permanent?

From 1 to 3 persons in post production. 2 employees in the tool workstation and 5 employees in the quality control department. Number of production workers is constant.

10. How much time do the machines require for tooling changeover?

3-4 hours.

11. How many and what storages have the company?

Just one open storage.

12. What is the bottleneck in the company and where is it occurring?

Bottlenecks occur on a workstation with automatic welding machine and large scale automatic bender. They are caused by excessively long tool change time of the machines, which, depending on the ongoing manufacturing process takes from 4 to 6 hours.

Step 4: The combination of physical and information flows

1. What information about the schedule are required at a given stage of the process?

Employees receive verbal instructions given by the engineers from the designing department.

2. What kind of work instructions are created?

Instructions are transmitted orally by foremen. In addition, a person working on automatic cutter, receives the appropriate data in the form of paper, which he introduces to the cam software.

3. How are information and instructions sent (sages of transmitting information)?

Client -> Chairmen -> Designing engineers -> Chairmen -> Foremen -> Suppliers -> Manufacturing

Step 5. Determining the length of production cycle and non value added

The entire production cycle lasts a minimum of 73,55 days and a maximum of 79,8 days. Non value added time in this cycle is a total of 30,5 days and includes queue time before process 14,5 days (including total of 5 days for employees breaks), setup time 9,1 days - the time needed to search and provide tools, time needed to familiarize employees with work instructions, time needed for failure detection and time for tool changes (including 3 days for searching tools, 2 days for failure detection and 1,5 day for instructing employees and 2,6 days in total for tool changes), run time – sum of manufacturing and business processes min (43,05 – max 49,3 days), waiting time after process (3,6 days) and motion time (1,8 days). Non value added time would be longer if the company had to design the product from scratch but they received general project of the boiler and the only task for the producer was to select proper materials recount if everything will work correctly and add few changes so that the boiler could be produced properly. To shorten the existing non value added time the company can use some of Lean Manufacturing methods such as 5S, Visual Control, Kaizen etc. To even consider shortening non value added time it is best to start with shortening setup time while taking under consideration companies financial capacity. Only one thing from setup time cannot be eliminated completely because the company does not have sufficient financial capacity to implement the SMED method. Value added time is 40,3 days and it contains manufacturing and business processes that add something to the product from the customer perspective (sum of designing the product and the manufactory processes from cutting pipes and sheets metal to hydraulic tests). Based on information given by the company in clear operating time with business time the production system would look like the one created on BPA map. It is important to remember that in best interest of the company is to try to achieve best possible results with production

system efficiency because every downtime would mean a great financial loss and since it is a small family company they could not afford it. However if the given data from the company were more objective than the efficiency would probably be smaller.

When creating Big Picture map, it is best to use existing icons, which are divided into material flow icons (processes, manufacturing processes with the information about how many people are working on the work station, outside sources- client, supplier, track shipment, inventory with information about the type of storage, shipping arrows and data boxes with the information about the process, what machine is going to be use, information about number of defects etc.), flow icons (electronic or manual information flow) and general icons (time icons, operators and quality control icons with the correct percentage of damaged products/parts). The top part of the map (fig. 2) shows what happens when the client orders the product and how long each stage is taking, from placing an order and selecting an offer to designing the product and production plan until ordering raw materials from the supplier needed to manufacture the final goods. The bottom part of the map contains information about manufacturing process, which processes are submit under control and what is the percentage of quality control. Data boxes includes machines used in manufacturing process, execution time, efficiency percentage, number of shifts, workstations, other required for process information and number of part that have to be made. Info about the delivery size from a supplier and to the client, about the storages used by the company and about reclama-tion are also included on the BPA map.

To define how big is non value added time for each manufacturing process companies should measure how long every process takes and how much time do employees waste for not needed activities. In this example appropriate measurements were made during visits at the company and based on that established the percentage of each non value added activity (calculated from total time of manufacturing processes which is 36,3 days):

- 40% for queue time before process, 25% for setup time, 10% for waiting time after process, 5% for motion time.

After the BPA map (fig. 2) was created the length of the production cycle was determined.

Process mapping

Data for the process map were collected during the visits in the company an observation of their work. Each process has a beginning – input, the end-output and a specific owner, or the person responsible for its implementation, as well as a specific purpose such as to provide the raw materials for production. The process map also includes the documents accompanying processes and decisions. The easiest way to present a final process map is to build a block diagram with the appropriate markings and description how to read them. Process map shows:

- management processes(e.g., financial management, customer acquisition),
- main processes (e.g., design, production, implementation of the contract),
- auxiliary processes (e.g. logistics).

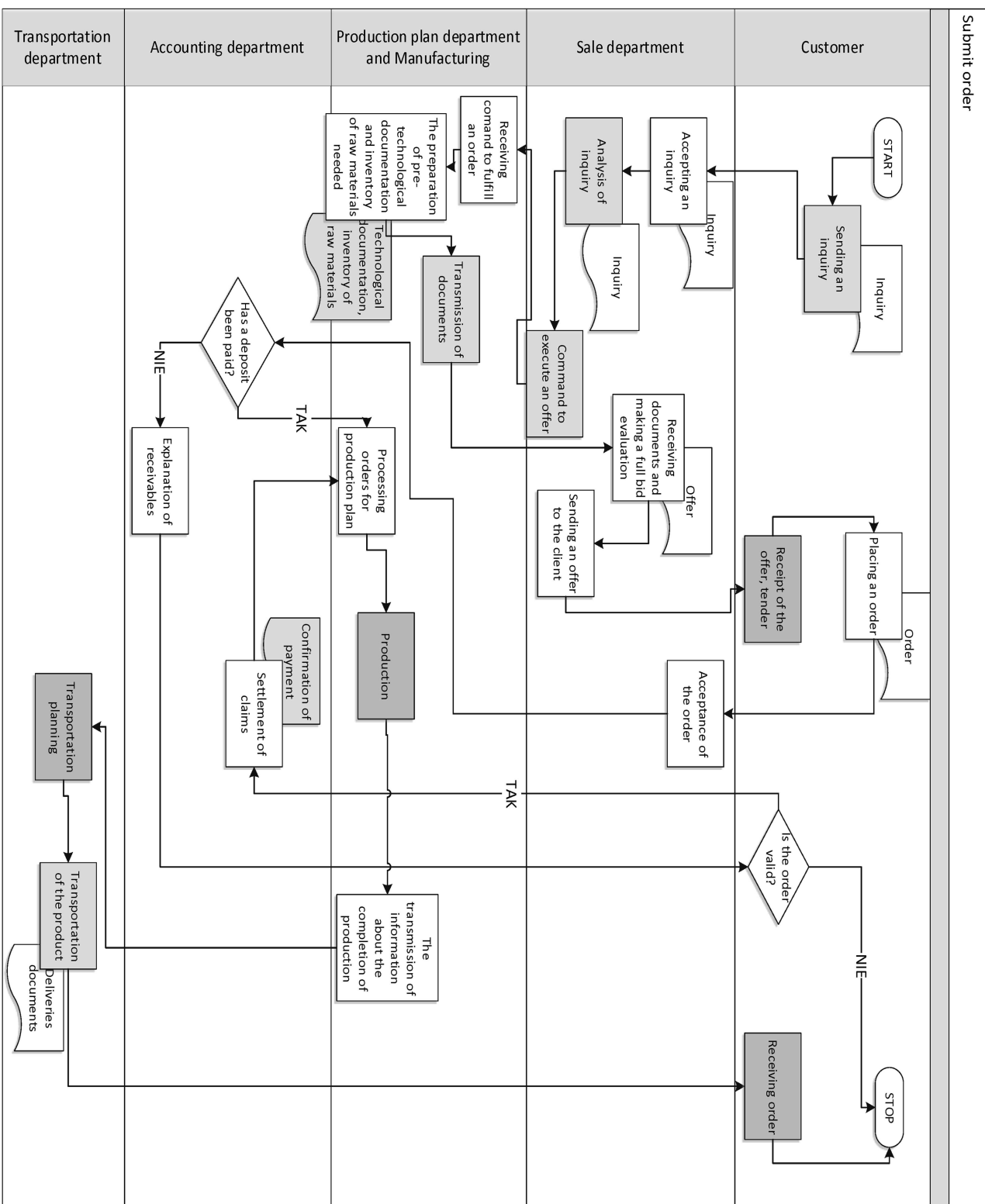


Figure 2. Process mapping – submit order
 Goal: visualize the process „submit order”

Table. Icons for process map

Icons	Description
	START/END procesu
	Process
	Decision
	Data
	Document
	Complex process

Properly created process map enable the company to control operation of the selected process.

The analyzed process is submit order and process map icons used to create the map are explained in table 3. The map shows what departments the information are passing through, what decisions are made and what kind of documents accompany each action (fig. 2). The process owner is the chairman of the company. Each process has a person responsible for it. Most of the documentation flow in the process is traditionally held. The manufacturing process was characterized in previous BPA map, so to avoid illegibility it is put on the map as a complex process. Thanks to this the map is more readable. Another complex process is the process of transport. Transporting the products require special preparation due to the fact that the product is oversized cargo. The transport route planning is very complicated and the company needs to have all the needed permits. In view of the fact that the products are oversized cargo often arise various problems such as the need to disassemble the traffic lights on the transportation rout. The company does not use any software to help with the process and that is why it usually takes the company almost 7 days to finish preparation and planning. An improvement to this complex process would be to use software that helps to plan the transport routes and start the process of planning a route before the actual finishing of the boiler, which will significantly save time. Companies should create process maps for every process from the BPA analysis.

4. Conclusions

VMS help to determine length of the production cycle and visualize how the entire process looks like and connected with process maps can give companies better understanding of what are the main wastes during the production cycles. If the company would take every processes especially business processes from the VSM and create a separate process maps for them than it will give the information about links between business cells and production cells and helps to better visualize parts of production cycle and reduce excess documentation if needed. So process maps are extension of VSM and thanks to that the final map is more clear. If companies were try to put all information from process maps on BPA map than it would become unreadable. Creating the maps should not give any problem to the people

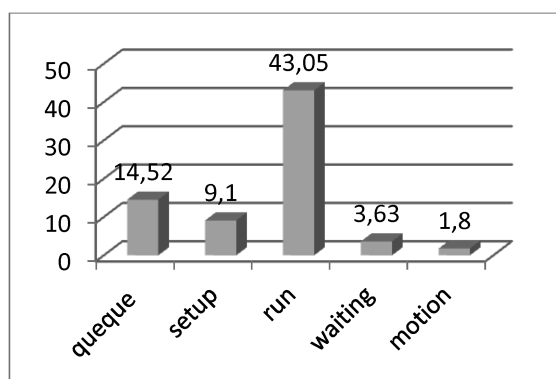


Figure 3. PLT before improvements

forming it and it is not related with adding any extra costs. To create VMS the enterprise does not have to hire a person from outside but just needs to appoint the team with the leader and give them all the information about production. The map does not have to even be created using any software. For better understanding the value stream map it is good to create the process maps along with it. After that the decisions about which processes are unnecessary can be made and those processes can be removed. To eliminate non value added time the companies should remember to first look for the most profitable and easy solution like 5S method or visual control and start with those because it can significantly reduce the waste. Sometimes the easiest solutions are overlooked and treated like unnecessary and the companies should remember to never have such an approach.

In given example it is possible to reduce non value added time by 6,5 days as it is seen on given charts (fig. 3 and fig. 4 with Production Lead Time diagrams) if the company would implement 5S method and visual control which are not described in this article due to space limitations. That way non value added time was 24 days. The shortened time would be more sufficient if analyzed company could apply SMED method. Based on conducted analysis the general non value added time is not very high and the production cycle of the tested company works fluently but there are always ways to make it better and more sufficient.

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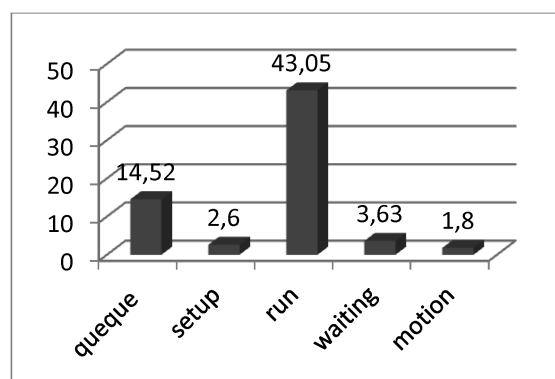


Figure 4. PLT after improvements

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Key words:

value stream map, Big Picture analyses, defining the duration of production cycle, Lean Manufacturing.

Abstract:

The paper shows a brief history of the Big Picture analysis and practical example of creating value stream map based on company manufacturing industrial boilers for special order. Production of boilers is in the presented case the additional task and it is manufactured in between the normal mass production of other products produced by the company. BPA delivers information about customer's requirements, information and physical flows and the impact of manufacturing on material planning. Thanks to creating a VSM, determination of the length of production cycle and non value added time were established. Determination of the non value added time allows for the selection of appropriate methods for their elimination. However, these methods must be feasible to implement by the company and not exceed the company financial capabilities. For the analysis of BPA to be more detailed, creating a process map for the selected business process „submit order” was proposed. Process map should be created for each process located on the VSM map, with the exception of manufacturing processes, in order to show links between business cells and

production cells and how the flow of information looks like when business processes are performed. It gives companies the chance to check whether any actions are unnecessary and whether or not there is an excess of documents during process. Article draws attention to the affordable possibility for companies to monitor production using simple tools such as BPA and mapping processes, enabling organizations to visualize the production cycle and try to take action to improve it and eliminate the excessive documentation.

WYKORZYSTANIE ANALIZY BIG PICTURE I MAPOWANIA PROCESÓW DO OKREŚLENIA CZASU TRWANIA CYKLU PRODUKCYJNEGO

Słowa kluczowe:

analiza Big Picture, mapowanie procesów, określenie długości cyklu produkcyjnego, Lean Manufacturing.

Streszczenie:

Artykuł pokazuje krótką historię analizy Big Picture i praktyczny przykład stworzenia mapy BPA na podstawie firmy zajmującej się produkcją kotłów wielkogabarytowych na zamówienie i innych produktów na potrzeby przemysłu energetyki. Produkcja kotłów wielkopieczowych jest w analizowanym przypadku zadaniem dodatkowym i realizowana jest między normalną produkcją seryjną innych produktów wytwarzanych w przedsiębiorstwie. Analiza BPA dostarcza informacji na temat wymagań klienta, przepływów informacji i przepływów materiałów oraz wpływu przebiegu produkcji na planowanie materiałowe. Dzięki stworzeniu mapy można określić całkowity czas cyklu produkcyjnego i czas wartości dodanej oraz pokazać jak wyglądają przepływy w firmie i przez jakie działy albo jakie osoby przechodzą dane informacje. BPA jest pewną metodą sieciową, która pozwala określić czasy operacji, wąskie gardła, stany zapasów, zlokalizować gdzie i jak przeprowadzane są kontrole i ogólnie śledzić przebieg produkcji. Określenie czasu niedodającego wartości pozwala na wybór odpowiednich metod pozwalających na ich eliminację. Należy jednak pamiętać, że metody te muszą być wykonalne do wdrożenia przez daną firmę i nie mogą przekraczać ich możliwości finansowych. W celu skrócenia czasu nie dodającego wartości można wykorzystać narzędzia z Lean Manufacturing. Aby analiza BPA była bardziej szczegółowa zaproponowano stworzenie mapy procesów dla wybranego procesu biznesowego „złożenie zamówienia”. Mapy procesów powinny być tworzone dla każdego procesu znajdującego się na mapie VSM, z wyjątkiem procesów wytwarzania w celu pokazania powiązań komórek biznesowych z komórkami produkcyjnymi i sprawdzenia czy któreś czynności są zbędne i czy nie występuje nadmiar zbędnych dokumentów. Artykuł zwraca uwagę na możliwość przystępnego dla firm śledzenia przebiegu produkcji z użyciem prostych narzędzi, jakimi są BPA i mapowanie procesów, dzięki czemu firmy mogą zwizualizować cykl produkcyjny i starać się podejmować działania dążące do jego usprawnienia i eliminacji nadmiernej dokumentacji.

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