

Applying the Lean System in the Process Industry

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Subject review

Today, when changes are the only thing that is constant, management based on Lean principles has proved to be an excellent tool for attaining high levels of flexibility. Small batches are the major prerequisite for flexibility and readiness of a company for quick response to those changes. But when the process industry is the case, there is an obstacle in achieving small batch production and that is change-over time.

This paper presents how it is possible by using Kaizen workshops (also one of the lean tools) to manage shorter change-over time on machines in the processing industry.

Primjena Lean sustava u procesnoj industriji

Pregledni članak

Danas, kada su promjene jedina konstanta, upravljanje zasnovano na principima Lean-a pokazalo se kao izvrstan alat za postizanje visoke razine fleksibilnosti. Glavni preduvjet za fleksibilnost i spremnost poduzeća za brze promjene jesu male serije proizvodnje. Međutim, kada je riječ o procesnoj industriji, najveća prepreka ka postizanju malih serija jeste vrijeme namještanja alata.

Ovaj rad pokazuje mogućnost skraćivanja vremena namještanja alata u procesnoj industriji primjenom Kaizen radionica (jedan od Lean alata).

1. Introduction

In the last decades, conditions in which companies work, have changed. These changes are constant and unpredictable and require great effort from the company to survive in the global market. Customer demand has been constantly changing and the customer is not anymore one who is adjusting to the market offer. Furthermore, the customer is the one who is dictating and only customer-orientated companies, which recognize customer's needs and demand and which respond on time following those demands, can keep up in the market race.

It has already been recognized that is necessary to reorganize the company by adopting new production paradigms which transform the functional orientated company into process orientated company. One of the well known concepts is the concept of Lean production whose principles application will be described.

2. Lean system

Everything began at Massachusetts Institute of Technology with International Motor Vehicle Program when the book "The machine that changed the world" was published as a report of the study of the world's auto industry. As they pointed out Lean production is "lean" because it uses less of everything compared with mass production [5]. Since then Lean has speeded up not just in the western auto industry, but also in all kinds of production industries and also in administration, healthcare, government, universities. The principle is the same: "bring value to the customer with less waste as possible".

Perhaps, the best way to describe what Lean production is, is to contrast it with craft and mass production [5]. This is shown in Table 1.

In craft production, products are produced one at a time, mostly according to customer requirements. The craft producer uses highly skilled workers and has simple

Symbols/Oznake

T_{VAT}	- Value-added time (total work time for material transformation), s - Vrijeme dodavanja vrijednosti (ukupno radno vrijeme za transformaciju materijala)	T_C	- Cycle time (total time from the order to shipment), s - Vrijeme ciklusa (ukupno vrijeme od narudžbe do isporuke)
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and flexible tools to make exactly what the consumer asks for [5]. The main disadvantage of this production system is the high price, which has resulted in a new production approach, mass production.

are achieved. By applying Lean tools many obtained innovations lead to shortened lead time and flow of the process.

Besides the production, Lean system could be also applied in production development, managing

Table 1. Comparison of craft, mass and Lean production [2]

Tablica 1. Usporedba zanatske, masovne i lean proizvodnje [2]

	<i>Craft production / Zanatska proizvodnja</i>	<i>Mass production/ Masovna proizvodnja</i>	<i>Lean Thinking/ Lean management</i>
Focus/ Fokus	Task/ Zadatak	Product/ Proizvod	Customer/ Kupac
Operation/ Način proizvodnje	Single items/ Pojedinačni proizvodi	Batch and queue/ Velike serije	Synchronized flow and pull/ Sinhronizirani tok i povlačenje
Overall aim/ Globalni cilj	Mastery of craft/ Vještina	Reduce cost and increase efficiency/ Smanjenje troškova i povećavanje efikasnosti	Eliminate waste and add value/ Eliminiranje gubitaka i dodavanja vrijednosti proizvodu
Quality/ Kvaliteta	Integration (part of the craft)/ Integrirana (dio vještine)	Inspection (a second stage after production)/ Kontrola (faza nakon proizvodnje)	Butli In by design and methods/ Ugrađena u proizvod od ideje do proizvodnje
Business strategy/ Poslovna strategija	Customization/ Prilagodavanje	Economies of scale and automation/ Ekonomija obujma i automatizacija	Flexibility and adaptability/ Fleksibilnost i prilagodljivost
Improvement/ Poboljšanja	Master-driven continuous improvement/ Konstantana poboljšanja vođena od strane majstora	Expert-driven periodic improvement/ Povremena poboljšanja vođena od strane eksperata	Worker-driven continuous/ Kontinuirano usavršavanje os strane radnik

The main characteristics of mass production are standardized and high volume products. The equipment is very expensive, and it does not allow non-utilization, so a mass producer very often works in three shifts, producing huge inventories of products, but also making extra supplies, extra workers etc. Switching to a new product costs a lot, so the mass producer keeps a product as long as possible, which leads to a cheap product.

The Lean producer, by contrast, combines the advantages of craft and mass production, while avoiding the high cost of the former and rigidity of the latter. [5]

The Lean system is a production management method which maximizes added value of any activity in service or production process, by eliminating the necessary resources [4]. Thus, by continuous improvement of all process activities, better quality and productivity

complex projects, service (public administration), health institutions (hospitals), universities etc. As a result of implementing The lean system in the afore-mentioned areas significant improvements could be achieved:

- Reduction of space
- Cutting inventory investments (spare parts, raw material, work in process, finished products)
- Increase of work productivity
- Bigger utilization of equipment
- Shorter product delivery time
- Better service and product quality
- Less loss of all resources inside production or service process
- Bigger employees' engagement in continuous improvement.

There is no definition of the Lean system, but if we want to describe the essence of the Lean system in one sentence, the best definition is: the Lean system, when is implemented, shortens the time from the customer order to the delivery, by eliminating all sources of waste in the process [7]. Therefore, we can say that by implementing the Lean system we can shorten the lead time, and thereby achieve flexible production, which means faster and easier response to customer demand.

There are five basic principles of the Lean system (thinking) and those are [6]:

- Value
- The value stream
- Flow
- Pull
- Perfection (Figure 1).

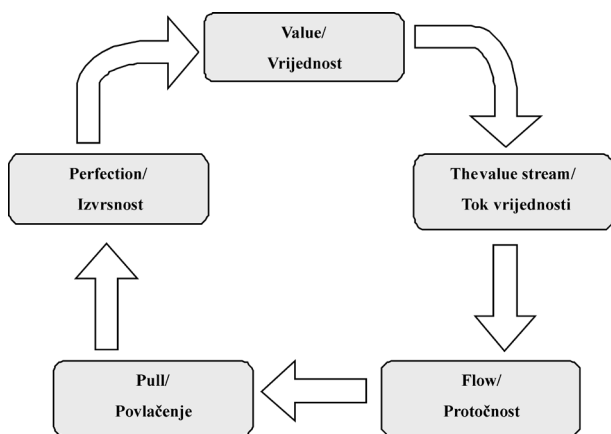


Figure 1. Five fundamental lean principles [6]

Slika 1. Pet osnovnih principa lean-a

Value is what the customer is willing to pay. On the other hand, waste is part of the production process which does not bring value to the customer, but sometimes is necessary and cannot be eliminated from the process, but could be shortened or reduced. The Value stream is all activities that create value, starting with raw materials or initial information and ending with the end customer/user [2].

Flow is the hardest principle to achieve. Basic preconditions for achieving flow are:

- Small batches
- Little or no inventory and WIP (work in process)
- Quick changeover time.

Pull means no one upstream should produce a good or service until the customer downstream asks for it. [6] And, finally, Perfection means that there is no end in becoming Lean, and one has to strive for perfection continuously. This comes from the Japanese word Kaizen (“continuous improvement”), which is the essence of Japanese production philosophy.

The foundation for Lean adoption are processes which are not just characteristic of production but also of service, because every set of actions which transform inputs to outputs is a process [2]. Everything could be defined as a process (order entry, launching the production, purchasing, warehousing, product development, invoicing, etc.). Every process has five characteristics (Figure 2):

- unit
- flow of the unit through the process
- set of the process activities

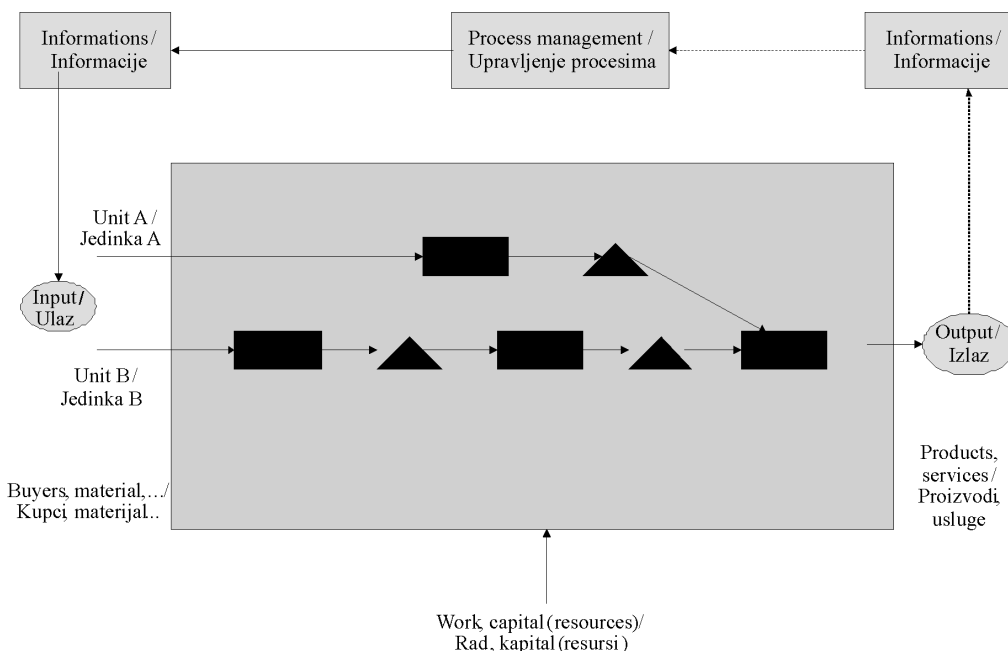


Figure 2 Characteristics of the process
Slika 2. Karakteristike procesa

- resource utilization
- information.

Successfully managing the production value chain is the goal of the company's management. Although the customer is at the end of that value chain, Lean points that everything starts from the customer (Figure 3). Customer demand (appropriate price, time of delivery, quality, number of product variances) is moved toward production function of the company, which has to provide minimal expenses, flow, quality and flexibility. In the same way, production function puts requests to suppliers.

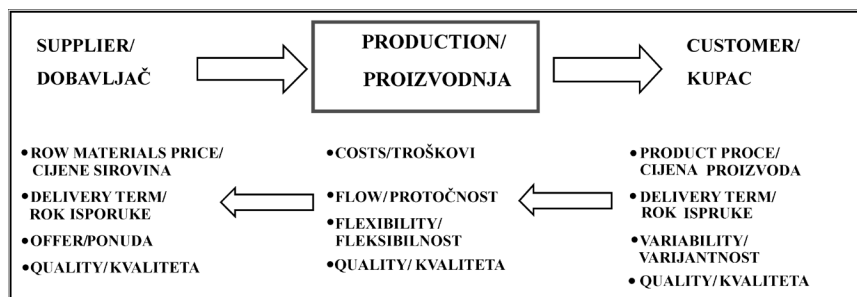


Figure 3. The value chain

Slika 3. Lanac vrijednosti

The final goal of Lean implementation is a balanced and quick flow of material. In order to achieve this it is necessary to:

1. eliminate disruptions (downtime, bad quality, late delivery)
2. accomplish flexibility (the system has to be able to readjust to all changes)
3. eliminate waste (overproduction, inventory, transportation, unnecessary movement, waiting, defects, over processing, underutilization of skills).

Elimination of waste, disruptions and flexibility have to be achieved in the whole business process, from the product development, design up to the shipping of the finished goods.

All process activities could be divided into three categories:

1. Value-added activities – customer is willing to pay it
2. Non-value-added activities – do not create value but are currently necessary because of current technologies or production assets [6]
3. Pure waste - does not create value, is not necessary, and just create losses by wasting resources.

Present experiences show that 70 % - 90 % of whole production lead time is Non-value added time.

Quantitative determination of production cycle time is important element of the Lean system. One of the indicators is production cycle efficiency (E_c):

$$E_c = \frac{T_{\text{VAT}}}{T_c} \cdot 100[\%], \quad (1)$$

T_{VAT} – Value-added time (total work time for material transformation)

T_c – Cycle time (total time from the order to shipment).

3. Kaizen

The word Kaizen means “Continuous improvement”. It is the foundation of Lean thinking. In Japanese, Kaizen means ongoing improvement based on knowledge from everyone – not just from experts, but also from managers and workers [3]. In the opposite of “western

philosophy” where just a great idea and great and big improvements count, the essence of Kaizen is continuous improvements based on everyday little improvements.

“Kaizen events” are one-time ‘blitz’ effort involving multiple stakeholders [4]. The basic concepts of Kaizen workshops is to define the problem, determine the current state, generate ideas for improvement, select the best ones, apply them directly and then evaluate them. It is very important to make a standardized work. If the work is not standardized and it is different each time, there is no basis for evaluation, meaning no reference point from which to compare [1].

The most common trap that everyone should be aware of is that such events can lead to “isolated islands” of improvements and that does not lead to a Lean, whole system approach.

The basic concept of this kind of workshop is to include all employees in the workshop flow and in the whole Kaizen process. One of the most important basis of Kaizen is team work. The task assigned to each employee is to spend part of their working time to participate in Kaizen activities. Kaizen activities are formed for each group of employees. Top management, for example, is responsible for implementing and encouraging Kaizen as a basic principle of Lean company, and for evaluating the advancement of the process. Middle management creates procedures for fulfilling top management’s requirements. Middle management is also responsible for implementing the Lean way of thinking into the company and all its employees. It can be successfully done by organizing seminars and education programs. Team leaders lead

their groups of employees in the process of developing and realizing ideas. Employees on the operational level (the ones that have day-to-day contact with production processes and all of its components) are responsible for creating concrete propositions for improving and optimizing the process flow and minimizing the “waste”. Team work has the best results when shaped as the work of small groups.

Kaizen events help find sources of waste in the production process in general, and they are amazingly simple to use. By continuous use of such methods it is possible to attain great effects and improvements regarding process perfection and performance, employees' satisfaction, and ultimately a company's profit.

Kaizen workshops are a good opportunity for exchanging possible ways of improvement between employees of different departments. It is a multi-discipline category. Sitting around the same table and exchanging the problems and possible solutions through open communication is called “obeya” (a Japanese word that literally means a big room used for meetings of the multi-functional teams and working groups in order to talk about and solve existing problems).

4. Kaizen workshop: case study

The main goal of the workshop held in Croatian company was to cut the changeover time of the filling machine. Two hours for changeover in the filling machine was the weak point of production. There were few ideas already about possible improvements on filling machine, but in order to motivate and engage employees and make them aware of the importance and useful aspects of change, the management of the company decides to organize this kind of event.

Next to the first one, but not less important was the goal to adopt achieved trial methods that give good results and make them a standard procedure in the company. It workshop was open to employees' ideas, whether they came from the top management layer, or from a machine operator. Workshop goals, set at the start were:

- cut changeover time (for filling machine),
- encourage employees' awareness for useful aspects of changes,
- open and widen point of view both for employees and managers,
- standardize existing processes (making a list of standard steps for changeover on filling machine),
- education of employees (operators) enabling them able to operate different machines,
- encouraging team work.

Mitigating circumstance was a great motivation and the effort of the plant manager who had already had basic knowledge and experience in Lean and Kaizen workshops and truly believed in the success of their workshop. He encouraged and motivated all employees, and played important role as a facilitator of the workshop. That was already a big step to the success of the event.

The workshop took three days when there was no production. That was necessary for performing the activities on the machine without any daily problems getting in the way and workshop participants could try out possible solutions without any stress. Participants of the workshop were plant manager, production analyst, maintenance team and operators. The key to the success of the team was having an “outside set of eyes” in Kaizen events [7].

Table 2. The workshop plan

Tablica 2. Plan radionice

WORKSHOP PLAN/PLAN RADIONICE			
Time/Vrijeme	1st day/1. dan	2nd day/2. dan	3rd day/3. dan
9:30-10:00	Introduction/ Uvod	1. day review/ Osvrt na 1. dan	2. day review/ Osvrt na 2. dan
10:00-11:00	Presentation/ Prezentacija	Brainstorming/ Brainstorming	Brainstorming/ Brainstorming
11:00-12:00	Game/ Igra	Brainstorming/ Brainstorming	Brainstorming/ Brainstorming
12:00-13:00	Process description/ Opis procesa	Changeover filler/ Izmjena alata na punjaču	Changeover filler/ Izmjena alata na punjaču
13:00-14:00	Changeover filler/ Izmjena alata na punjaču	Changeover filler/ Izmjena alata na punjaču	Changeover filler/ Izmjena alata na punjaču
14:00-15:00	Changeover filler/ Izmjena alata na punjaču	Changeover filler/ Izmjena alata na punjaču	Changeover filler/ Izmjena alata na punjaču
15:00-16:00	Changeover filler/ Izmjena alata na punjaču	Brainstorming/ Brainstorming	Results and conclusion/ Rezultati I zaključak

The time-table of the workshop is shown in Table 2. It was shaped so that enough time was ensured for realizing concepts and ideas into practice by repeating changeover activity and improving it bit by bit with every trial. It was obligatory to control and measure the effects and steps of the changeover process. The second part of the workshop was the "thinking process" which consisted of developing ideas individually (participants themselves) and through mutual communication (teams and groups) which helped to make choices of what will be done in the next step/trial and how.

In order to motivate the participants and show them the purpose and the meaning of Kaizen event, at the beginning of the first day an introduction presentation was held, and after that, they played a game which motivated a competitive spirit among the formed team and initiated team work.

After the game and the break, the real tasks of the workshop came into focus. The first one was the task to precisely determine all the activities of the changeover time for the filling machine. Together, the workshop team concluded that there were ten activities to be done from the last bottle out to the first bottle in:

1. Closing production
2. Emptying capping unit
3. Preparing "filler" for rising and lowering
4. Setting filler's height
5. Setting nozzle's volume
6. Installing CIP-cups on nozzles
7. Emptying filler
8. Preparation for CIP (Cleaning in Place)
9. Changing the format parts and tuning capping unit
10. CIP.

After doing this, a complete changeover was done, following the list of activities. The entire job was done by one operator, because it is the usual practice in this company and all activities were measured, so that the current state could be determined. The categories measured were time consumption and distance traversed (in steps, where 2 steps equalled 1 meter). All the activities, except the last one, CIP, were measured. CIP process is automated and its duration is determined for every specific changeover.

During the first changeover, participant that did not do any work at the machine, had the task to observe activities from a critical point of view, and to note every waste or unnecessary movement they notice. A number of them were in charge of measurement, and for that part the team had developed special forms for every participant to fill in. The main purpose was to measure activities, but also make their own opinion and ideas.

The results of the first changeover gave time for reflection into the current state, but also possibilities for optimization directions. The results are shown in table 3. There is huge waste in a process that produces nothing and lasts more than two hours. That presents a serious cost source, but it was clear from the very beginning that it is possible to reduce that time radically. If CIP is included in the total duration, the number rises to more than 4 hours. Once the changeover time is shorter, it also puts production flexibility on a much higher level. With limited warehouse capacities, it is much easier to produce smaller batches of a different product type. With shorter changeover times, it is possible to obtain smaller batches and much more levelled production.

A very big disadvantage, drawn from the first changeover results, is that during all the activities, the operator walks for approximately 765 meters and that is large scale time consumption. It is caused by inadequate work place ergonomics and absence of supplementary control units.

Table 3. Results: current state

Tablica 3. Rezultati: trenutno stanje

ACITIVITY/ AKTIVNOST	TIME/ VRIJEME, min	STEPS/ KORACI
1.	10	250
2.	4	112
3.	5,5	93
4.	7,5	130
5.	25	285
6.	9,5	200
7.	3	25
8.	12,5	135
9.	60	300
10.	-	-
TOTAL/ UKUPNO	137	1530

The second day of the workshop started with discussion in the meeting room, and some problems and their possible solution were addressed:

- A ergonomic of the workplace – the idea was to make panels just for the tools used in the changeover so they could always be available and easy to get,
- Some tools and equipment were inadequate – it was necessary to purchase those tools (like a device for adjusting nozzles),
- Command devices were unreachable (it generate unnecessary movement),
- The change of format parts is the longest activity and could be done by more operators, which would shorten the time.

Format parts are too far from the filler and also generate unnecessary movement and waste of time

After the problems and their possible solutions were addressed, preparations for a second changeover were made. Some of the solutions were applied: an improvised panel for tools was made, format parts were placed closed to the machine, two more operators were assigned to changeover, and a new list of activities was made:

1. Closing of production
2. Emptying capping out and preparing the filler for rising and lowering
3. Setting filler's height, setting nozzle's volume, CIP-CUP, changing format parts (taking off the old ones, and putting on new ones)
4. Emptying filler, preparing for CIP
5. Tuning the capping unit
6. CIP.

It could be noticed that the number of steps was shortened because some of the activities are now performed at the same time by three operators. The results after the second changeover are shown in Table 4.

Table 4. Results after second day of workshop

Tablica 4. Rezultati nakon drugog dana radionice

ACTIVITY / AKTIVNOSTI	TIME / VRIJEME, min	STEPS / KORACI Operator1 / Operator 1	STEPS / KORACI Operator2 / Operator 2	STEPS / KORACI Operator3 / Operator 3
1.	3	14	16	
2.	3		23	20
3.	36	82	93	112
4.	10		27	40
5.	6		22	16
6.				
7.				
8.				
9.				
10.				
TOTAL	58	96	181	188

The second changeover performance delivered a few more solutions on possibilities for improvement. Most ideas came from the plant workers. They suggested changing the CIP-cups round machines to two steps, instead of three steps and changing the machine's position three times. It also came up as necessary to adjust phases of changeover activity:

1. Closing of production
2. Emptying capping out and preparing filler for rising and lowering
3. Setting filler's height, setting nozzle's volume, CIP-CUP, taking off old format parts
4. Putting on new format parts, tuning the capping unit
5. Emptying filler, preparing for CIP
6. CIP.

After the second day of the workshop, a third day of work saw a conclusion to this workshop and to this first phase of lean production implementation in a water-filling company. The results of the second changeover trial were already great. Changeover duration was cut by more than 100 % and it took less than an hour to set the water-filling machine up and get it ready for the new batch of products. Now, the changeover work was done by three operators ("borrowing" operators from the other machines). Although there were three of them they covered only 250 meters during the changeover (altogether).

The third trial was an opportunity to implement additional changes and process optimization activities for the changeover process. It was changing the CIP-cups round the machines strake in two steps (two times 36 cups), instead of three steps and changing the machine's position three times. There were some changes that could not done at the very moment, so there was a date set to execute those actions – it was installation of the fast clutch on the capping mechanism, supplying special

tools for dismantling the machine and capping device and installing a sound alarm that indicates the machine's movement. In the third trial the changeover job was done by three operators (two of which did the nozzle setting job simultaneously). The results of the third changeover are shown in Table 5.

workshop is a great way of creating teamwork and team spirit as an everyday practice in the company.

It is very important for Kaizen process to be successful to make all good moves and changes (tried during the workshop) standard working procedure so that it could become base for next Kaizen steps.

Table 5. Results after third day of workshop

Tablica 5. Rezultati nakon drugog dana radionice

ACTIVITY/ AKTIVNOST	TIME / VRIJEME, min	STEPS Operator1/ KORACI Operater1	STEPS Operator2/ KORACI Operater 2	STEPS Operator3/ KORACI Operater 3
1.	2	15	20	
2.	3		17	28
3.	14	60	89	76
4.	15		36	
5.	11	17	18	
6.				
TOTAL/ UKUPNO	45	92	180	104

5. Results of workshop and future plans

All the benefits derived from this workshop show how great benefits are gained. It has confronted almost every one of 8 biggest waste sources in companies. Overall workshop results are listed in Table 5 and they show abbreviation of changeover time and reduction of travelled distance.

6. Conclusion

Kaizen events are an excellent opportunity for making rapid improvement in the production process. This case study showed that it is possible to cut change-over time almost threefold from the previous time. Overall, Kaizen is basic tool when applying the Lean system in the company. It should not be accepted as just a tool for rapid

Table 6. Overall workshop results

Tablica 6. Ukupni rezultati radionice

RESULTS OF THE WORKSHOP – PHASES/ REZULTATI RADIONICE - FAZE			
PHASE/ FAZA	1	2	3
TIME/ VRIJEME, min	137	58	45
CUTTING THE TIME REGARDING PREVIOUS PHASE/ SMANJENJE VREMENA OBZIROM NA PRETHODNU FAZU	-	136%	28%
DISTANCE TRAVELLED/ PREĐENA UDELJENOST, m	765	232.5	188
CUTTING THE DISTANCE REGARDING PREVIOUS PHASE/ SMANJENJE UDALJENOSTI OBZIROM NA PRETHODNU FAZU	-	229%	24%
NUMBER OF OPERATORS/ BROJ OPERATERA	1	3	3

For successful future of this company it is of relevant significance to continue with Kaizen activities and to validate employees and their work, opinion and stand, as well as stimulate their inventive nature for optimizing the system and processes they use every day. This kind of

improvement but as a way of the company's behaviour, which means constant awareness and readiness for learning and change (continuous improvement).

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