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## Preconditions for Learning Factory

A case study

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### Abstract

This paper discusses improvements of an existing manual assembly line for roller skis when it was used as a template for a learning factory in the university. These improvements were in terms of lean philosophy and operations management, angled towards the application of "flexibility" and "learning factories" concepts. The article introduces list of suggestions that were built up with the help of several techniques presented in the paper. These techniques can bring significant improvements if wisely applied. A novel contribution of this article is combination of theoretical knowledge with application of it to the real life case used to make necessary enhancements to increase production capacity of the assembly line and involve it into the learning factory.

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*Keywords:* Lean Production, Improvement, 5S, PDCA, Flexibility, Learning Factory, Operational Management, Efficiency, Effectiveness, Assembly Line

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### 1. Introduction

Later years the concept of learning factories has gone from an idealistic idea to numerous implementations. Although, not every implementation can be classified as a full learning factory, there are some common features [1]. Universality, mobility, modularity, scalability and compatibility were identified as the first order parameters for ideal classification of a learning factory. Scoring on every parameter are difficult, however, Wagner et al. [1] claimed that most of them must be met in order to be a true learning factory. In this sense, they indicate that establishing learning factory is a dynamic and evolutionary process.

The word 'learning' somehow explains the popularity of implementing learning factory, especially in Europe. Learning is the opposite of teaching and emphasizes experiential learning or learning by doing. Greater retention is one of the positive sides compared to more traditional methods, like lectures [2].

To implement learning factory many universities look at an existing production line as a starting point. This does not mean

that the learning factory implementation is a copy of the existing production line, but it is a sensible way to start. Differences in the means of learning factory compared to a normal production line ensure different features are emphasized. Or "*learning factories are not simply duplicates of industrial factories*" [1]. However, the benefits of a clear starting point in a real production environment is clear. This paper will look at this starting point and its preconditions are discussed.

This paper is the result of a project done in cooperation with the company TLI. Beside of the idea of using the manual assembly line as a template for a learning factory, the project had a goal to increase production capacity in four times.

Generally, four problem areas emerged from having a template for establishing learning factory. These are methods for improvement, what kind of improvement, learning areas covered by learning factory, and how to build more flexibility into the actual production line, as well as, into the learning factory.

Converging these problem areas into three questions for discussion sections of the article: Which exact improvements

should be done to meet the project goals of using it as template for learning factory? How can a focus on learning factory help the existing assembly line and what are the benefits of its application? How is flexibility dealt with at the actual production line?

### 1.1. TLI and Their Current Assembly Line Condition

TLI is a Norwegian company, which has roller skis as one of its products. It was founded in 1995. Roller ski is a straightforward product, consisting of an aluminium profile with two specialized wheels at each end. It is used for training purposes in the summer time. There are many suppliers of roller skis in the market. Ski-on-snow-like attributes determine the best product. Roller skis come in many different varieties, but there are two main groups. Classic is for training the classical way of skiing and skating is the other. Those two are according to the two main techniques in skiing competitions.

The assembly line under examination was a manual production line situated in a separate room, where the workstations and all the necessary parts and materials were kept. There were several issues related to the current state of this assembly line. The first issue was related to the lack of clear organization of the parts that are supposed to be put together to produce a pair of skis. This adds time to the assembly, as workers are supposed to be moving all around the room to take the parts and come back to the working place. Also, it creates problems for easy access to the workstations and needed space, as some of the boxes are standing on the floor and hindering easy access.

The second problem is position of the workstations in relation to each other. They are not situated one after the other in a logical sequence of the manufacturing process, this makes it inconvenient for workers to do their job and takes time.

The third problem is that the tools used for assembly do not have a standard place to be put at, this can bring more chaos into the manufacturing process and again request more time for the concrete operation to be completed. Those were the major problems noticed after the first glance on the assembly line, however, they were not the only ones.

In addition to above mentioned problems, the production line was clearly missing the standardization component, as each of the workstations could have had a description of the best algorithm to be followed to complete the action in the most optimal time limit. Also, the boxes with parts for the assembly contained stickers with numbers of parts stored in them, however, for the person who is just beginning to work on the line, it takes a lot of time to understand which part is situated where, as he or she does not know numbered parts by heart yet. Those were the minor mistakes noticed at the second glance on the line. As it is described, it is easy to understand that the production line had a lot space for improvements, which will be described further in the paper.

## 2. Method and theoretical background

This section is going to give a short overview over the theoretical methods used in order to complete the project with TLI. It will also explain the reasons for choosing these methods and not the others.

As a case study, the research is meant to give a deep insight into several specific problems. Solutions and discussions are deeply connected to the specific context. In this sense, the general implications derived from this can be more limited. However, the authors strongly believe that insights from case studies ease the implementations of learning factories for others, but there are no one-way solutions.

### 2.1. Continuous improvement

Lean is one of the most mainstream techniques applied for optimization and assembly line improvements. It contains numerous tools and has a key principle that can be formulated as follows: *“moving towards the elimination of all waste in order to develop an operation that is faster, more dependable, produces higher-quality products and services and, above all, operates at low cost”* [3]. On the other hand, in [4] lean production is described as a *“set of practices that is used to continually enhance process activity that are necessary, relevant, and valuable while eliminate wastes”*.

While some scientists are criticizing lean for lack of proper definition, description, and explanation of use, as well as for lack of flexibility as shown in [5] *“lean requires a stable platform, where scale efficiency can be maximized. Highly dynamic conditions cannot be dealt with, as there is no room for flexibility due to the focus on perfection”*, others are giving examples of cases where it was successfully implemented and brought significant results. Thus, *“while some lean practices are easily applicable others are more difficult to implement particularly when the degree of mass customization (MC) increases”* [6]. However, at the same time, in [7] it was highlighted that certain studies have shown that lean manufacturing produces higher levels of quality, productivity and customer responsiveness.

In this study, lean was used as it is aiming to increase efficiency and effectiveness of the manufacturing process and can bring benefits of eliminating unnecessary waste, as well as increase production quality. Lean application was a request from the side of the TLI stakeholders. The main lean tools used within the project are 5S and PDCA cycle [8,9].

### 2.2. Operations Management

Lean and its tools can be useful while carrying out the similar studies, however, the other method that gives a solid basis for products manufacturing and process improvements is operations management. Operations management according to [3] can be defined as *“activities, decisions and responsibilities of managing the production and delivery of products and services”*. In other words, this technique is about managing processes during the product manufacturing and production.

There are six main activities within operations management that need to be followed according to [3]. The first activity is dedicated to understanding of the operation's strategic objectives and afterwards development of a clear vision about how to achieve the main goal. The second activity is about creation of an operations strategy for the whole organization, which guides the operations management team. Designing the operation's products, services and processes, is the third activity. The fourth activity deals with the planning and control over the operation. The next activity is about improving the

operations performance. Last activity is linked to the responsibilities and concerns the company has towards globalization, or environment. This project work is mainly concentrating on the fourth and fifth activity types according to its main task.

The use of operations management is important. One of the reasons, as pointed out in [3], is that it can contribute to effective use of resources. However, in order to do this the manufacturing process must be creative and innovative. Additionally, the process must also be flexible in the manner of improving its processes, products and services. So, the concept of flexibility is critically important because it brings possibility to change the process according to the current situation. Another reason as to why operations management should be applied is the fact that it can prove to be effective and reduce costs. Thus, also, increase the revenue. All of these points are topical for TLI as well as for any other company, that is why elements of operations management were present within the project work.

### 2.3. Flexibility

Flexibility is a critically important concept, especially nowadays [10,11]. This can be explained by urgent need to be able to change different conditions of the manufacturing process, starting from flexibility of the process itself and ending with taking into account time needed to educate people to work with the assembly line. As mentioned in the Operations Management section, flexible processes make it possible to react to the changes in the environment. The paper [12] defines flexibility as *“the ability to change with little penalty in time, effort, cost or performance”*. Further, flexibility can be defined as a source of competitive advantage. In [12] flexibility is described as capability to produce a broad range of products, while in [13] it is highlighted that successful manufacturing demands technology and human craftsmanship to be combined in a way where the work is used together with flexibility and adaptability.

One of the beneficial external effects of this concept application is the increased ability to customize individual products. *“High flexibility gives the ability to produce a high variety of products or services”* [3]. At the same time, flexibility use makes it easier to be prepared to the changes of assembly line capacity in the short time and without putting significant efforts into it.

### 2.4. Learning factories

Learning factories are a concept that is becoming more and more popular in modern companies. From the first sight, it might seem that it does not bring valuable benefits for the enterprise and that it is mostly dedicated to education, not to the real world. However, such impression is totally wrong, first of all, because all techniques, methods and improvements can only evolve through education. Learning factory concept is important because it enables companies and students with a suitable environment and competence to increase productivity [14]. This means that students can bring theory to the real working environment and improve both their knowledge and the processes within the company. Learning factories can be dedicated either to education or to research, while both of goals

bring helpful benefits for the industry. Furthermore, the main goal of this application is either technological- or organizational innovation in case of using it as a research tool, or necessary competency creation while implementing it as educational/training tool [14].

What is special in using this concept is that it is similar to the idea of bringing the real world into the classroom. *“Learning Factories pursue an action-oriented approach with participants acquiring competencies through structured self-learning processes in a production-technological learning environment”* [15]. However, these are not all of the benefits. Another interest is for company to educate the future workers that will perfectly suit the working conditions and have all the knowledge to start their work. This concept can also help to reduce and shorten the time spent on education of workers as well as to increase mobility and flexibility of the assembly line.

In case of the project work, learning factory is suggested to be applied as education- and research tool, bringing new and necessary solutions.

## 3. Results

This section is aiming to present the results of the study. The questions introduced previously will also be answered here.

### 3.1. The First Question

The first challenge was what methods to use in order to make the necessary improvements in the existing line. The answer to this question was found by excessive literature research on the topic of efficiency of manual assembly line and other project goals mentioned previously. From this search, it was found that companies that used aspects of lean, 5S and PDCA cycle as a framework, as well as implementation of operations management, flexibility and learning factories concepts, were able to significantly increase their effectiveness. The paper [16] is reflecting on the lean techniques use and claims that the company implementing them managed to save 60% in cost. Also, after application of the theories a reduction in setup time, inventory and cycle time was achieved. As it was found that such methods provided success, it is therefore logical that it can also provide TLI with the same outcome, especially that decrease of the time spent for separate operations, cycle and idling time are important improvements needed to be done on the assembly line. Of course, the methods can bring benefits only as long as the things are done the right way and efforts towards implementation of techniques are carried out. This work of transforming the existing assembly line led to the first research question.

The first question was formulated as follows: *which exact improvements should be done to meet the project goals?* In order for TLI to meet the goal of increasing production capacity on the manual assembly line and the other aims, list over suggestions of improvements was developed. The list has a theoretical foundation described in the methods section of this paper.

### 3.2. List of improvements

The first suggestion is based on lean, 5S techniques and idea of integrating the assembly line to the learning factory. Its formulation is very simple: *organize the tools*, however,

explanation needs to be added. Organization is very important as it helps to diminish waste and adds opportunity to continuously maintain the order within the workspace. This can be done by organizing a fixed place of storage for each of the tools. The placement of tools needs to be natural and easy to access. A habit of returning used tool to its place should be also developed. Additionally, they need to be protected from bending, dust, oil, dirt to be new and possible to be used for the longer time [17].

Second suggestion was to *have a clear marking on the boxes with different assembly parts*. It is suggested to put pictures and names of the parts instead of the codes on the storage boxes. This suggestion also has 5S as its foundation and is related to learning factory concept. The clearly marked boxes will help to keep a tidy workplace and make it easier for workers to perform faster and more efficiently as they will not be confused by the parts code written on the storage box. It is also a part of the visual management of things as mentioned in [12].

Furthermore, by having markings on both sides of the box, efficiency will be increased. Also this type of marking will have quality and mistake prevention assurance, because the worker will be sure to use the right part.

The third suggestion is to *add a description of necessary assembly stage on each station*. This improvement is based on lean technique and operations managements aiming to increase quality of production. Having a description on each workstation will provide TLI with shortening their time of adapting new personnel and increase flexibility. The implementation of this suggestion will also increase extent of the process standardization and thus provide additional quality regulation as if the operations will be managed in a standard way. Also, to contribute to continuous improvement action, it is necessary to give workers an opportunity to improve these descriptions.

*Increase efficiency of layout* was the fourth suggestion. In other words, it is proposed to put all of the work stations in a logical order (in order of operations maintained) and afterwards have materials and manufactured parts on the moved shelf unit next to each workstation to shorten operation time and increase convenience. Further implementation of this idea according to [18] will simplify the assembly process. This means that on the side of each of the workstations will be a shelf unit containing shelves with marked boxes and materials needed for the assembly stage performed on this particular station. On the other side the workstation will have another shelf unit marked boxes for already manufactured or assembled parts, this will decrease significantly the time spent for manufacturing of one pair of the roller skis as well as increase level of efficiency and effectiveness. As mentioned before, the shelf units are requested to be capable of being moved around in order to increase mobility and thus make the assembly line closer to the learning factory implementation. This suggestion is based both on lean and operations management techniques as it is aiming to minimize waste.

As it was mentioned before, the first, second and fourth suggestions are not only based on 5S, but are also related to learning factories term. In this case, 5S will help to engage workers and form a self-discipline in achieving better work efficiency and better quality of products [19]. Engagement and

discipline is something that should be included also in learning environments, and the 5S implementation can work as a triggering activity as workers will have opportunity to experience the improved workplace design [20]. The suggestions of organizing tools, having clearer marking on assembly parts boxes, and increasing the efficiency of layout will contribute to having a well-organized and clean environment, which will, in its turn, result in increase of efficiency, effectiveness and quality level. This environment can be considered as one of the key features within learning factories.

The last suggestion of improvement is related to safety of employees. TLI's production line layout contained boxes with parts spread all around the room. This might cause safety issues and decrease accessibility of workstations or necessary assembly parts. The suggestion is to remove these boxes and arrange a place for them around the corresponding workstation, or accompanying marked storage space. This will not only make the working space safer, but will also help to maintain the orders, control over the stock, and also increase space for staff and shelf units to move around the plant.

Described list of improvements is proposed to be implemented at TLI and the PDCA cycle to be used for understanding the benefits of the following suggestions and development of new ones.

### 3.3. *The Second Question*

The second question was *how learning factory concept can be implemented on the existing assembly line and what are the benefits of its application?* This question is related to the current state and layout of the production line. Description of existing assembly line is provided in section 1.1. To summarize, the existing assembly line consists of several unorganized stations. Additionally, the stations are placed far from each other, and not in a logical order, however, in future it is suggested to organize the line in the next order: the first two stations to be used to assemble the wheels from their parts. The third one to add stickers to the roller skis frame, another station to be utilized to put the binding and "wheel shields" onto the frame. Fifth station should be dedicated to putting wheels on their places, quality checking and packaging.

Currently the assembly line is operated by two workers. All the parts that are used during the assembly process are stored in the boxes in the same room. The learning factory concept on TLI's assembly line might be partly implemented through use of suggestions number one, two and four. They might also help to limit the time future workers have to spend on the assembly line operations. Additionally, the current mobility of assembly line will increase. All these points will help TLI to achieve operational excellence and gain additional competitive advantage.

### 3.4. *The Third Question*

The last question was formulated as follows *how flexibility is dealt with at TLI?* In the beginning of the project, it was assumed that in case of necessity the improvements in means of flexibility will be also provided, however, after conversation with stakeholders at TLI, it was discovered that the examined assembly line does not struggle in relation to the flexibility

concept. Product and volume flexibility demands are met fully as TLI is manufacturing different kinds of products according to the customer's request, while volume is regulated through estimating amount of skis needed to be manufactured during the year. Afterwards, the amount of skis is produced according to the set up plan and after the work is completed employees are moved to the other activities and assembly lines within the factory.

#### 4. Discussion

This section is going to discuss the answers to research questions given in the previous part of the report.

Previously it was stated that Lean, 5S, PDCA, Operations Management, Flexibility and Learning Factory are decided to be appropriate methods and concepts to be used in the project. However, one of the aims of this part of paper is to link all the research questions together and show that the answer to one is helping answer another. The illustration to this statement is shown in Figure 1. It presents the list of suggestions and methods used in the form of a house. The house contains of four parts: foundation, two walls, middle and a roof. Parts correspond to the roles, which suggestions are playing if described as a house, next to each of suggestions it is also shown which methods it is related to.

The reason for transforming answers to all of research questions into the house is, first of all, to show how all of them are interconnected.

A house is always built from the foundation; this is why suggestion number four is used as the improvements house base. It is critically important to be implemented, as it will bring workers and TLI new opportunities and benefits. Use of this suggestion will significantly decrease time needed to maintain certain operation, thus, shortening the time of all manufacturing cycle. *“Although it will not solve today's competitive challenges, it does provide a solid foundation for achieving operational excellence”* [19]. As a result, time spent to manufacture one pair of skis will decrease leading to increase of efficiency and effectiveness as well as manufacturing capacity. Quality is also not left aside here, as it was mentioned in the previous section, use of similar improvements leaves less opportunity for errors, as self-discipline and organization is developed. Surprisingly, flexibility and learning factories will also receive their advantages. Making the assembly line movable leads to possibility of changing it when it is necessary, as shelf units can be easily relocated in case of need. Learning factory benefits because of the same reason. As described it is easy to see that improvement is based on lean, operations management and flexibility and learning factories concepts.

When the foundation is ready, it is necessary to start building the walls of the house. Walls in improvements house are suggestions number one and two. Both of them are highly influenced by 5S technique involving the aspects of learning factory. Suggestions are aiming to increase convenience of the assembly process. Tools and assembly parts are going to be available and always in order, this will decrease possibility of making an error. It will be possible to change the assembly line into learning factory because of these improvements as they will make the time for new people to understand what is going on during production much easier and faster.

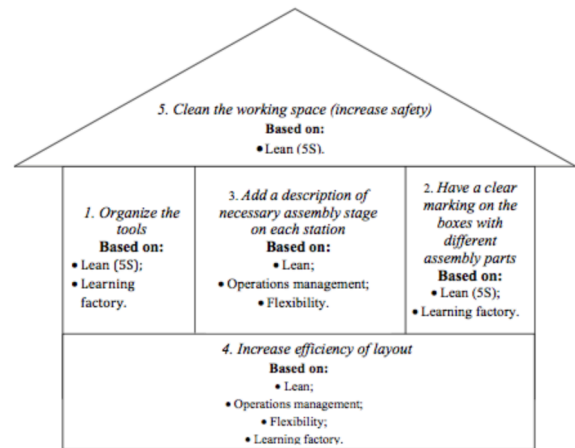


Figure 1. Improvements House

Roof of the house is based both on foundation and on the walls that are base for the roof itself. Suggestion number five is based on lean and more precisely on 5S tool aiming to make all the room, where the assembly is happening clean and safe for operations to be maintained. The order is part of organization of the working environment that makes it easier to move around and perform necessary movements, vanishing of unnecessary obstacles leads to increase of effectiveness, safety and production capacity.

This improvements house also contains a *middle* represented by suggestion number three, which was created based on theory from operations management, lean and flexibility. Implementation of it will lead to each working place having clear and easy to follow description of the learning process, resulting in increased efficiency and less time needed to educate workers potentially involved in the process. However, it is suggested to give people who work with certain manufacturing stages possibility to improve working algorithm according to their observations and needs. *The main objective of Learning Factory is to emphasize on product realization from the stage of the product and planning until the manufacturing of the product and to train engineers how to optimize each of these processes* [21]. This objective will be possible to achieve if the third suggestion is implemented.

Now that the Figure 1 was presented and all the used to build up a house techniques and concepts mentioned, the question of where was the PDCA cycle used arises. Within the project, as it was mentioned previously, only the first stage *plan* was accomplished, however, TLI is requested to use the procedure further to implement the suggestions and define benefits from their use. Next it is necessary to understand what can be done further in order to make the process even better and identifying the sore spots left, and from here the new cycle will begin and continuous improvements thinking is developed.

##### 4.1. TLI's Implementations of Presented Suggestions and Explanation of Possible Future Needs

The meaning behind this subsection is to show beginning of implementation of the suggestions from this project work by TLI. These implementations are not finished yet. Nevertheless, this paragraph illustrates that TLI have started the *do* phase of PDCA cycle.

This section briefly explains how assembly line will look like after finishing the *do* stage of the cycle. TLI have taken into account the suggestions list and reflected it partly in Figure 2.

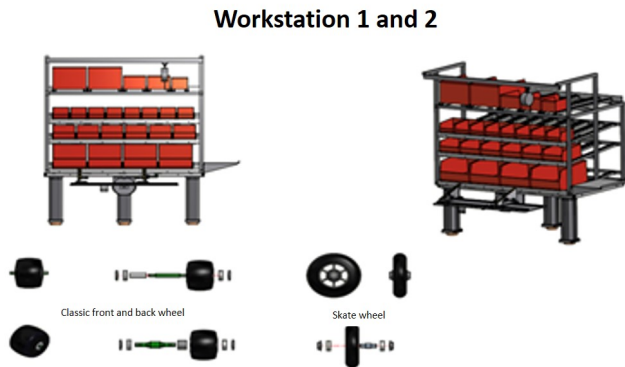


Figure 2. Stations 1 and 2.

Figure 2 describes the first stage of assembly process containing of two workstations, where wheels for skate and classic rollers skis are assembled. Here it is clear that TLI has taken some of suggestions into account, such as *organize the tools, have a clear marking on the boxes with different assembly parts, increase efficiency of layout and clean the working space (increase safety)*. TLI also have the plan of adding description of the necessary stages on each of the stations.

Now it is planned to use the third station to put stickers onto the frame, station four for the assembly of bindings and wheel shields. The last station is about assembly of wheels and frames together, quality checking and packaging.

From described previously results it is clear that TLI still have some work to do regarding balancing of the workload on each of the stations. These needs can be the aim of a new project work and further research studies after turning the assembly line into the learning factory. Additionally, there can be other ideas for improvements as there is no limit to perfection. PDCA cycle needs to be used to accomplish future tasks and keep being on the track of modern tendencies and demands.

## 5. Summarization and Conclusion

This paper has described project work that was conducted in cooperation with TLI dedicated to improvement of manual assembly line for roller skis manufacturing. This was done with help of certain theoretical techniques and concepts that were chosen as suitable after conducting the literature review on the topic. Lean (5S, PDCA), operations management, concepts of flexibility and learning factories were used to make the list of improvements suggested to be implemented in order to increase efficiency, effectiveness, manufacturing capacity and production's quality.

Paper reflects on the current state of the assembly line, shortly describes types of the roller skis manufactured and moves to theoretical overview of the methods used after analysis of the literature on related topics.

Three questions are presented in the paper, answered and discussed in different sections. The answers to the questions are

interconnected as they are influencing each other. The core of the answers is list of suggestions presented as reply to the question number two. These suggestions are: *organize the tools, have a clear marking on the boxes with different assembly parts, add description of necessary assembly stage on each station, increased efficiency of layout and clean the working space (increase safety)*. Discussion part also presents the improvements house based on results section of the paper, including answers to all of research questions at the same time. In the same section, reflection on the beginning of implementation process is also presented as well as opportunities for further project and research works briefly mentioned.

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