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Study Project

An eye tracking supported video analysis for assembly optimization at BARBIERI electronic snc

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1. Introduction

Technological advances are creating a new industrialization era in which ever-smarter and more flexible tools are being tested in the workplace. In many cases these systems are helping to improve tasks of human beings and therefore increase performance of the entire assembly scheme.

Now more than ever, industrial companies are making the necessary investments to apply continuous improvement throughout their assembling processes.

"Whenever there is a product for a customer, there is a value stream. The challenge lies in seeing it."

-Mike Rother

As Mike Rother writes in his book '*Learning to See'*, one of the biggest challenges of the companies lies in identifying the value stream of their products. He refers to the importance of recognizing value adding and non-value adding activities within the assembly process of a product.

Value stream investigation is precisely an imperative step of traditional lean thinking. [1] For many years, traditional lean concept provided the basis for operational excellence by standardizing processes, applying several optimization steps, and developing a culture of continuous improvement. However, given the evolving complexity of operations in the era of Industry 4.0, many organizations have found that traditional lean management alone is not enough to solve their operational challenges.

Lean management is slowly adapting to the new features of the industry and is applying new technologies, so that manufacturers can boost assembling speed and productivity. [2] In other words: Lean management is meeting Industry 4.0.

Emergent technologies like the Eye Tracking Glasses (ETG) are helping to understand the operators limits and perceptions throughout the working process in a much faster, accurate and digitalized way. Understanding how employees perform tasks and interact with their work environment is essential to achieve assembly optimization.

Since there are currently not enough studies on the real benefit of using the ETG technology for assembly optimization, it is opportune to initiate with preliminary researches.

2. Objective of the work

The study project is part of a series of investigations performed by the Free University of Bozen-Bolzano on the industrial usability of Eye Tracking Glasses for assembly optimization.

The specific objective of this study project is to analyze the potential benefits of using Eye Tracking Glasses for optimization of spectrophotometer assembly in the company BARBIERI electronic snc in cooperation with the Free University of Bozen-Bolzano.

For this reason, the assembly of a spectrophotometer will be recorded simulating a regular work environment in the company. The glasses will enable the video recording of the assembly process from the operator's perspective as well as the worker's eye movements and fixation points.

Based on lean management and on information obtained with the ETG, a classical state-target analysis will be performed and documented in an Excel tool. Recommendations for optimization of the assembly process will be presented.

The study project is structured as follows:

- General description of company, product to be assembled, and assembly process.
- State of the art and research concerning ETG technology, lean production, working conditions and ergonomics.
- State analysis of the assembly process with recommendations for action
- Target analysis presenting an optimized assembly process.
- Description of benefits of the ETG technology applied in assembly process.
- Explanation of following studies and conclusion

3. General descriptions

3.1. Company: BARBIERI electronic snc

BARBIERI electronic snc is an internationally manufacturer and supplier of intelligent color measurement systems. The company focuses on producing and selling spectrophotometers which ensure high image quality for professional digital printing. BARBIERI is the market leader of color measurement market for large format, flatbed and industrial printing.

Figure 1: Logo of BARBIERI electronic snc

The founder of the company is Siegfried Barbieri. The electronic engineer obtained his degree in Munich, Germany, where he later worked for Siemens in the R&D department. After his stay in south Germany, he started working for the firm Durst in Brixen, Italy, as chief engineer for the development of photographic color enlargers. In 1983 he founded the family business BARBIERI electronic. [3]

3.2. Product: SpectroPad

The product selected for the first study of usability of *ETG* for assembly optimization is a spectrophotometer SpectroPad. The study project focuses on the video analysis of the assembly process of this device. For a visual representation of the assembled product please see Figure 2.

Spectrophotometers measure light intensity as a function of wavelength. [4] The SpectroPad, launched into the market in 2011, is a color measuring and process control device used to measure a wide variety of different reflective media implemented in professional digital printing. The device developed by the company BARBIERI electronic is wireless, battery-powered, and easily transportable. With a touchscreen, users have the choice of selecting between spot measurement, strip measurement for linearization, profiling or quality control. [5]

Figure 2: SpectroPad of BARBIERI electronic snc [6]

The device is placed on the media and a cube-shaped measuring head slides manually over the chart. Measurement readings are sent to a computer or they can be shown on the device display providing instant measurement results. Fields of application of the device are the following [7]:

- Process and quality control
- Measurement of linearization, profiling and custom charts on a wide variety of materials
- Single measurements of spot colors with subsequent check for color true printing
- Image quality evaluations

3.3. Assembly process

There are mainly two methods of assembly in the industry, which are bench assembly and line assembly. The assembly process of the SpectroPad is based on a bench assembly method.

In bench assembly, the work-pieces stays stationary on a bench. [8] For the assembly process of the SpectroPad in BARBIERI electronic all required parts and equipment for assembly are stored near to the work area before starting the operation. The required materials and assembly pieces are sorted in a shelf bin (blue boxes) next to the operator. Assemblers are sitting in front of the work table and are able to pick by hand all materials and workpieces needed for the process. The concept is illustrated in Figure 3.

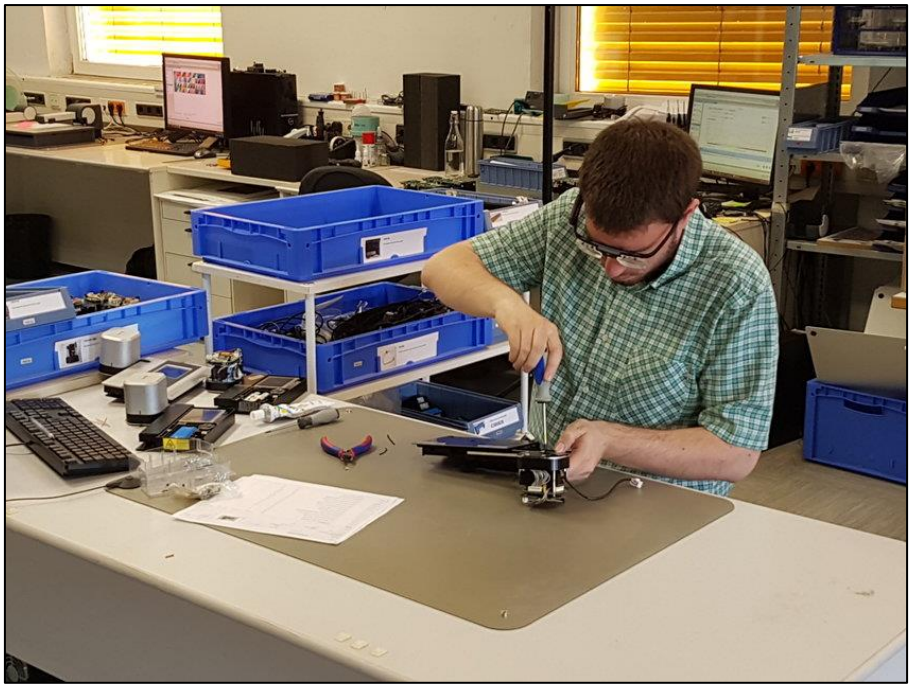

Figure 3: Assembly operation of SpectroPad in BARBIERI electronic [9]

4. State of the art and research

4.1. Eye Tracking Glasses

The ETG technology is well known in the field of marketing and psychology. It is being applied to study how people interact with their environment, what catches their attention, drives their behavior, and what influences decision making. [10]

There are currently not enough studies about ETG technology applied in the manufacturing field, but the creators of the glasses are selling the device as a tool that can also be applied in industry. The concrete benefits of this emerging technology applied in assembly processes is becoming an interesting topic for researchers.

Eye Tracking Glasses look like smartglasses, but not only stream POV video of the activity, but also mark with a red dot where the pupils of the user are focused on.

For this case study we are considering the Tobii Pro Glasses 2 (see Figure 4) of the Swedish company Tobii. Tobii Pro Insight research expert Martin Arvidsson, PhD, affirms that the device can be used to help with skills transfer and training, it can be used to streamline processes and identify waste in a system, and it can also be used to improve safety and increase situational awareness. [11]

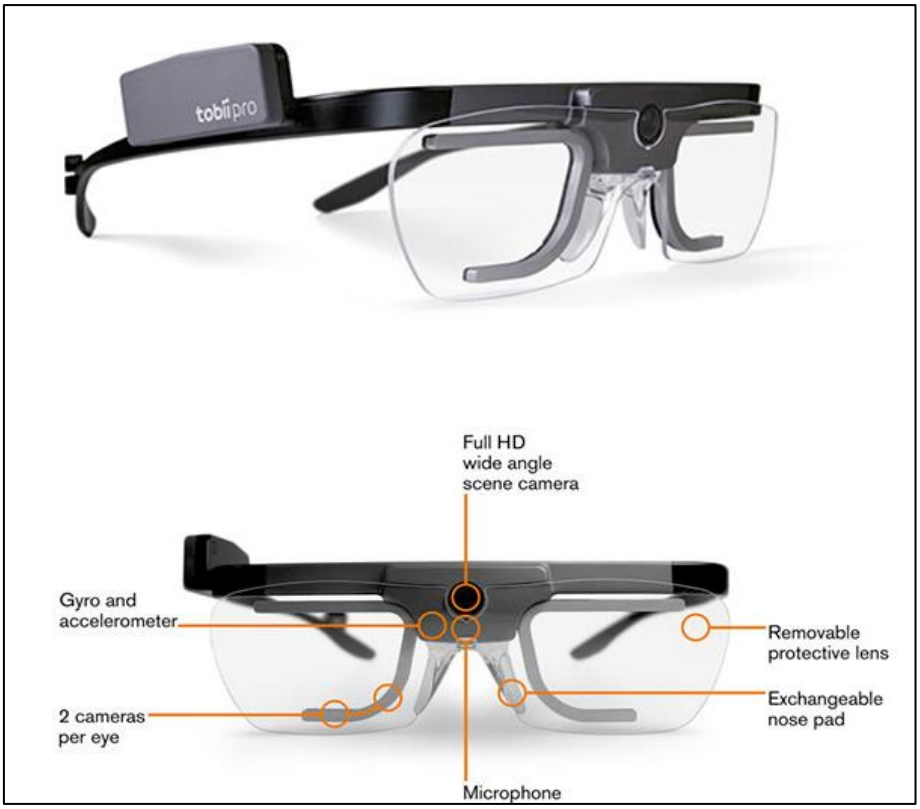

Figure 4: Tobii Pro Glasses 2 [12]

Eye tracking allows to see roles and tasks from the perspective of the worker (see Figure 5). It gives clear information on where they are focusing on (fixation point is marked red circles) and how they perform tasks, revealing about subconscious processes and behaviors which workers may be unaware of or unable to articulate.

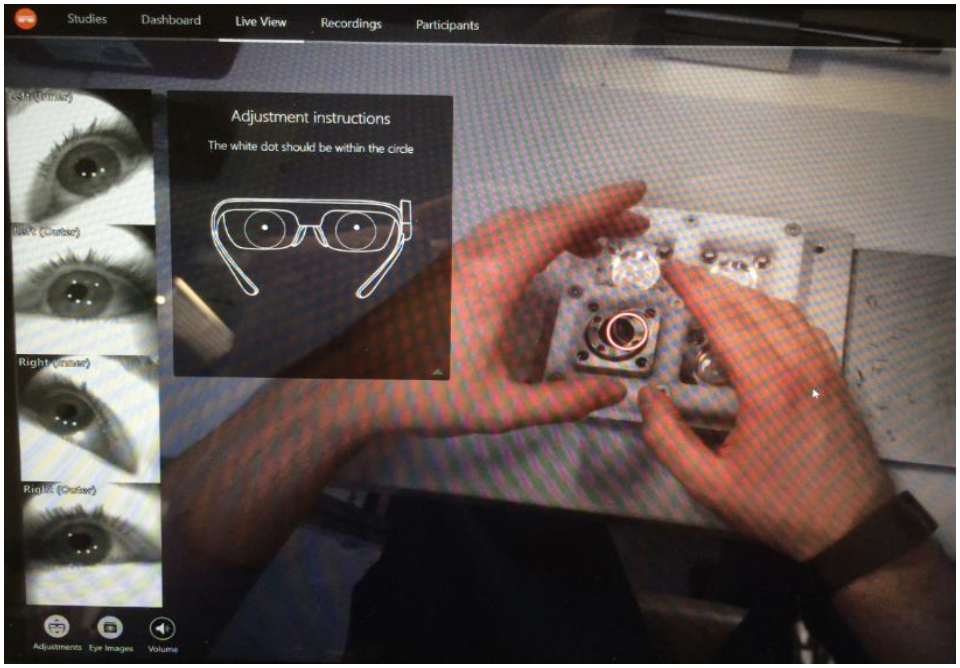

Figure 5: POV – assembly process with ETG

This technology records pupil diameter (assumptions for stress levels) and gaze/fixation data of workers, and thus enables access to insights about the thinking processes. [13]

Gaze data help to discover best practices of the more experienced people of a team. See Figure 6 for an example of gazeplot visualization. This gazeplot indicates how a junior worker (liliac) fared against an expert's (green).[14]

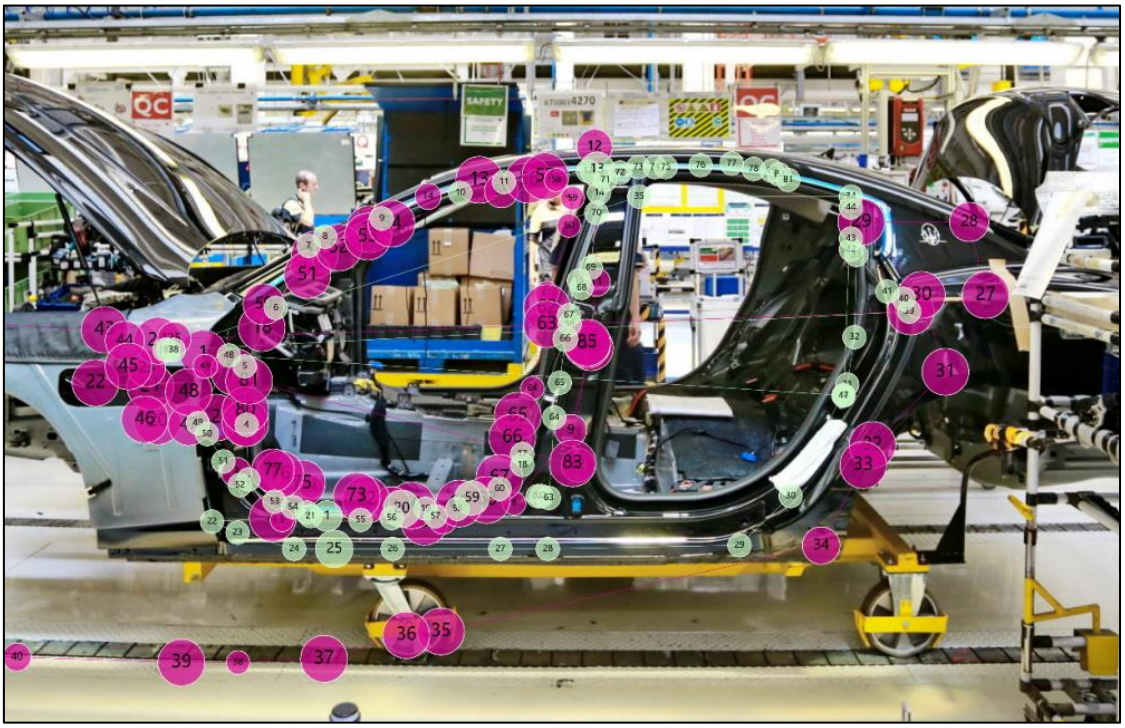

Figure 6: Gazeplot with Tobii Pro 2 [15]

The variables that can be directly extracted of the software of Tobii Pro 2 are:

1. Total duration of processes
2. Fixation
3. Fixation total duration
4. Fixation maximal duration
5. Saccade
6. Saccade total duration
7. Saccade maximal duration
8. Average pupil diameter
9. Standard deviation of a pupil diameter
10. Maximal pupil diameter

Saccades refer to fast, discrete eye movements that shift the eyes from one target to another, bringing an object of interest into focus on the fovea where visual acuity is highest. [16] Saccades are the fastest eye movements and they are of very short duration (typically less than 100 m sec). [17]

For the study case saccades represent an indicator for the visual search (eye paths). Unnecessary/many saccades in a short time period can be caused by insecurity of the employee, high stress levels, or for example not finding the required tool or pieces. [18]

Fixation refers to an obsessive interest in something. [19] For the study case Fixation represents an indicator of cognitive processing. A large fixation can be interpreted as the existence of a degree of difficulty. Fixation occurs when objects or processes are new/unknown, when the employee concentrates on an action, or when a complication of the process arises.

Pupil diameter. Studies suggest that the decrease (constriction) in pupil diameter normally accompanies increase of illumination and that the increase (dilatation) in diameter is related to decrease of illumination [20].

According to an article of Fanny Jimenez, published in the newspaper "Welt", the pupil diameter is augmented (dilatation) when the brain is under mental stress and high concentration is demanded. [21]

4.2. Lean production

To be more profitable in the global economy, businesses are improving the performance of manufacturing processes by reducing waste and making better products faster.

Lean continuous improvement is a strategy designed to help eliminate waste throughout a company. The core idea is to maximize customer value while minimizing anything that doesn't add value for the customer. [22]

Womack et al, describes lean thinking as a powerful antidote to "muda", which in Japanese means any human activity that absorbs resources but creates no value, and concludes that "lean thinking provides a way to do more and more with less and less – less human effort, less equipment, less time, and less space – while coming closer and closer to providing customers with exactly what they want." [23]

According to Taiichi Ohno, in the classical Lean Production a distinction between a total of seven types of waste is made. Ohno highlights the seven wastes that exist in a production system as follows: [24]

1. Transport
2. Inventory
3. Motion
4. Waiting
5. Over-production
6. Over-engineering
7. Defects

The kind of wastes that are relevant for the analysis at BARBIERIE electronics are: Transport, Motion and Waiting. All other wastes do not appear in the process, because the analysis is just made for on assembly. If the process were analyzed for many assembly rounds and if more parts of the process were considered, it would be necessary to analyze all kinds of waste.

Value added and non-value-added activities

A part of an operation that adds and does not add value to the product is therefore called value-added and non-value-added operation respectively. Value can simply be defined as something a customer is willing to pay to receive. If a customer is not willing to pay for it, then there is no value. [25]

Waste or non-value-added work includes all activities and processes that cost time, resources and/or space, but do not contribute directly to the fulfillment of customer requirements. Waste is therefore the part of the work for which the customer does not pay, e.g. internal transport of components to the assembly site, motion of workers, waiting time, etc. [26] For more examples of non-value-added activities see the 7 wastes presented in this chapter.

Transport

The transport of objects is a non-value-adding activity, which is very pronounced in many production plants.

Transportation of for example raw materials, workpieces, finished products, tools or equipment is a necessary waste, since materials inevitably must be transported

through production in some way during every manufacturing process. However, it is important to reduce waste through transport as much as possible.

The transport itself ties up resources for non-value-adding activities that could be used elsewhere to create value.

- Possible causes: An inadequate design of the workplace can result in the tools required not being available on site but having to be fetched if necessary.

- Effects: Employees must often interrupt their work on the product because things that they urgently need to continue working are missing. Thus, a different type of waste arises from the lack of materials or tools: waiting.

Motion

Unnecessary movement is another aspect that reduces productivity. Unnecessary movement includes small-scale movement such as reaching out for tools or reaching out to unnecessarily distant components, as well as large-scale movement such as going to the central tool dispenser to get a replacement tool.

- Possible causes: Often an unfavorable or missing workplace ergonomics is the reason for unnecessary movement, which not only limits the efficiency of the employee, but can also lead to accidents at work or poor quality in many cases.

To improve workplace and create optimum conditions for the work process ergonomics, work processes must be analyzed in detail. The correct arrangement of components and equipment on the assembly table, the complete availability of all required materials and tools, and the correct environmental conditions such as lighting and table height can often lead to significant improvements.

Unnecessary movement on a larger scale manifests itself in the employee running around regularly within the work area or even having to leave his own work to get missing items from other areas. Disorder is very often a reason why a lot of working time is wasted searching for tools or materials. In such search actions, the employee often covers considerable distances during which he/she cannot, clearly, add value.

Waiting

Waiting is, as the name implies, a period during which no activity takes place. It includes waiting for a machine/operator to finish its process, a part or component to

arrive from an upstream activity, or just taking breaks. Waiting does not add value to the final product, therefore it is a non-value activity and should be minimized.

4.3. Working conditions

The importance of working conditions will be detailed below. All information is based on reports from the International Labour Organization. [27] Working conditions have a direct influence on productivity, since they mark the environment in which productivity can develop properly. Therefore, to be able to define plans to increase productivity, it is primary necessary to make an analysis of the prevailing working conditions.

Poor working conditions are among the most recurrent causes of unproductive time, mainly due to shortcomings in business management, in addition to resulting in an excessive proportion of defective work, waste of material and therefore a level of service. inadequate to the client, which causes its removal negatively impacting the economy of the company. organization.

The main aspects that we must be considered for good working conditions are the following:

- Cleaning of the premises
- Lighting
- Ventilation and temperature
- Color of the environment
- Noise

Illumination is one of the most important working conditions that many companies don't consider in a proper way. Bad lighting causes negative effects on the worker's productivity, since it causes early mental and physical exhaustion, lack of motivation, errors in the development of the work, decrease in the rhythm of the work, increase in the number of interruptions to rest, apart from the injuries that can be caused by accidents. The effectiveness of lighting will depend on its intensity and quality. The latter is based on diffusion, direction and uniformity of distribution, color, brightness and glare intensity.

4.4. Ergonomics

The definition and importance of ergonomics will be detailed below. All information about this topic is based on reports from the International Labour Organization. [28]

Every day the machines perform more and more jobs. This spread of mechanization and automation often accelerates the pace of work and can sometimes make it less interesting. On the other hand, there are still many tasks that must be done manually and that involve a great deal of physical effort. One of the consequences of manual work, in addition to increased mechanization, is that more and more workers are suffering from back pain, neck pain, swelling of the wrists, arms and legs, and eye strain. Ergonomic design is the application of a body of knowledge about human abilities, their limitations and characteristics relevant to the design of tools, machinery, systems, tasks, jobs and environments that are safe, comfortable and effective for human use.

Ergonomics consists in the scientific study of the relationships between man and his working environment. It is used to determine how to design or adapt the workplace to the worker to avoid different health problems and to increase efficiency, i.e. to make the work adapt to the worker rather than forcing the worker to adapt to it. The ergonomist studies the relationship between the worker, the workplace and the design of the workplace.

General Objectives of Ergonomics:

- Reduction of occupational injuries and diseases
- Decrease in costs due to workers' inability to work
- Increase in production
- Improvement of the quality of work.
- Decrease in absenteeism.
- Application of existing standards.
- Reduction of losses in raw material.

<u>Recommendations for an ergonomic workplace</u>

Left-handed and right-handed workers: a work surface and tools that meet their need should be provided. Each workstation must be provided with a seat when the work is carried out standing up. Periodic pauses and changes in body posture reduce the problems caused by standing too long. Reflexes and shadows must be eliminated.

Good lighting is essential. Figures 7, 8, and 9 illustrate ergonomic workplaces and correct working postures.

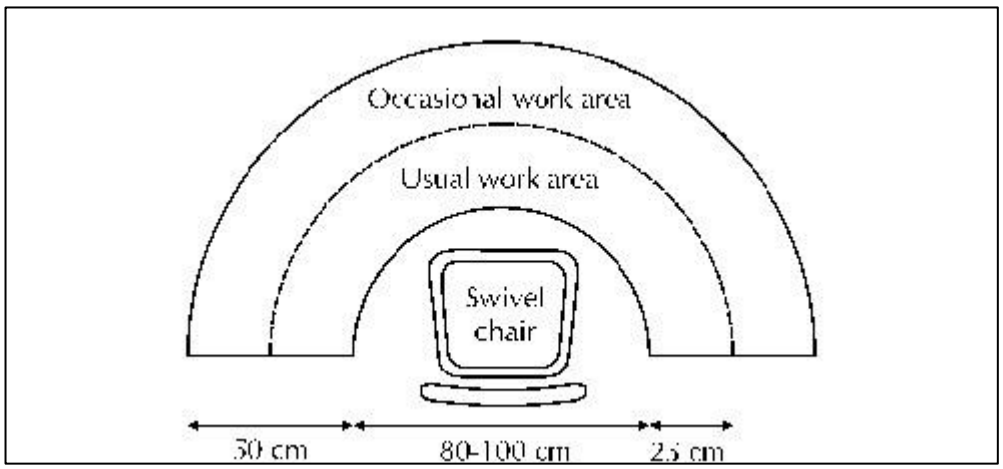

Figure 7: Ergonomic workplace measurements [29]

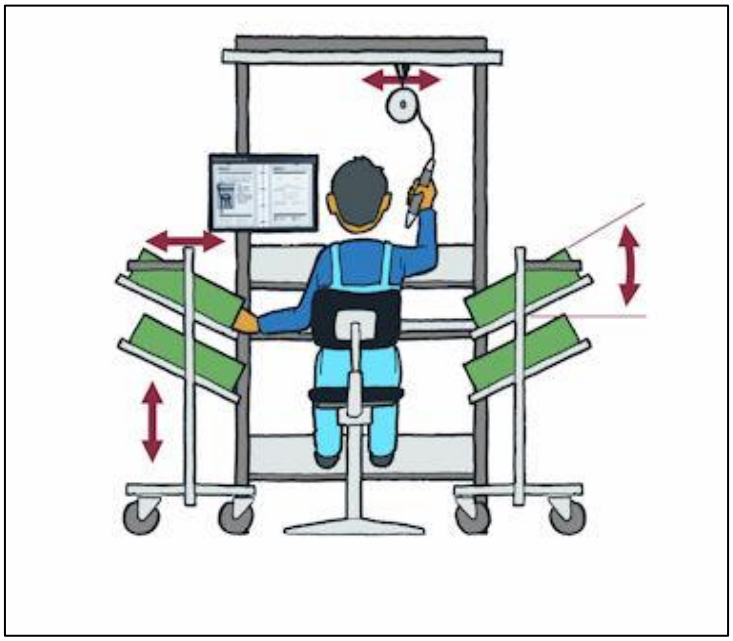

Figure 8: Example of ergonomic workplace [30]

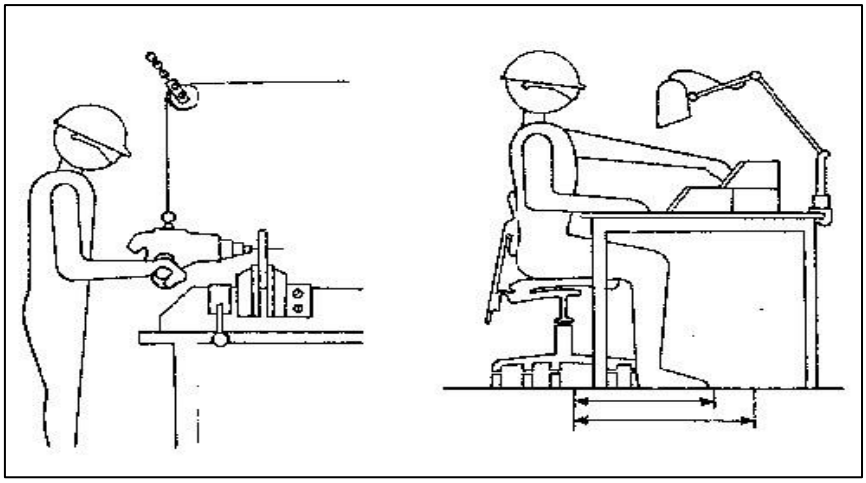

Figure 9: Ergonomic working postures [31]

The working position should be as comfortable as possible. According to the ILO to improve the position of the worker sitting on the right, the height of the chair should be lowered, inclined slightly forward and provided with a footstool to rest the feet. In Figure 10 the arrows indicate the areas to be improved to avoid possible injuries.

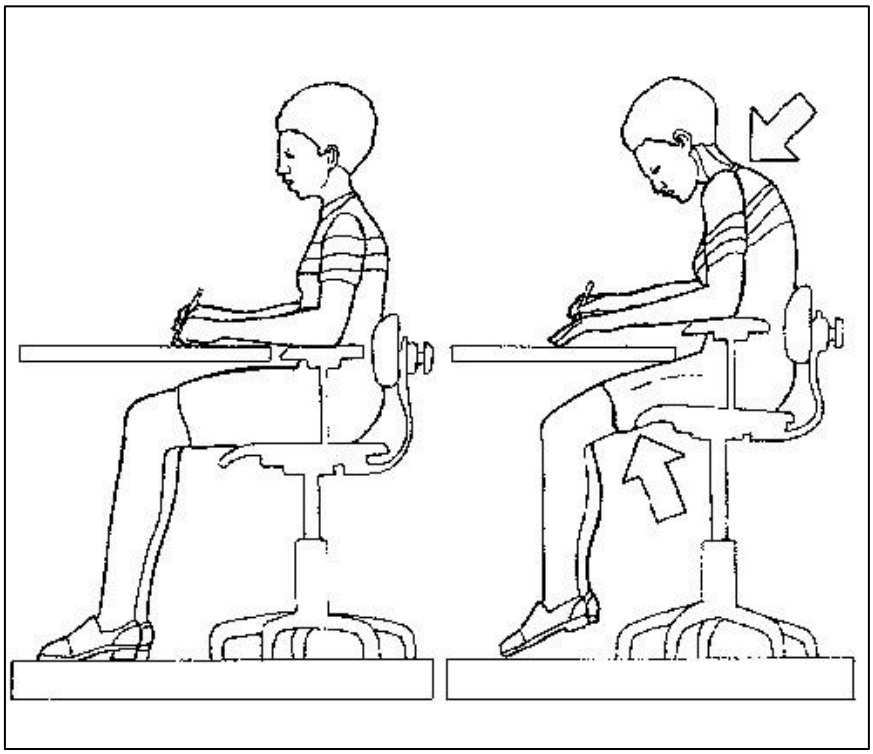

Figure 10: Working positions [32]

The International Labour Organization gives suggestions for an ergonomic workstation. Some important considerations for designing an optimal workplace are:

head height, shoulder height, arm reach, elbow height, leg length, hand size and body size. [33]

- Head height

There should be enough room to accommodate the tallest workers. Objects to be contemplated should be at eye level or a little lower because people tend to look down.

- Shoulder height

Control panels should be located between shoulders and waist. Frequently used objects or controls should not be placed above shoulder height.

- Arm reach

Objects should be placed as close to the arm as possible to avoid having to extend it. The tools needed for working should be placed so that the tallest worker does not have to bend over to reach them. Frequently used materials and tools must be kept close and in front of the body.

- Elbow height

In most cases the work surface must be adjusted to be at the height of the elbow or something lower.

- Leg length

The height of the seat must be adjusted to the length of the legs and the height of the work surface. There must be room to stretch the legs, with enough room for long legs. An adjustable footstool must be provided, so that the legs do not hang, and the worker can change the position of the body.

- Hand size

Grips and handles should fit the workers hands.

- Body size

Sufficient space should be left in the workplace for larger workers.

5. State analysis – Assembly of SpectroPad

In this chapter the practical part of the study will be detailed. For this case study it is essential to streamline the processes and record how employees use their tools during assembly to identify waste.

The state analysis includes the segmentation, process time documentation, and description of every process step of the workflow. Each step is classified according to the task being performed by the operator. List of task categories:

- Searching
- Documentation
- Positioning/Accommodating
- Testing
- Assembling/Adjusting/Fixing
- Cleaning
- Wrong Operation
- Handling
- Waiting

After the segmentation and categorization of the steps, value adding and non-value adding activities will be identified and documented.

By means of the video, the eye movements and the relation with the working process will also be investigated. Distinctive fixations and saccades will be pointed out. [1]

Next, a recommendation for the critical steps will be given. Critical steps are work processes that could be optimized (potential for improvement). The critical steps will be classified in the next 3 categories:

a) Improve ergonomics (work conditions)
b) Improve efficiency and productivity (acceleration of the work process)
c) Improve quality (seeking error-free assembly/error prevention).
d) Improve safety (reducing risk)

[1] Important to point out that to do a better and faster analysis of the fixation and saccade data, the software Tobii Pro Lab should be used for further analysis.

General process improvement considerations that are taken into account for the analysis are: eliminate non-value-added activities; simplify and standardize; clear responsibility of workplace and materials, optimize the order of activities to reduce search, training and setup times.

Segmentation and description of the processes. The state analysis was documented with help of an Excel tool. A screenshot of an excerpt of the analysis is presented In Figure 11 (PMV = value-adding; SMV = non-value-adding).

Nr.	Process description	Start time of step	Process time	Category	PMV / SMV	Fixation	Sakkaden	Remarks and recommendations for action
1	Searching case	0:00:05	0:00:02	B	SMV			Working Procedure is missing. Recommendation: Install Instructions projection (e.g.: Der Assistent) or interactive "step by step instructins".
2	Handling case	0:00:07	0:00:03	T	SMV			
3	worktable	0:00:10	0:00:01	J	SMV			
4	Searching display	0:00:11	0:00:02	B	SMV			a) Improve ergonomics (work conditions); Position shelf bin higher or in front of the operator
5	Handling display	0:00:13	0:00:03	T	SMV			
6	Positioning display	0:00:16	0:00:01	J	SMV			
7	connection cable (display - case)	0:00:17	0:00:02	B	SMV		Looking for cables	b) Improve efficiency and productivity; Arrange calbes before assembly.
8	Handling conection	0:00:19	0:00:11	T	SMV			
9	cable for assembly process	0:00:30	0:00:30	J	SMV	High work concentration		
10	g cable with display board	0:01:00	0:00:28	M	PMV			
11	Positioning display	0:01:28	0:00:01	J	SMV			
12	Searching for cable tie	0:01:29	0:00:02	B	SMV			a) Improve ergonomocs: position bins so that worker does not have to bend over to reach them.
13	Handling cable tie	0:01:31	0:00:10	T	SMV			

Figure 11: Excerpt of state video analysis

List of categories:

- B: Searching (*Bewegung/Suchen*)
- D: Documentation (*Dokumentation*)
- J: Positioning, Preparing, Accommodating (*Justieren / Einstellen*)
- K: Testing (*Kontrolle*)
- M: Assembling, Adjusting, Cutting, Screwing, Fixing (*Mechanischer Umbau*)
- R: Cleaning (*Reinigen*)
- S: Wrong operation (*Störungen*)
- T: Handling (*Transport*)
- W: Waiting (*Warten*)

Outcomes of state analysis. The state analysis of the video indicates that the assembly process is composed of 140 sub-processes and has a duration of 23 minutes and 20 seconds. Each process was categorized by task category and by type of activity. The results of the time analysis are presented in Table 1.

Table 1: Time analysis

Category	Time analysis	Percentage
SUM	**0:23:20**	**100%**
Assembling/Adjusting/Fixing	0:13:40	59%
Positioning/Preparing/Accommodating	0:02:29	11%
Handling	0:02:28	11%
Searching	0:02:11	9%
Wrong Operation	0:01:22	6%
Testing	0:00:46	3%
Waiting	0:00:24	2%

Assembling/adjusting/fixing. As noticed, the operator spends almost 60% of the total time doing direct assembling activities. Nevertheless, it is determined that not all this assembling sub-processes are value-adding activities. Some of the assembly operations were unnecessary or duplicated, what means that they can be eradicated. The achievable time reduction is presented in the target analysis in chapter 6.

Positioning/Preparing/Accommodating characterize 11% (2,5min) of the total process. In most of the cases these activities can be reduced if the pieces are prepared before the assemble. ready to assemble. An example of this category is "preparing cable for assembly process". This sub-process took more than a minute to be performed. If the cable was ready for installation the process would take less time.

Wrong operations (WO) represent 6% of the total assembly activities. Eliminating these errors would reduce the total process by 1,3 minutes.

Waiting times is 2% of the total time. In this assembly process it is also categorized as waste and must be eliminated. In this case, removing the unnecessary waiting times would reduce the process by approx. 0,5 minutes.

Searching and **Handling** activities cannot be totally eliminated but must be reduced as much as possible. Reducing these activities is feasible if the right methods are applied. In the excel tool are recommendations for improvement of the most remarkable activities.

Testing activities are in most of the cases necessary to achieve quality targets. However, it is observed that in some cases a test procedure is being unnecessarily repeated in the same operation.

As seen in table 2, according to the state analysis, the efficiency of the assembly process of the SpectroPad is at the moment 57%.[2] The non-value-adding activities represent 43% of the total process, that means that there is definitively a lot of room for improvement. 26% of all the activities represent 57% of the assembly time.

Table 2: Value / non-value-adding analysis

Value / non-value-adding	Number of activities	Time analysis	Percentage
SUM	**140**	**0:23:20**	**100%**
Non-value-adding	104	0:10:05	43%
Value-adding	36	0:13:15	57%

Some examples of the excel tool

The biggest waste within the process was observed in sub-processes 77 to 83 (see Figure 12). In this case, the operator did not remember the assembly procedure of the metal deck. The task can normally be finished in less than 1 minute, but the operator spent 4 minutes to assemble it. Recommendation to improve the efficiency of this sub-process is to install a tool for projection of instructions or a simple "step by step" manual. Furthermore, to improve this case, the ETG recordings can be used to train new employees or review the critical steps of the whole process.

Nr.	Process description	Start time of step	Process time	Fixation	Sakkaden	Remarks and recommendations for action
77	Assembling the metal deck	0:10:19	0:01:01	Process is unknown	Insecurity of the employee	b) improve efficiency. Install tool for projection of instructions (e.g.: Der Assistent) or interactive "step by step instructins".
78	Dismantling metal deck	0:11:20	0:00:08			"
79	Handling the metal deck	0:11:28	0:00:02			"
80	Searching for information about assembly process of	0:11:30	0:00:30			"
81	Assembling metal deck	0:12:00	0:00:35			"
82	Searching for information about assembly process of	0:12:35	0:00:08			"
83	Assembling metal deck	0:12:43	0:01:42			"

Figure 12: Excerpt of state analysis – biggest waste

With help of a filter function in the excel tool it is possible to see the sub-processes with the higher process times. See figure 13.

[2] Critical observation: This study is mainly for showing the procedure and possible benefits of combining ETG with lean methodology. The practical state analysis is based on the assembly of juts one SpectroPad. For an accurate result, more devices should be considered.

Nr	Process description	Start time of step	Process time	Fixation	Sakkade	Remarks and recommendations for action
83	Assembling metal deck	0:12:43	0:01:42			b) improve efficiency. Install tool for projection of instructions (e.g.: Der Assistent) or interactive "step by step instructins".
134	Preparing cable for assembly process	0:20:55	0:01:23			b) improve efficiency. Cable should be ready for assembly. Operator repeats the same subprocess several times unnecessarily
77	Assembling the metal deck	0:10:19	0:01:01	Process is unknown	Insecurity of the employee	b) improve efficiency. Install tool for projection of instructions (e.g.: Der Assistent) or interactive "step by step instructins".
21	Assembling display board with case	0:02:11	0:00:51	High work concentration		Good work
63	Assembling cable tie (cable	0:08:07	0:00:45			Good work
60	Adjust cables	0:07:20	0:00:40			b) improve efficiency: Eliminate duplicate work. Adjusting the cables inside the black case shoud be done in this point and not before. Compare with process step 54 and 58 (-50s)
137	Fixing screw in PCB	0:22:21	0:00:37			duplicate work. Fixing screws should be done directly after the corresponding assemble process and not later
59	Unscrew screws for better adjustment of cable	0:06:44	0:00:36			a) improve efficiency: Unnecessary step! Do not tighten the screws in the first place
54	Accommodating cables and testing movement of parts	0:05:37	0:00:35			b) imporve efficiency: Eliminate duplicate work. Adjusting the cables inside the black case shoud be done later
81	Assembling metal deck	0:12:00	0:00:35			b) improve efficiency. Install tool for projection of instructions (e.g.: Der Assistent) or interactive "step by step instructins".
80	Searching for information about assembly process of the metal deck	0:11:30	0:00:30			b) improve efficiency. Install tool for projection of instructions (e.g.: Der Assistent) or interactive "step by step instructins".
126	Waiting	0:19:39	0:00:24	Process is unknown		b) Improve efficiency. Operator does not know what the next working step is. Instructions needed!

Figure 13: Most time extensive sub-processes

6. Target analysis - Assembly of SpectroPad

The target analysis gives an estimate of the time that can be saved if the improvement recommendations (from excel tool - state analysis) are implemented.

The suggestions are made based only on the video analysis and the eye movements (fixations and saccades). It will be the task for another study project, to investigate the recording data with the software for this purpose Tobii Pro Lab.

The results of the target analysis are presented in Table 3. As shown in this table, total savings of approx. 34% (approx. 8 minutes) are achievable when applying the improvements recommendations. After doing a sensitivity analysis of the saving potential the results are the next ones:

- Pessimistic results: 10%-time reduction
- Target results: 34%-time reduction
- Optimistic results: 40%-time reduction

Table 3: Time target analysis

Category	Time analysis	Savings	Target Times	Percentage
SUM	**0:23:20**	**00:07:58**	**0:15:22**	**100%**
Assembling/Adjusting/Fixing	0:13:40	0:02:45	0:10:55	71%
Positioning/Preparing/Accommodating	0:02:29	0:02:03	0:00:26	3%
Handling	0:02:28	0:00:02	0:02:26	16%
Searching	0:02:11	0:00:47	0:01:24	9%
Wrong Operation	0:01:22	0:01:22	-	-
Testing	0:00:46	0:00:35	0:00:11	1%
Waiting	0:00:24	0:00:24	-	-

Recommendations for action:

All recommendations for action that lead to time savings can be find in the excel sheet named Target_Analysis_ETG_BARBIERI (see appendix). Figure 14 shows an excerpt of the process descriptions and its recommendations for improvement. Some examples will be detailed in this report.

Nr.	Process description	State - Process time	Fixation	Sakkaden	Remarks and recommendations for action	Time savings	Target process time
134	Preparing cable for assembly process	0:01:23		Insecurity of the employee	b) improve efficiency. Cable should be ready for assembly. Operator repeats the same subprocess several times unnecessarily. Eliminate step.	0:01:23	0:00:00
77	Assembling the metal deck	0:01:01	Process is unknown	Insecurity of the employee	b) Wrong operation! Improve efficiency. Install tool for projection of instructions (e.g.: Der Assistent) or interactive "step by step instructins".	0:01:01	0:00:00
59	Unscrew screws for better adjustment of cable	0:00:36			a) improve efficiency: Unnecessary step! Do not tighten the screws in the first place	0:00:36	0:00:00
54	Accommodating cables and testing movement of parts	0:00:35			b) imporve efficiency: Eliminate duplicate work. Adjusting the cables inside the black case shoud be done later	0:00:35	0:00:00
81	Assembling metal deck	0:00:35			b) Wrong operation! improve efficiency. Install tool for projection of instructions (e.g.: Der Assistent) or interactive "step by step instructins".	0:00:35	0:00:00
9	Preparing connection cable for assembly process	0:00:30	High work concentrati on		b) improve efficiency. Cable should be ready for assembly. Operator repeats the same subprocess several times unnecessarily	0:00:30	0:00:00
80	Searching for information about assembly process of the metal deck	0:00:30			b) improve efficiency. Install tool for projection of instructions (e.g.: Der Assistent) or interactive "step by step instructins".	0:00:25	0:00:05
126	Waiting	0:00:24	Process is unknown		b) Improve efficiency. Operator does not know what the next working step is. Instructions needed!	0:00:24	0:00:00
38	Disassembling screw.	0:00:18			WO	0:00:18	0:00:00

Figure 14: Excerpt excel tool (Target analysis)

Table 4: Value / non-value-adding TARGET analysis

Value / non-value-adding	Number of activities	Time analysis	Percentage
SUM	**119**	**0:15:22**	**100%**
Non-value-adding	87	0:04:46	31%
Value-adding	32	0:10:36	69%

As seen in table 4, according to the target analysis, the efficiency of the assembly process of the SpectroPad can reach 69% if the improvements recommendations are followed.

Examples

- Improve ergonomics (work conditions): Place shelf bin higher or in front of the operator. Example of well-organized workplace is presented in figure 15. As seen in the example, the bins should be positioned in front of the operator considering all ergonomic characteristics. In addition, the "step by step" instructions of the assembly should be positioned as in the example.

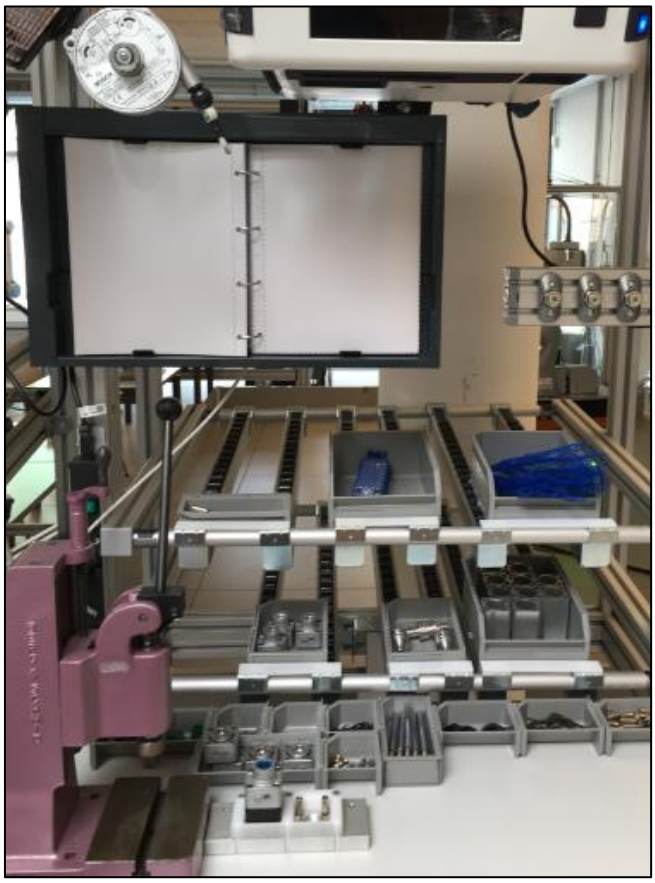

Figure 15: Recommendation for workplace organization

- Improve efficiency. Tweezers were not in the toolbox. The workplace should be organized before starting. Assign a storage place for tweezers. With this improvement a reduction time of 30seconds is estimated.

- Wrong operations can be eliminated with help of a tool in the work table that support projections of procedures and quality controls (metal deck example – min 00:10:19). In the case of Barbieri, an operator does several tasks a day and is only assembling the SpectroPad occasionally. The assembly is not continuous. The operator has to know the assembly process of different types of products (in some cases more than 140 assembly steps for assembling 1 product), what makes the assembly process more prone to failure. With a tool that supports projections in the worktable the quality of the products can be increased, the errors can be minimized, and the workers will be more confident in the assembly process. In Figure 16 an example of projection of instructions is presented.

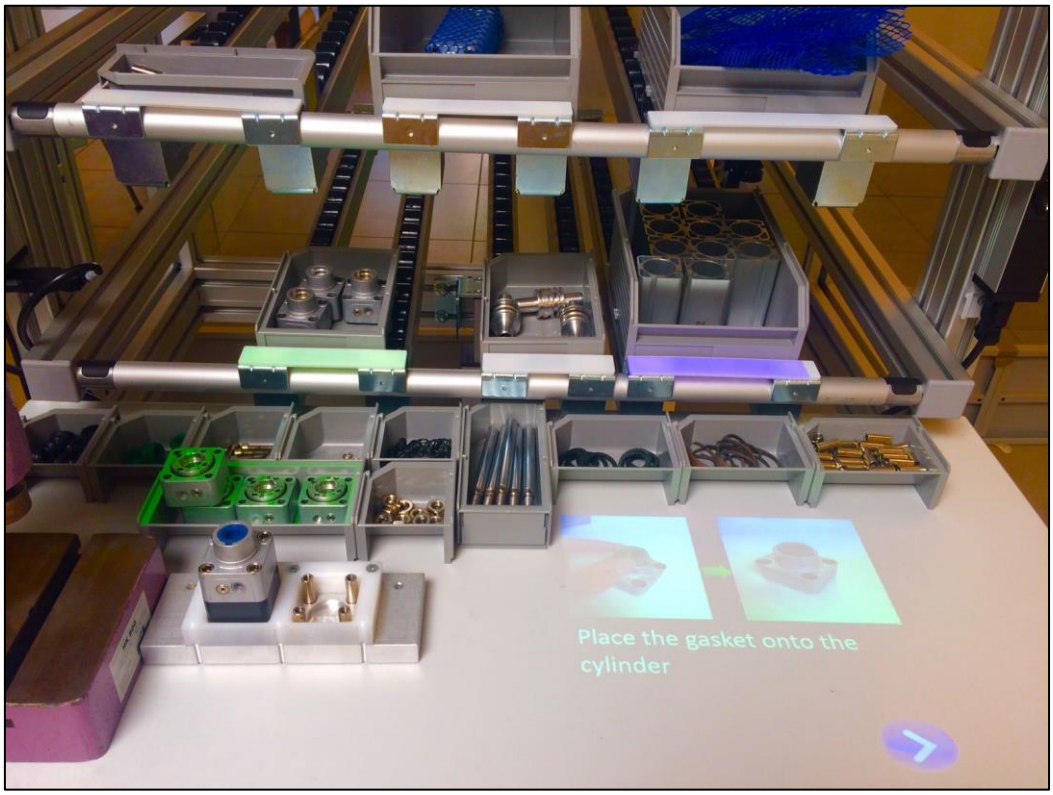

Figure 16: Projection of instructions in worktable – Tool: "Der Assistent"

7. Benefits of Eye Tracking Glasses for assembly optimization

The ETG technology is an effective tool for obtainment and visualization of data. As described in this study, the benefits of ETG are many. In this specific case, a state analysis was performed much easier thanks to the technology.

As demonstrated with the video analysis, *Eye Tracking Glasses* Technology can be utilized to support assembly optimization. It is a tool that improves workflow standardization and allows the identification of best practices.

Thanks to the data provided by the technology, it was possible to observe relations between saccades/fixations and waste activities.

By observing the sub-processes better decisions can be made to increase efficiency, quality of processes, but also ergonomic design of the workplace for employees.

By wearing eye-tracking devices during assembly, it can be determined whether the stress level of the worker in certain assembly processes is rising unusually high, or whether critical quality control points are receiving insufficient attention.

The results of the eye-tracking analysis, can thus provide valuable inputs for the human-centered optimization of the workplace in production. The knowledge gained can be utilized to improve instruction manuals and the placement of equipment.

Eye tracking can reveal insight of experienced operators which can then be used to train other staff, giving them these skills faster than if they had to learn them themselves. The assembly process recorded with ETG can now be used as training material for employees at BARBIERI.

8. Outlook and following studies

As described in the objective of the work, this study project is part of a series of investigations performed by the Free University of Bozen-Bolzano on the industrial usability of Eye Tracking Glasses for assembly optimization. This preliminary study has opened the door to do further research.

With the aim of deepen the investigation of industrial usability of Eye Tracking Glasses for assembly optimization, a second part of the study project was established. In this case a series of assembly tests were made in the Smart Mini Factory Laboratory of the Free University of Bozen-Bolzano.

The second part of the study project includes the organization and conduction of test series with 15 students as well as the segmentation of process steps and evaluation of the test results using the software of Tobii Pro. Optimization recommendations will also be given, based on statistical data of the test series.

In this case, the assembly process of a commercial pneumatic cylinder is studied. Each test person had to assemble five cylinders following a working procedure (see Figure 17). In total, 75 cylinders were assembled. During the entire assembly process (approx. 5min recording time/cylinder), the participants wore ETG in order to record the data.

Figure 17: Part of working procedure – Cylinder assembly

It is important to point out that the organization, conduction, and the segmentation of all process steps (state analysis) was successfully completed. The state analysis of the 75 assembly tests was made with the software Tobii Pro Lab. The data acquired from this 75 assembly tests is now available for further analysis.

Table 3 shows the categories of process steps that were used for the segmentation with the Tobii Pro Lab software (Figure 18).

Figure 18: Video analysis with software

Table 5: Categories of process steps

Category	Explanation
Assembling	• putting together two or more components • starts when two pieces are in the right position • stops when next category begins
Break	• each video has five “breaks”, which indicate always the end of the last operation of a cylinder and the time where one cylinder is ready-assembled • time for assembling of one cylinder is always the start of first “operation” till “break”
Handling	• when the participant holds a part in the hand and brings it to another place • starts when a piece is in the hand of the worker or when the last of simultaneously searched piece is out of its box • stops when the next category begins
Information	• searching for information, both in person and in paper • starts when the participant searches for information • stops when next category starts
Operation	• the time after “operation” is always “searching” -time • separates the four different steps of the ready assembled cylinder • first step begins with “operation”, fourth (last) step stops with “break” • (Before “operation” is usually “positioning” or “break” -time. Except at beginning of experiment)
Positioning	• starts when the ready part is positioned on its designated place • stops when the next category starts
Searching	• searching with eyes as well as with hands for parts that will be used for the next step • starts when the participant begins to search for pieces in the box • stops when the next category, usually “handling”, starts
Wrong Operation	• starts at the beginning of a wrong operation

A big amount of information is handled for the second part of the study project (approx. 350min recording duration). Figure 19 shows an excel sheet with part of the data obtained with the 15 tests.

Entire Recording	Average, Median, Sum, Standard Deviation (N-1) measured in seconds						
Interval Duration	**Participant**	**1**	**Average**	**Median**	**Count**	**Total Time o**	**Total Rec Duration**
Recording005	Richard	1195,99	1195,99	1195,99	1	1195,99	1195,99
Recording006	Sebastian	843,65	843,65	843,65	1	843,65	843,65
Recording007	Philip	1002,03	1002,03	1002,03	1	1002,03	1002,03
Recording008	Aaron	1115,51	1115,51	1115,51	1	1115,51	1115,51
Recording010	Linda	1515,94	1515,94	1515,94	1	1515,94	1515,94
Recording011	Stephano	990,99	990,99	990,99	1	990,99	990,99
Recording012	Hab 1	1259,50	1259,50	1259,50	1	1259,50	1259,50
Recording014	Tim	1407,15	1407,15	1407,15	1	1407,15	1407,15
Recording015	Lorenzo	1483,29	1483,29	1483,29	1	1483,29	1483,29
Recording016	Angelo	1598,05	1598,05	1598,05	1	1598,05	1598,05
Recording018	Leon	1158,04	1158,04	1158,04	1	1158,04	1158,04
Recording020	Davide	2179,36	2179,36	2179,36	1	2179,36	2179,36
Recording021	Stephan	1787,55	1787,55	1787,55	1	1787,55	1787,55
Recording022	Heider	1735,60	1735,60	1735,60	1	1735,60	1735,60
Recording112	Carlos	1393,95	1393,95	1393,95	1	1393,95	1393,95
Average		1305,85	1305,85	1305,85	1,00	1305,85	1305,85
Count		15					
Variance		200007,42	200007,42	200007,42	0,00	200007,42	200007,42
Standard Deviation (N-1)		447,22	447,22	447,22	0,00	447,22	447,22

Figure 19: Interval duration – cylinder assembly

In order to make an accurate statistical evaluation of the data given by the Tobii Pro Lab software, Dr. Yuri Borgianni, researcher at the Free University of Bozen-Bolzano, is creating a MATLAB tool. When the tool is ready, the second part of the study project will be continued.

In forthcoming studies, the optimization recommendations will be applied to the assembly process. The effect of reducing the eye movements (due to the optimization) will be examined to draw conclusions about an efficiency increase, which should also be measured in the form of performance data.

9. Conclusion

In conclusion it can be stated, that assembly optimization is achievable with the implementation of Eye Tracking Glasses technology. In general, this technology facilitates the direct visualization of an assembly process, allows you to quickly identify non-value activities, and is key to making better decisions. Nevertheless, it is important to point out that ETG are a support tool for analysis and do not guarantee an optimization of the system. Humans are still the decision makers and are responsible for finding better process solutions and make adequate recommendations for optimization.

Appendix

State Analysis

State video analysis			Team: Study Project - Barbieri Electronic		Date: 05.09.2018			
Investigation field: SpectroPad DOC								
Nr.	Process description	Start time of step	Process time	Category	PMV / SMV	Fixation	Sakkaden	Remarks and recommendations for action
1	Searching case	0:00:05	0:00:02	B	SMV			c) Improve quality and b) improve efficiency; Working Procedure is missing. Recommendation: Install Instructions projection (e.g.: Der Assistent) or interactive "step by step instructins".
2	Handling case	0:00:07	0:00:03	T	SMV			
3	Positioning case on worktable	0:00:10	0:00:01	J	SMV			
4	Searching display	0:00:11	0:00:02	B	SMV			a) Improve ergonomics (work conditions); Position shelf bin higher or in front of the operator
5	Handling display	0:00:13	0:00:03	T	SMV			
6	Positioning display	0:00:16	0:00:01	J	SMV			
7	Searching for connection cable (display - case)	0:00:17	0:00:02	B	SMV		Looking for cables	b) Improve efficiency and productivity; Arrange calbes before assembly.
8	Handling conection cable	0:00:19	0:00:11	T	SMV			
9	Preparing connection cable for assembly process	0:00:30	0:00:30	J	SMV	High work concentration		b) improve efficiency. Cable should be ready for assembly. Operator repeats the same subprocess several times unnecessarily
10	Connecting/Assembling cable with display board	0:01:00	0:00:28	M	PMV			
11	Positioning display board on worktable	0:01:28	0:00:01	J	SMV			
12	Searching for cable tie	0:01:29	0:00:02	B	SMV			a) Improve ergonomocs: position bins so that worker does not have to bend over to reach them.
13	Handling cable tie	0:01:31	0:00:10	T	SMV			
14	Fastening cable to display board with cable tie	0:01:41	0:00:15	M	PMV			
15	Searching for cable tie cutter in worktable	0:01:56	0:00:01	B	SMV			
16	Handling cable tie cutter	0:01:57	0:00:01	T	SMV			
17	Cutting overhanging cable tie	0:01:58	0:00:03	M	PMV			a) Improve ergonomics and b) Improve efficiency and productivity: disposal of cut cable tie in a bin for this purpose.
18	Positioning cable tie cutter in worktable	0:02:01	0:00:01	J	SMV			
19	Searching display board	0:02:02	0:00:01	B	SMV			
20	Handling display board	0:02:03	0:00:08	T	SMV			
21	Assembling display board with case	0:02:11	0:00:51	M	PMV	High work concentration		Good work
22	Searching PCB in toolbox	0:03:02	0:00:02	B	SMV			
23	Handling PCB (Leiterplatte)	0:03:04	0:00:05	T	SMV			
24	Positioning PCB in worktable	0:03:09	0:00:01	J	SMV			
25	Searching for "special screw with spring" in toolbox	0:03:10	0:00:01	B	SMV			
26	Handling "special screw with spring"	0:03:11	0:00:03	T	SMV			
27	Assembling "special screw with spring" (in cable base)	0:03:14	0:00:11	M	PMV			
28	Searching for screw in the screw box 1	0:03:25	0:00:04	S	SMV		Looking for screws	b) Improve efficiency and productivity: Identify screw boxes with number or color
29	Handling screw	0:03:29	0:00:06	S	SMV			WO wrong screw
30	Assembling (cable base - PCB)	0:03:35	0:00:05	S	SMV			WO wrong screw
31	Identifying wrong operation: wrong screw	0:03:40	0:00:01	S	SMV			WO wrong screw
32	Positioning screw in worktable	0:03:41	0:00:01	S	SMV			WO wrong screw
33	Searching for screw in the screw box 2	0:03:42	0:00:01	B	SMV		Looking for screws	
34	Handling screw	0:03:43	0:00:01	T	SMV			
35	Searching screw driver	0:03:44	0:00:06	B	SMV			
36	Assembling screw using screw driver (cable base - PCB)	0:03:50	0:00:09	S	SMV			WO: b) Improve efficiency: Projections of step by step instructions
37	Identifying wrong operation: Assembling should inlcude cable base, PCB and case)	0:03:59	0:00:01	S	SMV			WO
38	Disassembling screw.	0:04:00	0:00:18	S	SMV			WO
39	Assembling screw using screw driver (cable base - PCB - case)	0:04:18	0:00:32	M	PMV			
40	Positioning screw driver in worktable	0:04:50	0:00:01	J	SMV	High work concentration		
41	Handling SpectroPad	0:04:51	0:00:02	T	SMV	High work concentration		
42	Turning SpectroPad upside down	0:04:53	0:00:02	T	SMV			
43	Searching screw and screw driver	0:04:55	0:00:02	B	SMV			
44	Handling screw with screw driver	0:04:57	0:00:02	T	SMV			

45	Assembling screw	0:04:59	0:00:04	M	PMV			
46	Searching screw and screw driver	0:05:03	0:00:01	B	SMV			
47	Handling screw with screw driver	0:05:04	0:00:03	T	SMV			
48	Assembling screw	0:05:07	0:00:03	M	PMV			
49	Searching screw and screw driver	0:05:10	0:00:01	B	SMV			
50	Handling screw with screw driver	0:05:11	0:00:03	T	SMV			
51	Assembling screw	0:05:14	0:00:07	M	PMV			
52	Adjusting/fitting assembled screws	0:05:21	0:00:10	M	PMV			a) increase efficiency: Eliminate duplicate work. Adjusting the screws should be done directly after the assemble process and not later
53	Turning SpectroPad to normal position	0:05:31	0:00:06	T	SMV			
54	Accommodating cables and testing movement of parts	0:05:37	0:00:35	K	PMV			b) imporve efficiency: Eliminate duplicate work. Adjusting the cables inside the black case shoud be done later
55	Searching screw driver	0:06:12	0:00:01	B	SMV			
56	Handling screw driver	0:06:13	0:00:01	T	SMV			
57	Adjusting/fitting assembled screws	0:06:14	0:00:16	M	PMV			
58	Adjust cables	0:06:30	0:00:14	M	PMV			b) increase efficiency: Eliminate duplicate work. Adjusting the cables inside the black case shoud be done later
59	Unscrew screws for better adjustment of cable	0:06:44	0:00:36	M	SMV			a) improve efficiency: Unnecessary step! Do not tighten the screws in the first place
60	Adjust cables	0:07:20	0:00:40	M	PMV			b) improve efficiency: Eliminate duplicate work. Adjusting the cables inside the black case shoud be done in this point and not before. Compare with process step 54 and 58 (-50s)
61	Searching for cable tie in toolbox	0:08:00	0:00:03	B	SMV			a) Improve ergonomics: position cable tie bin in front of operator
62	Handling cable tie	0:08:03	0:00:04	T	SMV			
63	Assembling cable tie (cable to case)	0:08:07	0:00:45	M	PMV			Good work
64	Searching for cable tie cutter in worktable	0:08:52	0:00:01	B	SMV			
65	Handling cable tie cutter	0:08:53	0:00:03	T	SMV			
66	Cutting overhanging cable tie	0:08:56	0:00:09	M	SMV			a) Improve ergonomics (work conditions) and b) Improve efficiency and productivity: disposal of cut cable tie in a bin for this purpose.
67	Handling screw driver	0:09:05	0:00:07	T	SMV			
68	Assembling/fitting screws	0:09:12	0:00:29	M	PMV			
69	Searching for screws	0:09:41	0:00:01	B	SMV			
70	Handling screws	0:09:42	0:00:02	T	SMV			
71	Assembling screws	0:09:44	0:00:08	M	PMV			
72	Searching for screws	0:09:52	0:00:01	B	SMV			
73	Handling screws	0:09:53	0:00:02	T	SMV			
74	Assembling screws	0:09:55	0:00:15	M	PMV			
75	Searching for metal deck	0:10:10	0:00:02	B	SMV			
76	Handling the metal deck	0:10:12	0:00:07	T	SMV			
77	Assembling the metal deck	0:10:19	0:01:01	M	PMV	Process is unknown	Insecurity of the employee	b) improve efficiency. Install tool for projection of instructions (e.g.: Der Assistent) or interactive "step by step instructins".
78	Dismantling metal deck	0:11:20	0:00:08	S	SMV			"
79	Handling the metal deck	0:11:28	0:00:02	T	SMV			"
80	Searching for information about assembly process of the metal deck	0:11:30	0:00:30	B	SMV			"
81	Assembling metal deck	0:12:00	0:00:35	M	PMV			b) improve efficiency. Install tool for projection of instructions (e.g.: Der Assistent) or interactive "step by step instructins".
82	Searching for information about assembly process of the metal deck	0:12:35	0:00:08	B	SMV			"
83	Assembling metal deck	0:12:43	0:01:42	M	PMV			b) improve efficiency. Install tool for projection of instructions (e.g.: Der Assistent) or interactive "step by step instructins".
84	Testing the correct motion of the parts.	0:14:25	0:00:05	K	SMV			
85	Searching for adhesive	0:14:30	0:00:01	B	SMV			
86	Handling the adhesive	0:14:31	0:00:04	T	SMV			
87	Rubberizing the metal deck	0:14:35	0:00:10	M	PMV			
88	Searching for metal cover	0:14:45	0:00:03	B	SMV			
89	Handling metal cover	0:14:48	0:00:03	T	SMV			
90	Assembling metal cover	0:14:51	0:00:03	M	PMV			
91	Searching for screw	0:14:54	0:00:05	B	SMV			
92	Handling screw	0:14:59	0:00:04	T	SMV			
93	Screwing	0:15:03	0:00:01	M	PMV			
94	Searching for screw	0:15:04	0:00:02	B	SMV			
95	Handling screw	0:15:06	0:00:06	T	SMV			
96	Screwing	0:15:12	0:00:08	M	PMV			
97	Unscrewing assembled screw in PCB	0:15:20	0:00:10	M	SMV			
98	Positioning screw driver in worktable	0:15:30	0:00:09	J	SMV			
99	Accommodating cable	0:15:39	0:00:05	J	SMV			
100	Screwing	0:15:44	0:00:19	M	PMV			

101	Searching for "white plastic clip"	0:16:03	0:00:06	B	SMV			
102	Handling "white plastic clip"	0:16:09	0:00:05	T	SMV			
103	Fixing "white plastic clip" to cable	0:16:14	0:00:12	M	PMV			
104	Connecting/Assembling cable with PCB board	0:16:26	0:00:09	M	PMV			
105	Searching for wire	0:16:35	0:00:05	B	SMV		Looking for wire	b) Improve efficiency: wire should be in respective bin and not on the worktable
106	Handling the wire	0:16:40	0:00:06	T	SMV			
107	Fixing cable to PCB board using the wire (cable - PCB board)	0:16:46	0:00:31	M	PMV			
108	Connecting case to display board	0:17:17	0:00:19	M	PMV			
109	Searching for screw and screwdriver	0:17:36	0:00:06	B	SMV			
110	Handling screw and screwdriver	0:17:42	0:00:05	T	SMV			
111	Screwing	0:17:47	0:00:11	M	PMV			
112	Searching for screw and screwdriver	0:17:58	0:00:05	B	SMV			
113	Handling screw and screwdriver	0:18:03	0:00:05	T	SMV			
114	Screwing	0:18:08	0:00:28	M	PMV			
115	Searching for screw and screwdriver	0:18:36	0:00:03	B	SMV			
116	Handling screw and screwdriver	0:18:39	0:00:02	T	SMV			
117	Screwing	0:18:41	0:00:09	M	PMV			
118	Searching for screw and screwdriver	0:18:50	0:00:01	B	SMV			
119	Handling screw and screwdriver	0:18:51	0:00:02	T	SMV			
120	Screwing	0:18:53	0:00:11	M	PMV			
121	Searching for screw and screwdriver	0:19:04	0:00:02	B	SMV			
122	Handling screw and screwdriver	0:19:06	0:00:03	T	SMV			
123	Screwing	0:19:09	0:00:23	M	PMV			
124	Testing the correct motion of the parts	0:19:32	0:00:06	K	SMV			
125	Positioning of spectropad	0:19:38	0:00:01	J	SMV			
126	Waiting	0:19:39	0:00:24	W	SMV	Process is unknown		b) Improve efficiency. Operator does not know what the next working step is. Instructions needed!
127	Searching for tweezers	0:20:03	0:00:19	S	SMV		Looking for tweezers	b) Imporve efficiency. Tweezers were not in the toolbox. Organice the workplace before starting. Tools required must be available on site! Separate bin or storage place for tools
128	Handling the tweezers	0:20:22	0:00:08	S	SMV		Looking for tweezers	d) Improve safety: Obstructions in the corridor
129	Positioning tweezers in worktable	0:20:30	0:00:02	S	SMV		Looking for tweezers	
130	Searching for cable	0:20:32	0:00:06	B	SMV			
131	Handling cable	0:20:38	0:00:10	T	SMV			
132	Searching and handling cable tie cutter	0:20:48	0:00:02	B	SMV			c) improve quality and b) Improve efficiency and productivity (acceleration of the work process) cable tie had to be removed before.
133	Cutting/removing cable tie from cable	0:20:50	0:00:05	M	SMV			c) improve quality and b) Improve efficiency and productivity (acceleration of the work process) cable tie had to be removed before.
134	Preparing cable for assembly process	0:20:55	0:01:23	J	SMV		Insecurity of the employee	b) improve efficiency. Cable should be ready for assembly. Operator repeats the same subprocess several times unnecessarily
135	Searching for screwdriver	0:22:18	0:00:01	B	SMV			
136	Handling screwdriver	0:22:19	0:00:02	T	SMV			
137	Fixing screw in PCB	0:22:21	0:00:37	M	PMV			a) improve efficiency: Unnecessary step! Eliminate duplicate work. Fixing screws should be done directly after the corresponding assemble process and not later
138	Positioning screwdriver in worktable	0:22:58	0:00:02	J	SMV			
139	Searching Information	0:23:00	0:00:12	B	SMV		Insecurity of the employee	Process unknown. Something is missing?
140	Positioning cable and spectropad in worktable	0:23:12	0:00:13	J	SMV		Insecurity of the employee	Process unknown. Something is missing?
141	Finish	0:23:25	0:00:00	W				

Target Analysis

Nr.	Process description	Process time	Category	PMV / SMV	Fixation	Sakkaden	Remarks and recommendations for action	Time savings	Target process time
1	Searching case	0:00:02	B	SMV			c) Improve quality and b) improve efficiency; Working Procedure is missing. Recommendation: Install Instructions projection (e.g.: Der Assistent) or interactive "step by step instructins".	0:00:00	0:00:02
2	Handling case	0:00:03	T	SMV				0:00:00	0:00:03
3	Positioning case on worktable	0:00:01	J	SMV				0:00:00	0:00:01
4	Searching display	0:00:02	B	SMV			a) Improve ergonomics (work conditions); Position shelf bin higher or in front of the operator	0:00:01	0:00:01
5	Handling display	0:00:03	T	SMV				0:00:00	0:00:03
6	Positioning display	0:00:01	J	SMV				0:00:00	0:00:01
7	Searching for connection cable (display - case)	0:00:02	B	SMV		Looking for cables	b) Improve efficiency and productivity; Arrange cables before assembly.	0:00:01	0:00:01
8	Handling conection cable	0:00:11	T	SMV				0:00:00	0:00:11
9	Preparing connection cable for assembly process	0:00:30	J	SMV	High work concentration		b) improve efficiency. Cable should be ready for assembly. Operator repeats the same subprocess several times unnecessarily	0:00:30	0:00:00
10	Connecting/Assembling cable with display board	0:00:28	M	PMV				0:00:00	0:00:28
11	Positioning display board on worktable	0:00:01	J	SMV				0:00:00	0:00:01
12	Searching for cable tie	0:00:02	B	SMV			a) Improve ergonomocs: position bins so that worker does not have to bend over to reach them.	0:00:01	0:00:01
13	Handling cable tie	0:00:10	T	SMV				0:00:00	0:00:10
14	Fastening cable to display board with cable tie	0:00:15	M	PMV				0:00:00	0:00:15
15	Searching for cable tie cutter in worktable	0:00:01	B	SMV				0:00:00	0:00:01
16	Handling cable tie cutter	0:00:01	T	SMV				0:00:00	0:00:01
17	Cutting overhanging cable tie	0:00:03	M	PMV			a) Improve ergonomics and b) Improve efficiency and productivity: disposal of cut cable tie in a bin for this purpose.	0:00:00	0:00:03
18	Positioning cable tie cutter in worktable	0:00:01	J	SMV				0:00:00	0:00:01
19	Searching display board	0:00:01	B	SMV				0:00:00	0:00:01
20	Handling display board	0:00:08	T	SMV				0:00:00	0:00:08
21	Assembling display board with case	0:00:51	M	PMV	High work concentration		Good work	0:00:00	0:00:51
22	Searching PCB in toolbox	0:00:02	B	SMV				0:00:00	0:00:02
23	Handling PCB (Leiterplatte)	0:00:05	T	SMV				0:00:00	0:00:05
24	Positioning PCB in worktable	0:00:01	J	SMV				0:00:00	0:00:01
25	Searching for "special screw with spring" in toolbox	0:00:01	B	SMV				0:00:00	0:00:01
26	Handling "special screw with spring"	0:00:03	T	SMV				0:00:00	0:00:03
27	Assembling "special screw with spring" (in cable base)	0:00:11	M	PMV				0:00:00	0:00:11
28	Searching for screw in the screw box 1	0:00:04	S	SMV		Looking for screws	b) Improve efficiency and productivity: Identify screw boxes with number or color	0:00:02	0:00:02
29	Handling screw	0:00:06	S	SMV			WO wrong screw	0:00:06	0:00:00
30	Assembling (cable base - PCB)	0:00:05	S	SMV			WO wrong screw	0:00:05	0:00:00
31	Identifying wrong operation: wrong screw	0:00:01	S	SMV			WO wrong screw	0:00:01	0:00:00
32	Positioning screw in worktable	0:00:01	S	SMV			WO wrong screw	0:00:01	0:00:00
33	Searching for screw in the screw box 2	0:00:01	B	SMV		Looking for screws		0:00:00	0:00:01
34	Handling screw	0:00:01	T	SMV				0:00:00	0:00:01
35	Searching screw driver	0:00:06	B	SMV				0:00:00	0:00:06
36	Assembling screw using screw driver (cable base - PCB)	0:00:09	S	SMV			WO: b) Improve efficiency: Projections of step by step instructions	0:00:09	0:00:00
37	Identifying wrong operation: Assembling should inlcude cable base, PCB and case)	0:00:01	S	SMV			WO	0:00:01	0:00:00
38	Disassembling screw.	0:00:18	S	SMV			WO	0:00:18	0:00:00
39	Assembling screw using screw driver (cable base - PCB - case)	0:00:32	M	PMV				0:00:00	0:00:32
40	Positioning screw driver in worktable	0:00:01	J	SMV	High work concentration			0:00:00	0:00:01
41	Handling SpectroPad	0:00:02	T	SMV	High work concentration			0:00:00	0:00:02
42	Turning SpectroPad upside down	0:00:02	T	SMV				0:00:00	0:00:02
43	Searching screw and screw driver	0:00:02	B	SMV				0:00:00	0:00:02
44	Handling screw with screw driver	0:00:02	T	SMV				0:00:00	0:00:02
45	Assembling screw	0:00:04	M	PMV				0:00:00	0:00:04
46	Searching screw and screw driver	0:00:01	B	SMV				0:00:00	0:00:01
47	Handling screw with screw driver	0:00:03	T	SMV				0:00:00	0:00:03
48	Assembling screw	0:00:03	M	PMV				0:00:00	0:00:03
49	Searching screw and screw driver	0:00:01	B	SMV				0:00:00	0:00:01

50	Handling screw with screw driver	0:00:03	T	SMV				0:00:00	0:00:03
51	Assembling screw	0:00:07	M	PMV				0:00:00	0:00:07
52	Adjusting/fitting assembled screws	0:00:10	M	PMV			a) increase efficiency: Eliminate duplicate work. Adjusting the screws should be done directly after the assemble process and not later	0:00:04	0:00:06
53	Turning SpectroPad to normal position	0:00:06	T	SMV				0:00:00	0:00:06
54	Accommodating cables and testing movement of parts	0:00:35	K	PMV			b) imporve efficiency: Eliminate duplicate work. Adjusting the cables inside the black case shoud be done later	0:00:35	0:00:00
55	Searching screw driver	0:00:01	B	SMV				0:00:00	0:00:01
56	Handling screw driver	0:00:01	T	SMV				0:00:00	0:00:01
57	Adjusting/fitting assembled	0:00:16	M	PMV				0:00:00	0:00:16
58	Adjust cables	0:00:14	M	PMV			b) increase efficiency: Eliminate duplicate work. Adjusting the cables inside the black case shoud be done later	0:00:14	0:00:00
59	Unscrew screws for better adjustment of cable	0:00:36	M	SMV			a) improve efficiency: Unnecessary step! Do not tighten the screws in the first place	0:00:36	0:00:00
60	Adjust cables	0:00:40	M	PMV			b) improve efficiency: Eliminate duplicate work. Adjusting the cables inside the black case shoud be done in this point and not before. Compare with process step 54 and 58 (-50s)	0:00:00	0:00:40
61	Searching for cable tie in toolbox	0:00:03	B	SMV			a) Improve ergonomics: position cable tie bin in front of operator	0:00:01	0:00:02
62	Handling cable tie	0:00:04	T	SMV				0:00:00	0:00:04
63	Assembling cable tie (cable to case)	0:00:45	M	PMV			Good work	0:00:00	0:00:45
64	Searching for cable tie cutter in worktable	0:00:01	B	SMV				0:00:00	0:00:01
65	Handling cable tie cutter	0:00:03	T	SMV				0:00:00	0:00:03
66	Cutting overhanging cable tie	0:00:09	M	SMV			a) Improve ergonomics (work conditions) and b) Improve efficiency and productivity: disposal of cut cable tie in a bin for this purpose.	0:00:00	0:00:09
67	Handling screw driver	0:00:07	T	SMV				0:00:00	0:00:07
68	Assembling/fitting screws	0:00:29	M	PMV				0:00:00	0:00:29
69	Searching for screws	0:00:01	B	SMV				0:00:00	0:00:01
70	Handling screws	0:00:02	T	SMV				0:00:00	0:00:02
71	Assembling screws	0:00:08	M	PMV				0:00:00	0:00:08
72	Searching for screws	0:00:01	B	SMV				0:00:00	0:00:01
73	Handling screws	0:00:02	T	SMV				0:00:00	0:00:02
74	Assembling screws	0:00:15	M	PMV				0:00:00	0:00:15
75	Searching for metal deck	0:00:02	B	SMV				0:00:00	0:00:02
76	Handling the metal deck	0:00:07	T	SMV				0:00:00	0:00:07
77	Assembling the metal deck	0:01:01	M	PMV	Process is unknown	Insecurity of the employee	b) improve efficiency. Install tool for projection of instructions (e.g.: Der Assistent) or interactive "step by step instructins".	0:01:01	0:00:00
78	Dismantling metal deck	0:00:08	S	SMV			"	0:00:08	0:00:00
79	Handling the metal deck	0:00:02	T	SMV			"	0:00:02	0:00:00
80	Searching for information about assembly process of the metal deck	0:00:30	B	SMV			"	0:00:25	0:00:05
81	Assembling metal deck	0:00:35	M	PMV			b) improve efficiency. Install tool for projection of instructions (e.g.: Der Assistent) or interactive "step by step instructins".	0:00:35	0:00:00
82	Searching for information about assembly process of the metal deck	0:00:08	B	SMV			"	0:00:08	0:00:00
83	Assembling metal deck	0:01:42	M	PMV			b) improve efficiency. Install tool for projection of instructions (e.g.: Der Assistent) or interactive "step by step instructins".	0:00:00	0:01:42
84	Testing the correct motion of the parts.	0:00:05	K	SMV				0:00:00	0:00:05
85	Searching for adhesive	0:00:01	B	SMV				0:00:00	0:00:01
86	Handling the adhesive	0:00:04	T	SMV				0:00:00	0:00:04
87	Rubberizing the metal deck	0:00:10	M	PMV				0:00:00	0:00:10
88	Searching for metal cover	0:00:03	B	SMV				0:00:00	0:00:03
89	Handling metal cover	0:00:03	T	SMV				0:00:00	0:00:03
90	Assembling metal cover	0:00:03	M	PMV				0:00:00	0:00:03
91	Searching for screw	0:00:05	B	SMV				0:00:00	0:00:05
92	Handling screw	0:00:04	T	SMV				0:00:00	0:00:04
93	Screwing	0:00:01	M	PMV				0:00:00	0:00:01
94	Searching for screw	0:00:02	B	SMV				0:00:00	0:00:02
95	Handling screw	0:00:06	T	SMV				0:00:00	0:00:06
96	Screwing	0:00:08	M	PMV				0:00:00	0:00:08
97	Unscrewing assembled screw in PCB	0:00:10	M	SMV				0:00:00	0:00:10
98	Positioning screw driver in worktabl	0:00:09	J	SMV				0:00:00	0:00:09
99	Accommodating cable	0:00:05	J	SMV				0:00:00	0:00:05
100	Screwing	0:00:19	M	PMV				0:00:00	0:00:19

100	Screwing	0:00:19	M	PMV				0:00:00	0:00:19
101	Searching for "white plastic clip"	0:00:06	B	SMV				0:00:00	0:00:06
102	Handling "white plastic clip"	0:00:05	T	SMV				0:00:00	0:00:05
103	Fixing "white plastic clip" to cable	0:00:12	M	PMV				0:00:00	0:00:12
104	Connecting/Assembling cable with PCB board	0:00:09	M	PMV				0:00:00	0:00:09
105	Searching for wire	0:00:05	B	SMV		Looking for wire	b) Improve efficiency: wire should be in respective bin and not on the worktable	0:00:04	0:00:01
106	Handling the wire	0:00:06	T	SMV				0:00:00	0:00:06
107	Fixing cable to PCB board using the wire (cable - PCB board)	0:00:31	M	PMV				0:00:00	0:00:31
108	Connecting case to display board	0:00:19	M	PMV				0:00:00	0:00:19
109	Searching for screw and	0:00:06	B	SMV				0:00:00	0:00:06
110	Handling screw and screwdriver	0:00:05	T	SMV				0:00:00	0:00:05
111	Screwing	0:00:11	M	PMV				0:00:00	0:00:11
112	Searching for screw and	0:00:05	B	SMV				0:00:00	0:00:05
113	Handling screw and screwdriver	0:00:05	T	SMV				0:00:00	0:00:05
114	Screwing	0:00:28	M	PMV				0:00:00	0:00:28
115	Searching for screw and	0:00:03	B	SMV				0:00:00	0:00:03
116	Handling screw and screwdriver	0:00:02	T	SMV				0:00:00	0:00:02
117	Screwing	0:00:09	M	PMV				0:00:00	0:00:09
118	Searching for screw and	0:00:01	B	SMV				0:00:00	0:00:01
119	Handling screw and screwdriver	0:00:02	T	SMV				0:00:00	0:00:02
120	Screwing	0:00:11	M	PMV				0:00:00	0:00:11
121	Searching for screw and	0:00:02	B	SMV				0:00:00	0:00:02
122	Handling screw and screwdriver	0:00:03	T	SMV				0:00:00	0:00:03
123	Screwing	0:00:23	M	PMV				0:00:00	0:00:23
124	Testing the correct motion of the parts	0:00:06	K	SMV				0:00:00	0:00:06
125	Positioning of spectropad	0:00:01	J	SMV				0:00:00	0:00:01
126	Waiting	0:00:24	W	SMV	Process is unknown		b) Improve efficiency. Operator does not know what the next working step is. Instructions needed!	0:00:24	0:00:00
127	Searching for tweezers	0:00:19	S	SMV		Looking for tweezers	b) Imporve efficiency. Tweezers were not in the toolbox. Organice the workplace before starting. Tools required must be available on site! Separate bin or storage place for tools	0:00:17	0:00:02
128	Handling the tweezers	0:00:08	S	SMV		Looking for tweezers	d) Improve safety: Obstructions in the corridor	0:00:08	0:00:00
129	Positioning tweezers in worktable	0:00:02	S	SMV		Looking for tweezers		0:00:00	0:00:02
130	Searching for cable	0:00:06	B	SMV				0:00:00	0:00:06
131	Handling cable	0:00:10	T	SMV				0:00:00	0:00:10
132	Searching and handling cable tie cutter	0:00:02	B	SMV			c) improve quality and b) Improve efficiency and productivity (acceleration of the work process) cable tie had to be removed before.	0:00:02	0:00:00
133	Cutting/removing cable tie from cable	0:00:05	M	SMV			c) improve quality and b) Improve efficiency and productivity (acceleration of the work process) cable tie had to be removed before.	0:00:05	0:00:00
134	Preparing cable for assembly process	0:01:23	J	SMV		Insecurity of the employee	b) improve efficiency. Cable should be ready for assembly. Operator repeats the same subprocess several times unnecessarily	0:01:23	0:00:00
135	Searching for screwdriver	0:00:01	B	SMV				0:00:00	0:00:01
136	Handling screwdriver	0:00:02	T	SMV				0:00:00	0:00:02
137	Fixing screw in PCB	0:00:37	M	PMV			a) improve efficiency: Unnecessary step! Eliminate duplicate work. Fixing screws should be done directly after the corresponding assemble process and not later	0:00:10	0:00:27
138	Positioning screwdriver in	0:00:02	J	SMV				0:00:00	0:00:02
139	Searching Information	0:00:12	B	SMV		Insecurity of the employee	Process unknown. Something is missing? --> Projection of instructions	0:00:10	0:00:02
140	Positioning cable and spectropad in worktable	0:00:13	J	SMV		Insecurity of the employee	Process unknown. Something is missing? --> Projection of instructions	0:00:10	0:00:03
141	Finish	0:00:00	W					0:00:00	0:00:00
142								0:00:00	0:00:00
143								0:00:00	0:00:00
144								0:00:00	0:00:00
								0:07:58	**0:15:22**

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