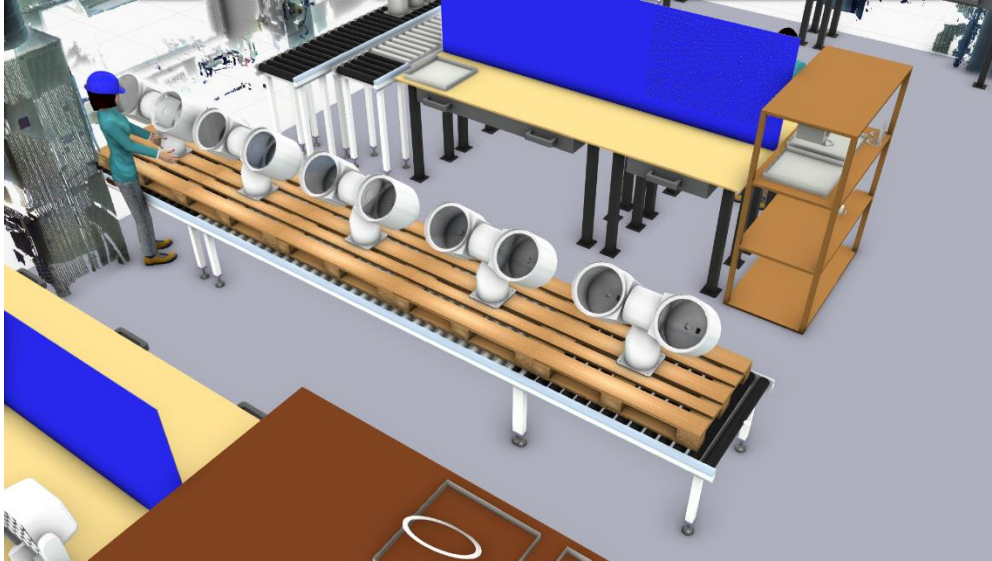




CHALMERS
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Optimizing Factory Layout for Mobile Luminer Manufacturer

Bachelor of Science thesis in the Bachelor Degree Programme, Mechanical Engineering.

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PREFACE

This thesis is written for Chalmers University of Technology under the institution for industry and material science during the spring of 2019. The project was carried out by Kristoffer Wallin and Rasmus Anker in collaboration with Luminell Sweden AB.

First and foremost, we would like to thank our supervisor Clarissa González who with a genuine joy and interest in the project, has always contributed with support and constantly pushed us in the right direction. Thank you for keeping us on the right track, without you we would never have been able to concretise our thoughts and ideas in the same way!

We would also like to thank our examiner Björn Johansson for the constructive feedback and all administrative assistance that made our work much easier. Also a big thanks to Jonatan Berglund who have helped us tremendously within areas where our competences needed to be complemented.

Finally, we would like to thank Luminell's employees for having welcomed us with such open arms to their fantastic workplace. Special thanks to Luigi Guglielmo and Mirza Sehic who during the projects development always made time for us and contently answered countless of questions, no matter how trivial they may have been.

Thanks!



ABSTRACT

Luminell began as an idea and a dedication to improve an old outdated sector, which further on resulted in a startup. Today Luminell is a small-sized company with 12 employees that manufactures and sells various luminary solutions, primarily in the marine sector. Luminell's department in Halmstad specializes in mobile luminaires such as searchlights for a variety of vessels, e.g. transporting ships, rescue vessels and yachts.

Now, Luminell calls for an optimized work plan that reduces waste and non-value-adding activities in the everyday assembly work. Through a new work strategy, it is also possible to achieve a better control at material and components, which today lacks systematization. This problem creates a vicious cycle, where missing materials generate confusion in the production plan, and lead to overproduction. As a result of improving mentioned problem areas, increased production efficiency is expected.

This report presents the workflow and the different methodologies that have led to a new production system with associated production layout.

An extensive mapping of the current production system and work routines was crucial for being able to approach the problems in a reliable way. This has partly been done by us practically working with the company's products, data gathering, but also through many conversations with the company's employees. All this was put together in an IDEF-0, which constituted a base during the project.



By producing three different concepts of production systems, a discussion ground was created to work further with. With these concepts as a basis, we collectively with the company came to an idea for a future scenario which was further worked on.

With the help of 3D scanning, a virtual environment could be made, where a simulation model furthering was created. In this simulation model the production system was built, with focus on developing a layout that was practically applicable in the facility premises.

This simulation model was then presented to the company and constituted a good decision-making basis for conversion. Today, several measures have already been made in order to shift into the new production system.



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Glossary

Term	Definition
WIP (Work In Progress)	The number of products which exists in the production system simultaneously.
Cycle time	The time it takes to carry out a specific work task.
TAKT time	The longest cycle time creates the time of the whole process.
HMI	Hydrargyrum medium-arc iodide lamp.
Muda	Wastefulness, non value-adding and unnecessary for end costumer

1.0 INTRODUCTION

1.1 Background

Luminell is a small company that manufactures and sells various luminary solutions, primarily in the marine sector, where quality and reliability are high priority due to exposure to environments with harsh conditions, e.g. wind, saltwater and extreme weather. Luminell's department in Halmstad specializes in mobile luminaires such as searchlights for a variety of vessels, e.g. transporting ships, rescue vessels and yachts.

What makes Luminell a world-unique company in their sector is that the searchlights can rotate endlessly without movement limitations. This feature applies to both the vertical and horizontal lamp's axis. See figure 1.



Figure 1. Finished searchlight, model CL25 HMI with dual LED customization

In 2018, Luminell produced 273 searchlights which are sold globally. Production volumes are expected to increase significantly in 2019 and in the coming years, as a consequence of their efforts to target a broader market segment through the development of a more simple and general product which can be used by several vessel models.

1.2 Aim

The aim of the thesis is to provide Luminell with a sustainable solution for increased structure in production, without compromising the product's quality. As the company's growth curve shows a trend to exponentially increase, systems should be flexible and develop adaptation capabilities for future expansions and product diversification. This thesis suggests that the implementation of Lean Production principles could support the simplification of sub-processes, which currently lead to a high number of time-consuming operations for piece assembly.

Luminell's facilities consist of a large space that combines a workshop and a warehouse divided by a wall. The mentioned facilities show potential for space optimization and a more organized flow of component layers. Our thesis project focuses on making every working hour as effective and efficient as possible by optimizing the layout of working stations in the facility and applying optimization methods for the product flow from order to final delivery.

1.3 Limitations

The broad catalog of products offered by Luminell has resulted in a large amount of components and high variation in the assembly process.

This, in combination with the relatively low production volumes (on average about 1 produced searchlights per working day) complicates the possibilities for automating sub-processes, which is a challenging task in an assembly environment in general. Luminell is also a small company with a low investments budget for production layout reorganization. Also, the workforce includes 12 employees, where only 6 of them execute operational tasks in the workshop. For these reasons, automated processes have not proved yet to be economically justifiable.

Luminell presents a relatively low production volume, this is why our main focus is not to cut down cycle time, but rather to improve in-site logistics and working methods that result in more efficient processes. The premises of the facilities have large unused areas and are currently not used to their full potential. This represents a great opportunity to optimize the placement of working cells.

1.4 Clarification of the issue

During the active years of Luminell, the company has steadily grown from being a small startup business from an idea to conducting the multiproduct company that exists today. During this development, the main focus has been on improving the product and developing new models, rather than innovating in their working methodologies and assembly processes.

Therefore, the company is lacking an efficient and standardized working method in their production environment. As a result, overproduction occurs to a very high extent, where sub-assemblies are built and then stored for a long time. This generates lead times that are significantly higher than necessary and limits the cash flow by having high cost parts tied up.

In order to increase production efficiency, Luminell calls for an optimized work plan that reduces waste and non-value-adding activities in the everyday assembly work. Through a new work strategy, it is also possible to achieve a better control at material and components, which today lacks systematization. This problem creates a vicious cycle, where missing materials generate confusion in the production plan which leads to inefficiencies in material handling generating high *work in process* (WIP).

2.0 THEORETICAL REFERENCE

2.1 Objects of study

This chapter concludes objects of basis used to conduct further progress in the project.

2.1.1 Searchlight

Searchlights are defined as a source of light concentrated into a beam by using reflectors and often have the capability to project light onto a far distance surface. The beam has the ability to be directed towards a single target by being mounted on joints or revolving axis to make it movable in reference to the surface it is mounted on. Searchlights are manufactured to be highly durable and resist exposure to harsh environments. High quality requirements have been established because users should be able to trust their functional reliability, as they are essential elements during navigation and particularly during rescue missions.

2.2 Methodology

Following section defines methods used during the project.

2.2.1 IDEF0

The IDEF0 methodology suggests a model used to map production routines, tools, working tasks and the relation between them. This method provides a simple visualization of a system which could be a complete organization, a production system, or similar.

IDEF (Integration Definition) first arrived in the late 1970s, at that time as a branch from the development of ICAM (Integrated Computer Aided Manufacturing) to then became a standard. The United States Air Force was the actors behind the development of IDEF, during a time when the USAF was striving to make the production more efficient using computer-aided tools and modeling (Vestnik, S., 2009). IDEF0 is an ISO standardized method since 1993, released by the Computer Systems Laboratory of the National Institute of Standards and Technology (Knowledge Based Systems, Inc., 2019).

IDEF0 is a hierarchically constructed model. In the first level, the production system is shown as whole, and for each descending level of the model, the gradual exposure of details increases. Each level of the model is framed by a so-called "diagram box", which has the purpose of describing where in the hierarchical order each level is located.

An IDEF0 consists of several different boxes, so-called "function boxes". These are the framework of the model and describe a function or moment in the mapped production system, for example "lacquer polishing" or "Sub assembly 3". To each side of these function boxes, arrows (information carrier) are then connected, *see figure 2*. These arrows have different characteristics, depending on whether they are above, below or sideways of the function box. The arrows on top of the function box symbolize so-called "controls", the arrows under "mechanisms", while the arrows at the sides show "inputs" and "outputs"

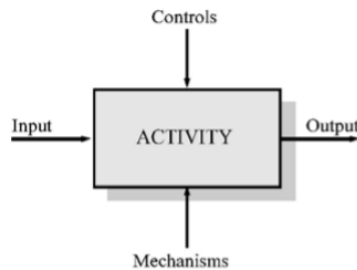


Figure 2, function box and information carriers.

Controls

Various means for regulating how and when the function should be handled. Standards, safety regulations and routines are common examples of different controls and these need to be followed when the function is executed. Each individual control should be symbolized with its own arrow.

Mechanisms

Mechanisms can be seen as necessary physical aids that are required to be able to perform the task that the function treats. Examples of mechanisms are tools, machines, but also personnel.

Inputs

Within the category of inputs material and components are found, but also governing information, such as an order. In two subsequent function boxes, the output signal from the previous function box also becomes the input signal to the latter.

Outputs

An output arrow represents the result of repetitive function box. An examples of this could be "drilled bottom piece". Different types of data and information obtained by the process are also a type of output.

In summary, input makes outputs using mechanisms, with respect to the controls. (Vestnik, S, 2009).

2.2.2 Lean

Lean production is a production philosophy developed by Toyota in times when the company had to achieve more, with less resources. The core idea of lean production is basically to reduce “waste” (non-value adding activities) such as transportation, overproduction and waiting. In order to achieve this, different tools can be used and implemented (Vorne Industries Inc., 2019). The principles of the tools that has been used during this thesis follows underneath.

2.2.3 Kanban

Kanban is mainly used to reduce overproduction, and large inventories. This method is widely implemented as a supplementary tool within lean production. Kanban is developed to create a pull system where the need for parts or subassemblies is based on the following work station. A system like this makes it easy to distinguish bottlenecks and creates an overall structured overview of the complete chain of production (Adnan, A. N. B., 2013).

2.3.4 5S

5S is a tool design for creating a structured order at workplaces, with a great focus on preserving the established structure. The method is divided into five steps (Black, Straight, Sweep, Standardize, Sustain), which the name stands for. These steps must be followed in the standardized order, in order to avoid falling into old patterns during the transition, but also afterwards (Bagi, J. S., 2013).

2.3.5 Line Balancing

In industrial environments, problems with unbalanced work stations arise constantly. In some cases, an unbalanced production system can severely penalize the production efficiency, which means that the potential efficiency is reduced, and waste types like overproduction occur.

By line balancing it is meant that the time it takes for different parts of a production chain to be implemented, is to be controlled against a so-called tact time. This is to be able to divide the personnel resources in an equal way, and to minimize the time when, for example, machines stand still. (Scholl, A., Becker, C., 2006)

First thing in line balancing is to identify each individual work and process. During this step, it is of the utmost importance that all time-consuming parts are included, otherwise the model is built on incorrect data and thus results in a defective result.

When the identification of the time-consuming elements is done, the next data collection must take place, namely the cycle times for each torque. When all the information is collected, the work parts are divided into a hierarchical order, where it must clearly state which elements (processes and tasks) must necessarily be made before the relevant process.

Then a so-called "Precedence Chart" is made. In this diagram, the above-mentioned order for the various processes is visualized, together with the cycle times for each process. The precedence chart creates a good picture of how the production system is structured. From this diagram, the tasks are then divided up to create such a logical and time-balanced distribution of the tasks as possible.

2.3.6 Layout planning

Layout planning is an important part of all conceivable activities and situations, regardless of whether it is a manufacturing factory, an office, or even a student apartment. The concept of a good factory layout is based upon time saved by decreasing transporting distance of both human work processes and the distance goods has to be moved in order to create a natural order the product flows through the process without unnecessary detours. Simply put the physical arrangements of

procedures, working cells and staff from components to final product that consume space in the facility (Lin, Q., Liu, H., Wang, D., Liu, L., 2013).

An important part when it comes to planning a layout is finding synergies between different areas. One example is that two subsequent machines should be located close to each other, or that a pantry should reasonably be located in the kitchen, where cooking is done.

In the case of poor layout planning, many classic *muda* arise, such as movement, transport, warehousing, waiting and in many cases overproduction.

2.4 Tools and software

This Chapter defines hardware and software used throughout the thesis.

2.4.1 3D Scanning (FARO Focus 3D)

During this project the FARO Focus 3D scanner has been used. The 3D scanner works in such a way that the instrument rotates 180° around its vertical axis while it sends out laser beams in both directions and thus covers 360° around the surroundings of the scanner. During the scan, a mirror reflecting the laser beams also rotates, resulting in the instrument covering the entire room, see Figure 3.

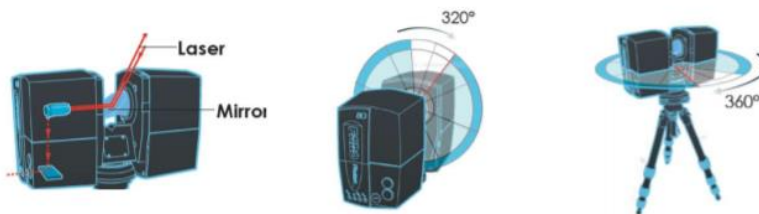


Figure 3. Scanning instrument

These laser beams then hit objects and surfaces that reflect the laser, which is then returned to the scanner. The time it takes for the laser pulses to reach the object and get reflected back to the instrument is analyzed and determines how far from the scanner the object is located. One additional feature that the laser also possesses is to measure color codes for the surfaces.

When a scan is completed, an extensive point cloud is formed with XYZ coordinates and the color codes for each specific point where the laser has got to. This measurement data is then imported into, for example, the Autodesk ReCap software, where the model can then be handled.

When an environment is to be scanned, several scans are often required, which are then linked together by common reference points. How many required depends on several different factors, such as the size of the room or area, how many objects that generate "scan shadows", meaning the areas covered by objects, but also how high the quality is requested by the scanned 3D room. (Faro, 2019).

2.4.2 Autodesk Recap

Autodesk ReCap (Reality Capture) is a software developed by Autodesk, designed to be able to process and manage point cloud data from 3D scans.

After importing a point cloud, there are several simple tools to manage the virtual environment. The parts which are not wanted in the scan can be removed using these tools. Other parts of the point cloud, such as ceilings and walls, can also be placed in different sections, which during work can then be displayed or hidden at will (Coppinger, J., 2019).

2.4.3 Catia V5

A software developed by Dassault Systems in order to visualize and analyze 3D-models with following features: computer aided designs (CAD), computer aided manufacturing (CAM), computer aided engineering (CAE), PLM and 3D (DS Academy, 2019).

2.4.4 Visual Components 4.0

Software used for modeling, simulating, analyzing and visualizing a process by giving outputs in the form of material flows and different parameters of effectivity from different. The application is developed by Visual Components Oy with the purpose of evaluating and testing both general and detailed logistics in different systems. (Visual Components OY. (2019))

Simulation software is a powerful tool to use in order to test and visualize different processes but to keep in mind is the time and work that goes into even the simplest of tasks. The value of the amount of work put into contrast to the value of extracted simulation and its attention to detail. This could be described by Steward Robinson with following graph that illustrates the correlation between accuracy and amount of model complexity put into the simulation (Steward, Robinson, 1994).

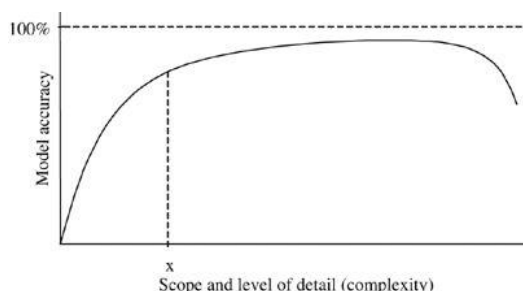


Figure 4, Simulation Model Complexity and Accuracy

"Increasing levels of complexity (scope and level of detail) improve the accuracy of the model, but with diminishing returns. Beyond point x there is little to be gained by adding to the complexity of the model. A 100% accurate model will never be achieved because it is impossible to know everything about the real system." (Robinson, 1994, p. 29).

Robinsons observations should be kept in mind not only as a reference to the simulation but also applied throughout the project in order to provide a final production system that contains all these elements and data.

3.0 METHOD

The methods used in this project are listed below in hierarchical order.

- Practical experience and observations
- Interviews
- IDEF0
- Concept generation
- Optimizing and balancing of Work cells
- Simulation

3.1 Execution of production process

The first week at Luminell was mainly aimed to understand the product catalogue in depth. In order to achieve this, By following different fitters (assembly operators) for two full days and documenting the work process that is needed for the production of searchlight, in standard model. During these days two complete sets of assemblies by different models was executed to develop a deeper understanding of the product, which helped understanding the complexity of the process. Many tasks make high demands on accuracy, but above all, on knowledge of the products where experience is of the utmost importance.

3.2 Continuous interviews

During the practical experience week, a myriad of questions was asked to the fitters and for each new submission a new question mark appeared. All these considerations were received with great enthusiasm by product technician Luigi and production manager Mirza, who have constantly been at their full disposal during the project.

Despite training week, there were still some gaps in the understanding of the assembly process and some specific tasks. Therefore, there were several ongoing interviews with the fitters, which granted clarity to fully understand the process.

3.3 IDEF-0

The methodology of IDEF-0 is used to map the whole process with all its sub-assemblies, routines and tools from start to finish product. The IDEF-0 for the general process is reoccurring trough out the project as a collaborative tool towards other methods and used as pillar to rely on while testing progress.

3.4 Concept generation of production system

In order to achieve a more effective process all the workspaces had to be designed with consideration to fit into a production line and provide a clearer division between sub-assemblies. In a well-balanced line neither of the operators should be left without a task while waiting for components from previous station. Organization for tools and machine elements should be considered when optimizing a steady flow and all tools should be easily accessible at the cell. The elements needed when balancing is the amount of time used for each task divided into sub-assemblies and the number of workstations/fitters that is operating at the same time. During this work, the IDEF-0 was used to a great extent and provided a good basis for line balancing.

First of all, a precedence chart was made of the production system, see figure 6, according to the links in IDEF-0. Now the respective cycle times for the work tasks were lacking. Initially, these were documented by gathering information from the fitters, but it turned out quickly to be an unreliable procedure. Since many mounting moments are complex to execute, high demands are placed on both precision and experience to perform the task in a quick and quality-assuring way. In order to get reliable data with an average process time we mainly went to clock fitters who worked with the moments in the daily operations and received cycle times at moments that arise with low frequency.

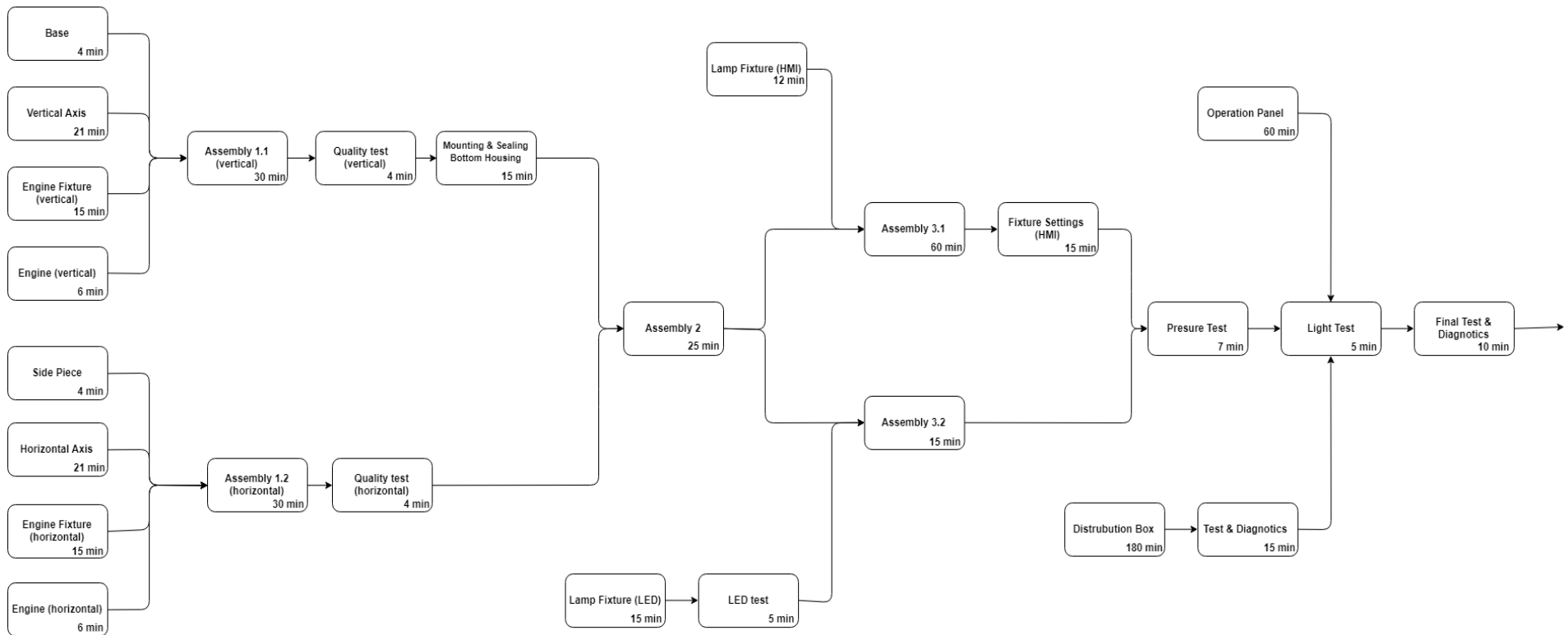


Figure 6, Precedence chart

When the data collection of cycle times was collected, the precedence chart was implemented. By calculating each summation to approximately match the others, three different concepts with various pros and cons were made.

This step was made extra challenging because many time-consuming tasks do not appear in daily work, and that product flexibility contributed with many varying cycle times. With this identified and analyzed at an early stage in the project requirements where to be set to reach solutions that meet these challenges.

To tackle this situation, a concept was made in which one of the staffs was completely freed from any specific work station and area of responsibility, and another where an employee was solely responsible for the final tests, which in relation to other stations takes much less time. The purpose of this new freed position is to relieve staff who currently has a large workload, but also have responsibility for materials and supporting functions that are required to maintain production.

One of the major challenges was the large time variation at the HMI (Hydrargyrum medium-arc iodide)/ LED lights. As the products are customized, a lamp can thus consist of two HMI lamps, two LED lamps, or one of both. The demand for HMI and LED lamps can be assumed to be 50% each. When a lamp of HMI is so much time-consuming to mount (87 min / lamp versus LEDs 35 min / lamp) a work cell was desired where both types of lamps were made. In this situation, a large time variation is collected on only one station, and that the variation becomes less apparent. This is when the staff in any case will have some type of lamp to work with, instead of the binary situation that could arise when separating the two different models.

Another aspect that was kept in mind during the concept generation was that different variations first appeared after assembly 2. Until then, only two different models exist on components, depending on the size of the product. Therefore, there was an aspiration to give the following moments a little more space, as its cycle times are more variable from lamp to lamp.

The quality tests after Assembly 1 and the tests for distribution box were set as a requirement to belong to the work steps that take place before these tests. This with the motivation that when errors are discovered in the tests, the staff already has knowledge of the product concerned and can therefore rectify the error with greater ease.

With all these aspects in mind, three completely different concepts were designed. By approaching this task with an openminded perspective conceivable solutions were formed, despite how perplexed they seemed at first glance, and the concepts managed to differ greatly among themselves. The aim was not to directly establish a concept to work on with, but to contribute a good basis for discussion to Luminell.

Concept 1

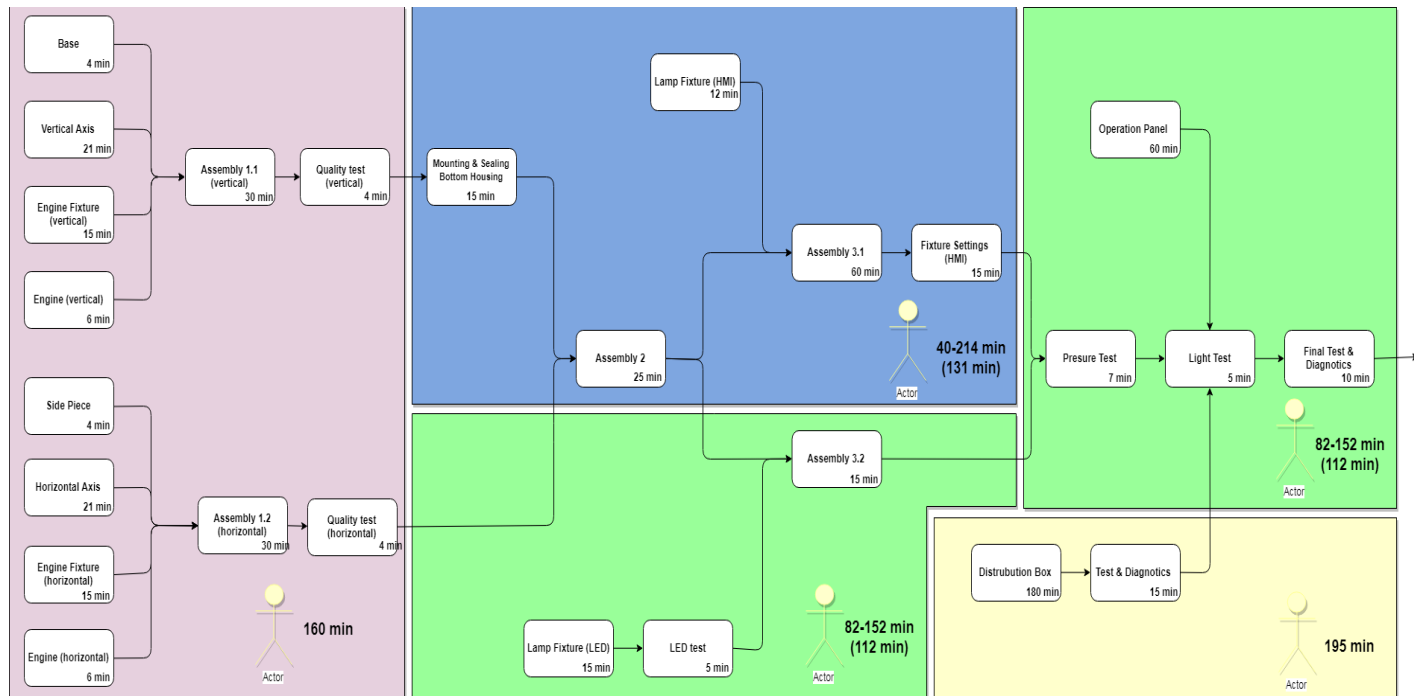


Figure 7, Concept 1

Pros

- ◆ Natural role for the production manager, overview of unassigned tasks and inventory
- ◆ Flexible system
- ◆ Even cycle times
- ◆ Only one solder station needed

Cons

- ◆ Low amount of workload at station C
- ◆ High variation in cycle time at B
- ◆ Too high degree of flexible system
- ◆ Could create unstructured work and instability
- ◆ Difficult to determine factual takt time

Table 1, Pros and cons for concept 1

Concept 2

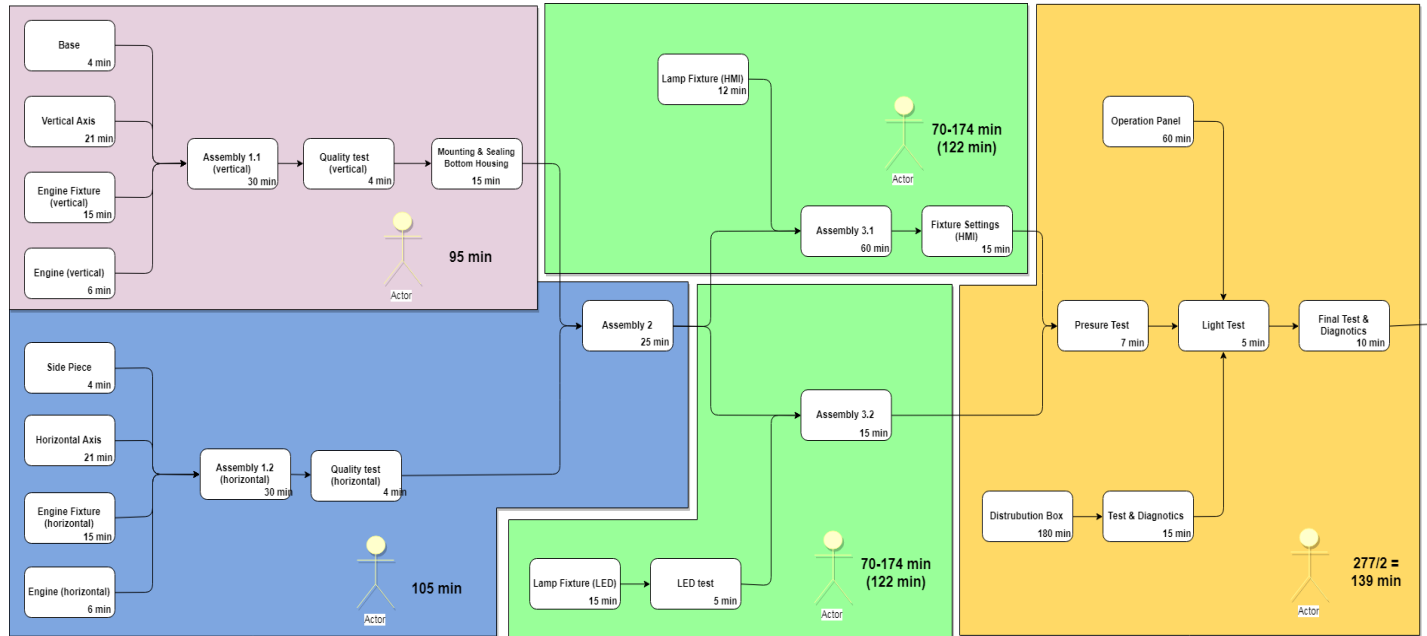


Figure 8, Concept 2

Pros

- ♦ An designated area to light fixtures, lower variation
- ♦ Less workload at station A & B
- ♦ Low theoretical takt time
- ♦ High degree of structure
- ♦ Well-balanced

Cons

- ♦ Low degree of flexibility
- ♦ No natural role for production manager Mirza
- ♦ Two soldering stations

Table 2, Pros and cons for concept 2

Concept 3

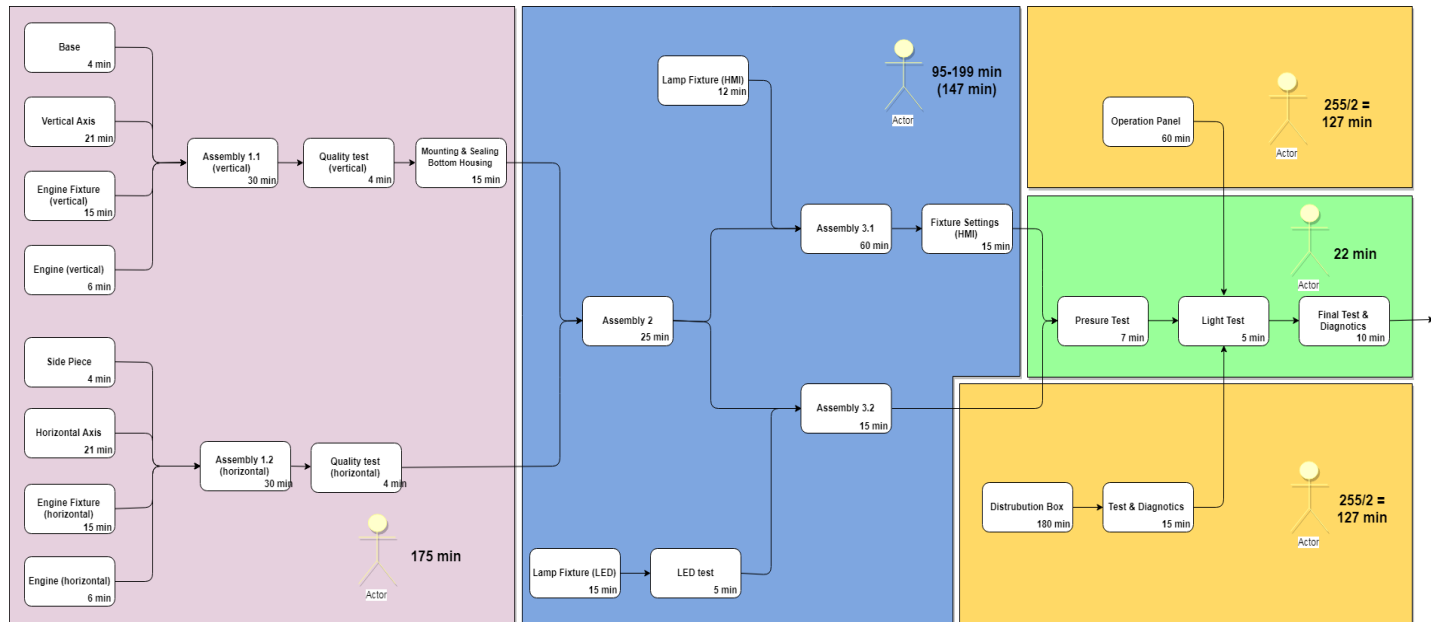


Figure 9, Concept 3

Pros

- ◆ Natural role for the production manager, overview of unassigned tasks and inventory
- ◆ An area dedicated to light fixtures, lower variation
- ◆ Low theoretical takt time
- ◆ Clear division between the tasks provides a more organized layout
- ◆ Only one solder station needed
- ◆ Very high degree of flexibility in the system

Cons

- ◆ A lot of tasks for worker at A & B
- ◆ The distribution box area will not be improved

Table 3, Pros and cons for concept 3

3.5 Optimization of work cells

When it came to the optimization of now divided workstations, IDEF-0 was selected again. Thanks to the work of early mapping of all tools and machine elements, well-adapted stations could be designed for each work step.

In order to solve the problem with disorganized tools, where these sometimes are missing when needed, tool boards were introduced at each workstation. These boards are adapted for the tools used at the relevant work moments, and its location on the board also marked.

Underneath the worktables, drawers were also placed where small machine elements, such as screws, nuts and small components, should be easily accessible. For the larger components, different shelves were made which are placed along the workstation.

3.6 Facility scans

During the scan at Luminell, a 3D laser scanner has been used. When the scanning was executed, nine separate scans were required to achieve a satisfactory result, due to the many objects that caused scanning blind spots at the facility. The Autodesk ReCap software was then used to compile all separate scans before the work of digitally emptying the facility progressed. A negative aspect of not having an empty facility when the scanning is made, is that the floor was covered with blind spots when the objects placed on the floor later were digitally removed. To reconstruct the premises in a visually more satisfactory order, a separate floor was then made in Catia V5 which was joined into the scan in Visual Components

3.7 3D-simulation

With the converted and processed scan data of the facility imported into the simulation software Visual Components, the simulation process was initiated.

CAD models of the product and its components was the first things needed, *see appendix 4 (CAD-models)*. This is to see clearly during the simulation how the lamp is refined through the different workstations and tasks. The CAD models was done in Catia V5, where first of all the product's sub-assemblies was done as part files. Then, a separate assembly was required for each component or subassembly mounted at the base component. In addition to the product and its sub-assemblies, Catia models were also required on various other equipment's, such as work tables, cabinets and a staircase. A new floor was also made, as it had previously been defaced with blind areas when the room's contents were emptied. These models were only required as part files.

When all CAD models were completed, the work in Visual Components could finally begin. First, the facility was stationed after it was emptied and processed in Autodesk Recap. The other stationary things such as the floor and the staircase were imported and then placed in the simulation model, then the construction of the production system could be initiated.

With concept 3 conformed, as the most suited cell division for a structured system, the visual in the simulation could start with a targeted flow out of the facility towards loading dock. According to concept 3, *see appendix 3 (concepts)*, a division into four areas of responsibility with 6-8 work cells is given depending on the physical possibilities and limitations of the facility. By implementing the CAD files such as work benches, rackets and machines into visual components and the facility that was obtained, a 3D-scanning. Now design and dimensioning could easily take place. Subsequently, the deployment of dedicated cells for the various tasks.

4.0 RESULTS

4.1 IDEF-0

See appendix 2 (IDEF-0). Luminell has today ownership the completed IDEF-0 and can now use it for continued work when a detailed mapping of the product structure is required.

4.2 Balancing of Work cells

Concept 3, final concept

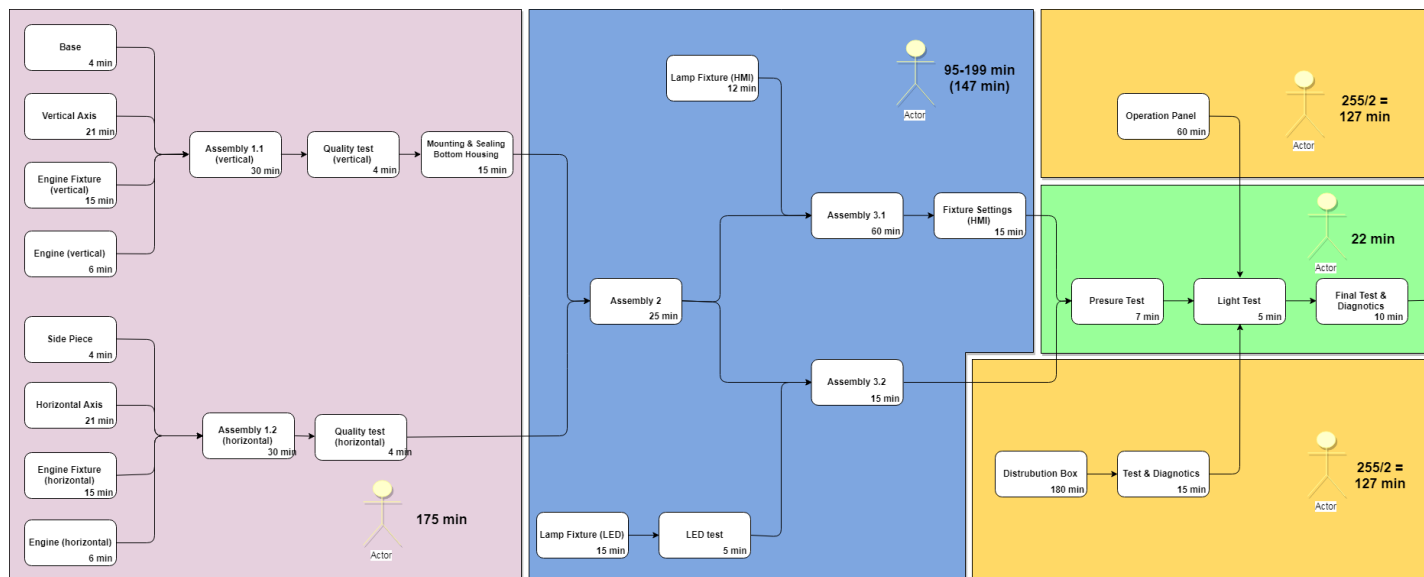


Figure 10, Concept 3

The concepts were presented to Mattias Svensson (CEO) and Mirza Sehic (Production manager). After long and productive discussions and valuing pros and cons, it was agreed that the new production system should have its foundation in concept 3.

The aspects that Luminell appreciated the most are finding a satisfying balance between a good structure and a balanced flow in the system, but still being able to work in a flexible way. This, together with an endeavor to achieve an efficient production system as possible permeated the conversation.

4.3 Optimization of work cells

Well-adapted workstations were created where all necessary equipment is in place. This was achieved through using tool boards, storage shelves for large components and drawers beneath work benches. As a result, several classic time-consuming tasks can be eliminated or minimized, especially movement and transport distances.

A 5S-thought has been implemented where all storage locations must be marked, and routines should be introduced for whether the storage of components and machine elements at the work stations should be carried out.

4.4 Layout planning

To create a good layout for production system 3, the material flow and material handling were first examined. The room holds two large ports in each part of the facility where materials can be shipped in and finished products out, but it is only the southern gate in the outermost part of the facility that can be used due to practical complications.

As it is much easier to handle components rather than finished products of much higher weight, the best solution was to create a production flow from within the factory out to the gate.

What mainly characterizes concept 3 is the two large assembly stations, A and B. Since the search light is assembled completely from scratch to finished product in only these two stations, a large area is required. Assembly station B is also completely subsequent and dependent on A, which means that the stations should be located as close as possible. For this reason, together with a wish to create a targeted flow out of the facility towards to the loading dock, mounting station A was placed at the inside corner of the premises and station B was thus placed next to station A. *See appendix 1 (current state of facility) and 5 (future state of facility).*

At present, there is no stationary place for the final light test of the search lights. This is something that Luminell has requested, and which was then placed next to the old service station. This request was made because the final tests require a wall at approximately 15 meters distance to be able to project the light image. This test station should include 3-5 fixed test rigs so that multiple search lights can carry out the time-consuming tests simultaneously. The cabling required for the station should suitably be on rails from the nearby wall to eliminate triple risk and facilitate truck traffic.

For the new test rigs, scissor lifts should be used where a lamp standing on a pallet can easily be placed. This decision to eliminate the poor working height when the lamp is directly placed on the floor and that the lamp never needs to be transported by hand, but instead with a pallet lift. Through the mentioned changes, it is expected to see significant improvements regarding their ergonomic conditions.

In the new factory layout, the service station has been extended and placed completely along the wall behind the racking, to leave area for the new test station.

The distribution boxes, which are located where assembly station A will be placed, will instead be moved to the area for cable cutting and preparation. This change allows that the distribution boxes are located closer to the shipping port.

Instead, the cable cutting and preparation will take place at the old workstation for LED modules, where the cables are then placed in the middle of the facility in close connection with both tests, distribution boxes, and assembly stations, where they are then used.

The workstation for LED modules is instead placed in front of the electrical room where shelves for machine elements are today. These shelves are replaced with box and cabinets at the work stations.

4.5 Simulations

Through the use of simulation in combination with the completed 3D-scan, a good visual image of the new production system could be achieved. Since the physical frames of the simulation consisted of the actual limitations of the facility, it could be directly seen whether the layout was realistic or not.

Since testing and verification should not interfere with daily production, simulation also provided a good understanding of how the production system would work and how well the line balancing fell out during continuous production.

5.0 CONCLUSIONS

Developing a more efficient process when the transition takes place from workshop to factory is easier said than done since most tools, methods and literacy is based on the transition from factory to more efficient factory. By combining several methods together with discussions about the company's input, a result with good conditions for further development could be given.

During this project, a new production system with associated layout has been developed. To carry out this conversion, a lot of planning is required. Everything from determining inventory levels, revising work routines and clarifying which machine elements that should be present in respective work areas. These are parts that are handed over to Luminell, with a recommendation to clarify these parts before the transition is fully implemented to avoid the risk of again falling back into an unstructured working situation.

Interactive systems could also be implemented towards the Corporate Procurement Office which gives a real-time material balance according to what is manufactured to be used with facilitate calculations. This is one of many steps toward implementing factory methods in a business that is undergoing major development and we tried to cover as much ground as possible in order to present a practical solution that Luminell would be ready to implement.

The simulation model has been presented to the company and has constituted a good decision-making basis for conversion. Today, several measures have already been made in order to shift into the new production system.

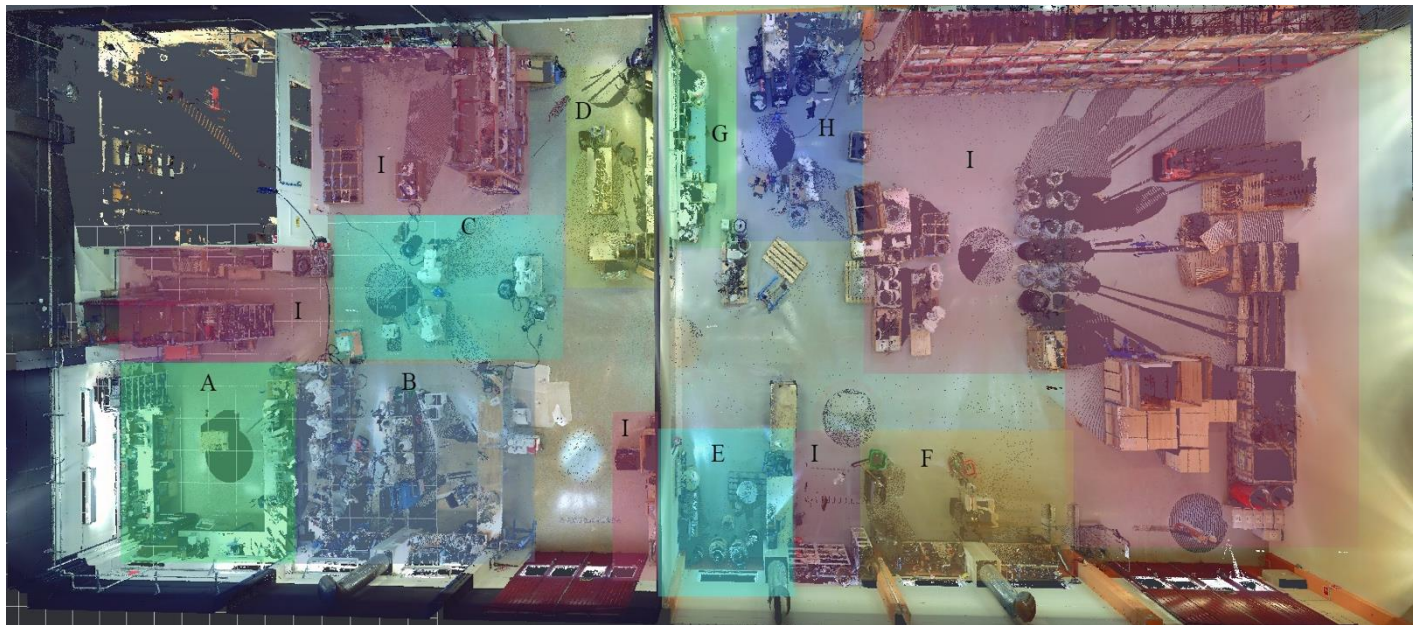
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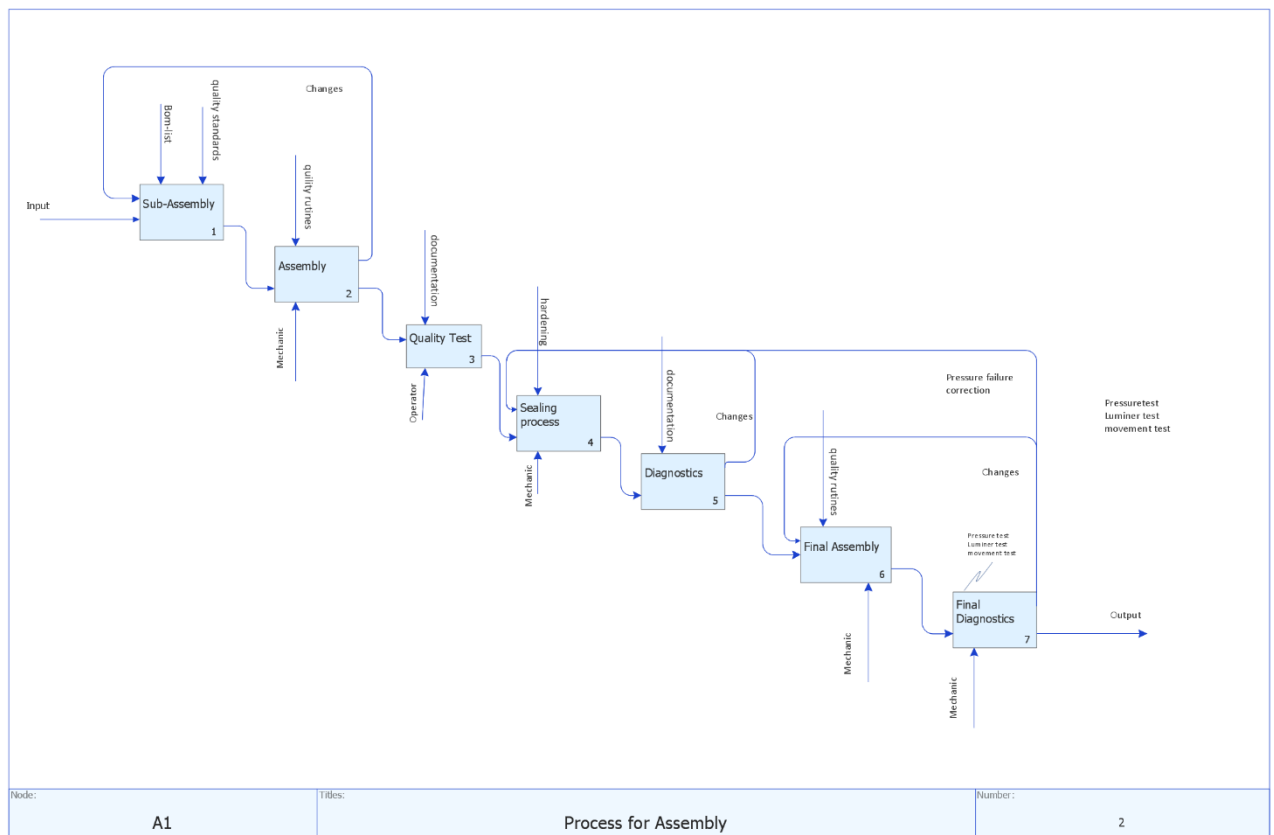
APPENDIX

1) Current state of facility

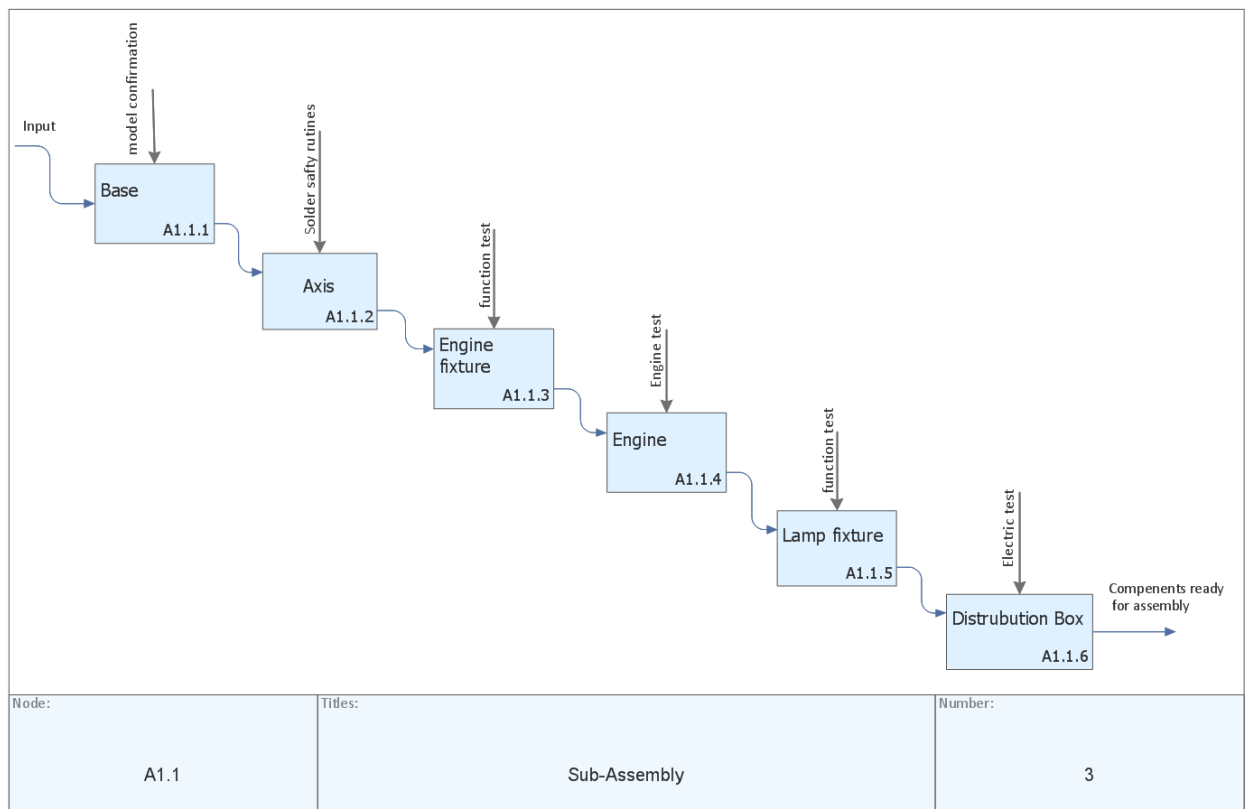


- A. Area for distribution box
- B. Assembly station
- C. Provisional light test area
- D. Area for assemble LED-modules
- E. Cable cutting and preparation
- F. Area for solder axis
- G. Packaging
- H. Service station
- I. Warehousing

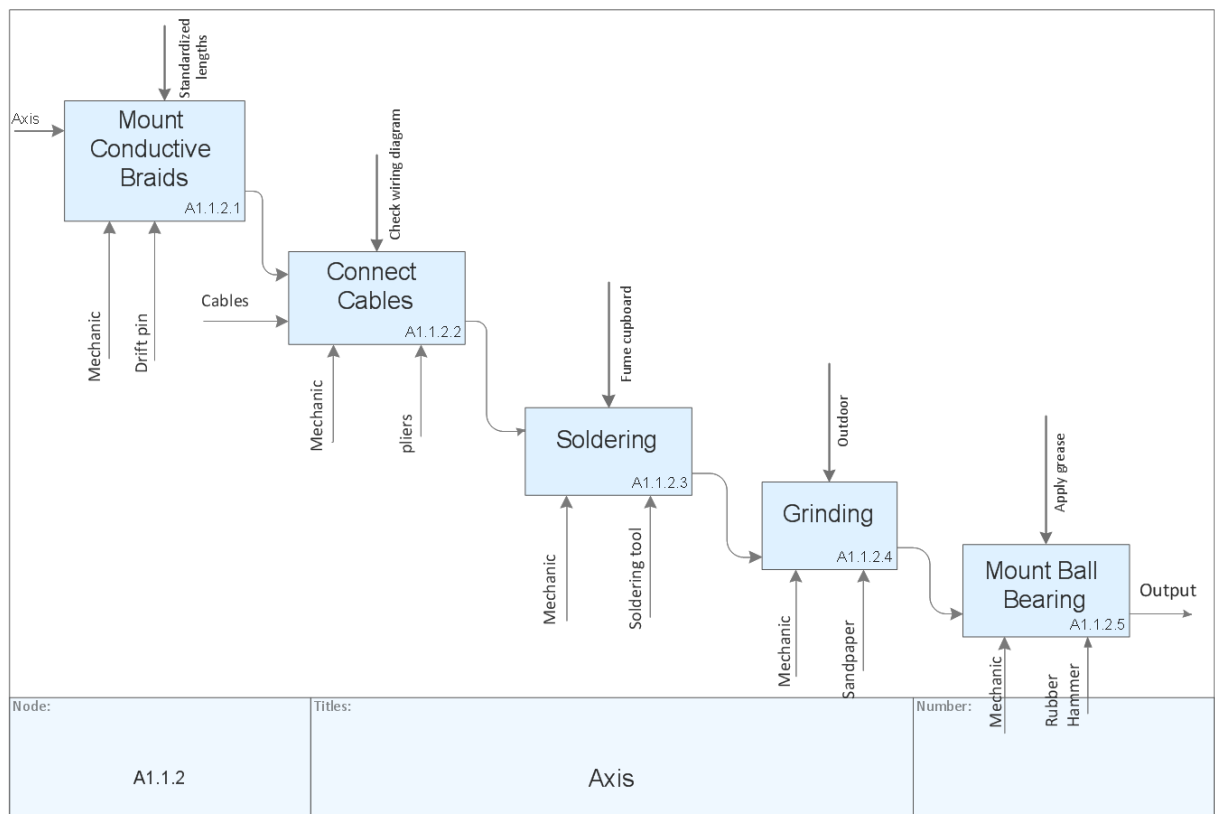
2) An excerpt from IDEF-0



A1, process for Assembly



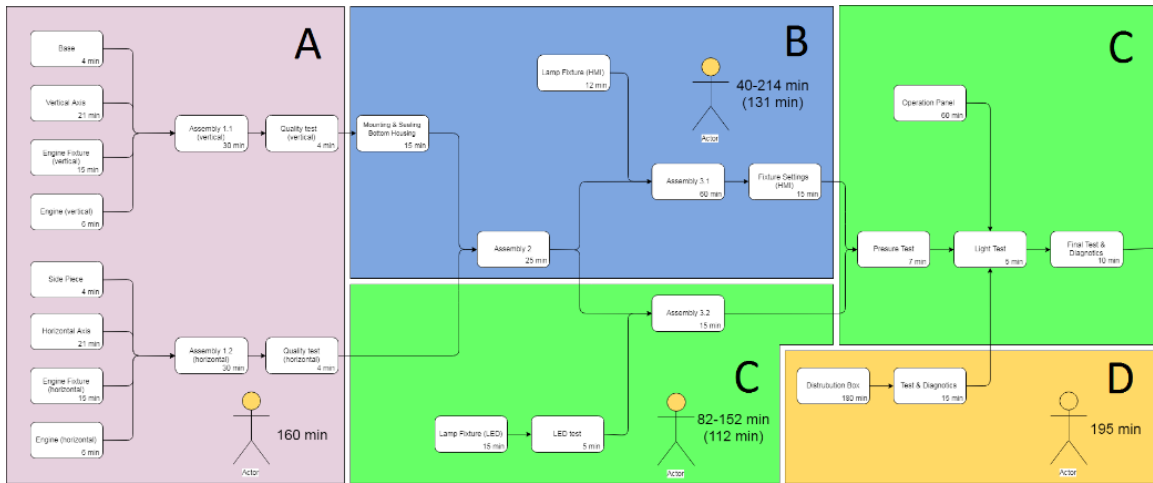
A1.1, Sub-Assemblys



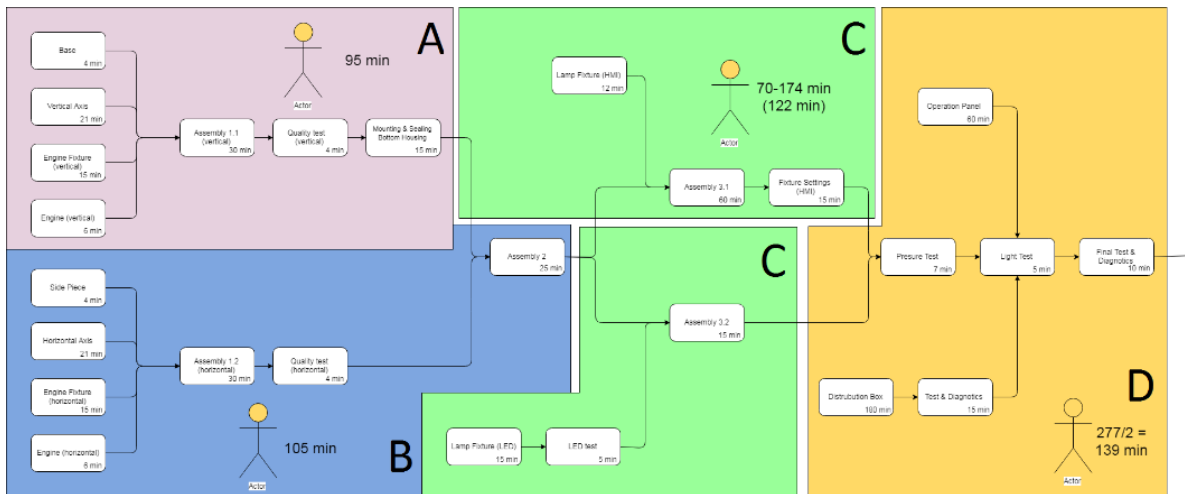
A1.2.1

A1.2.1, Axis

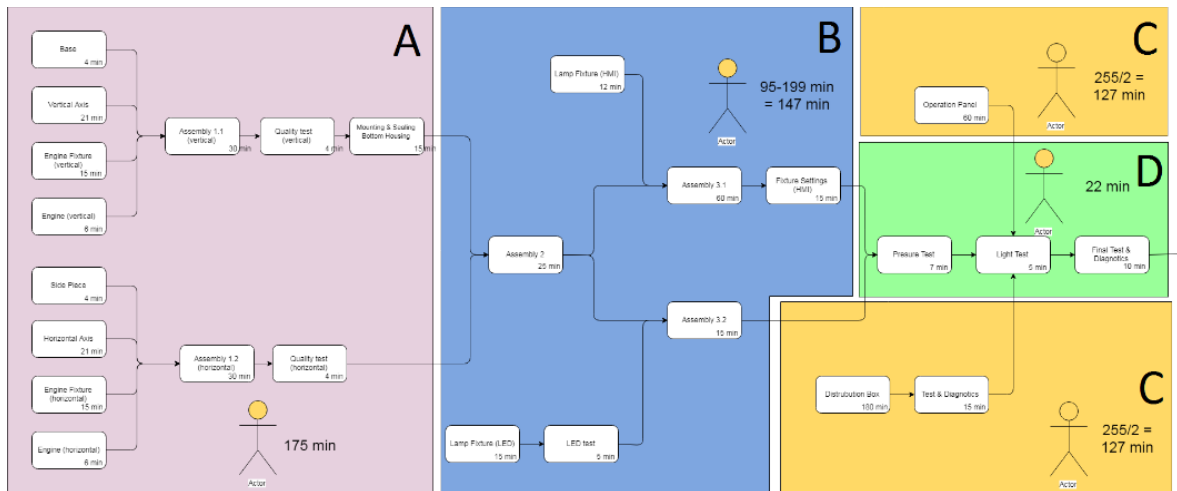
3) Concepts



Concept 1

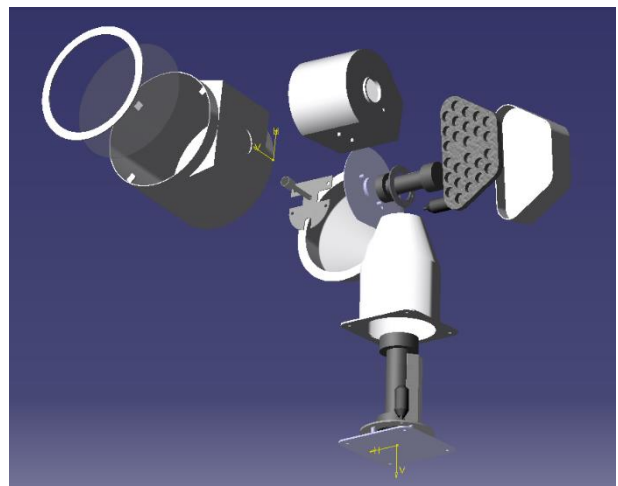
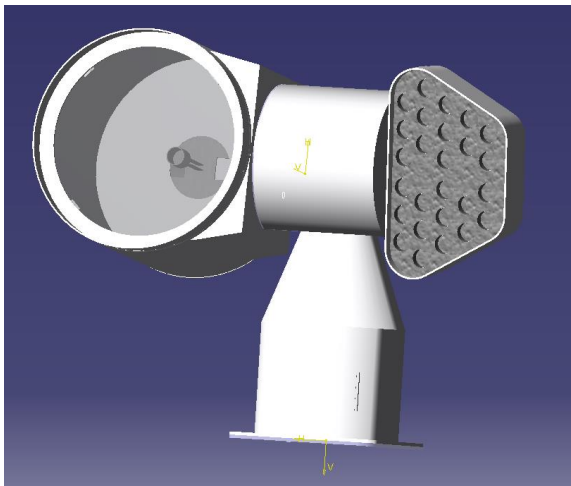


Concept 2

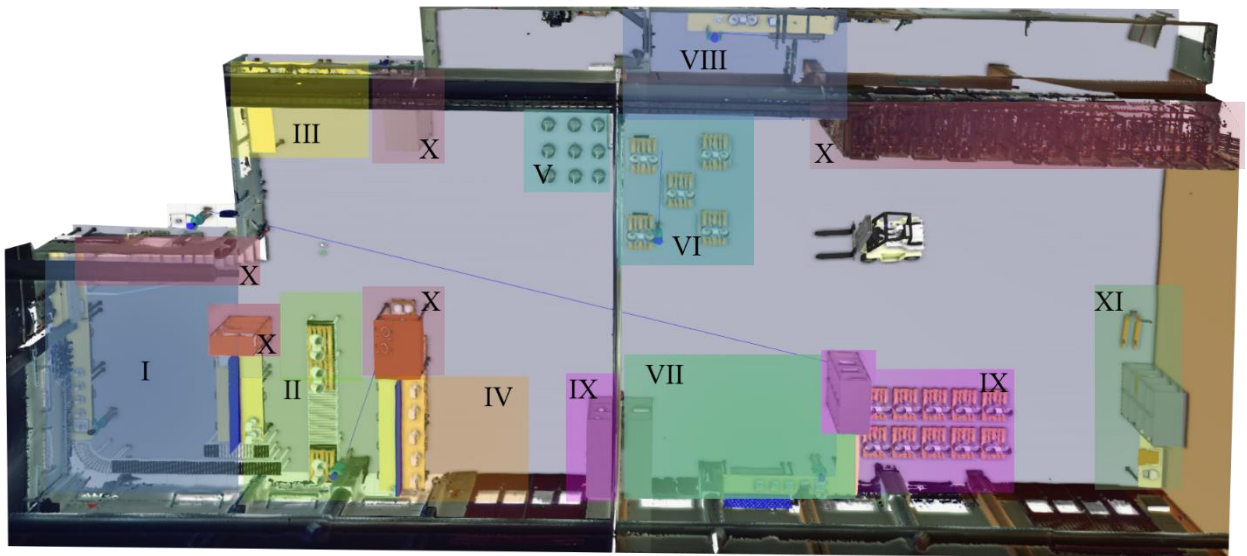


Concept 3

4) CAD- models

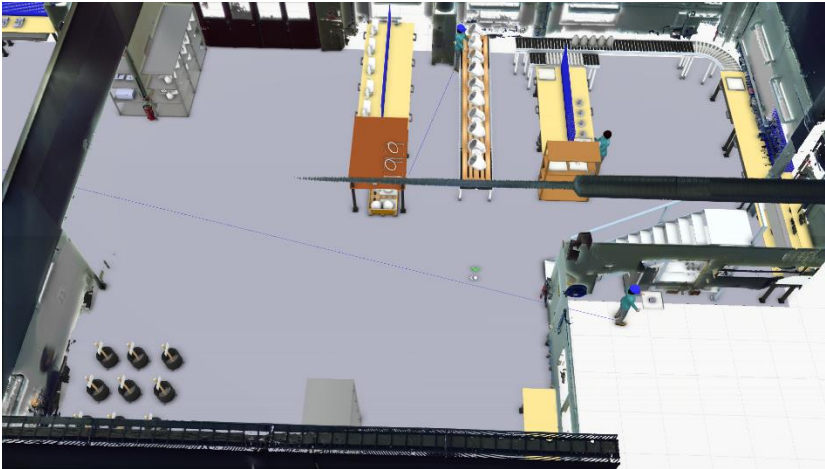


5) Future state of facility



- I) Includes the first subassemblies until mounting and sealing according to the *Precedence chart*
- II) Station providing final assembly
- III) LED light assembly station
- IV) Station dedicated to CL1
- V) Cable inventory and processing
- VI) Final testing
- VII) Distribution box assembly
- VIII) Service station
- IX) final products ready for delivery
- X) Inventory
- XI) Packaging area

6) Pictures from simulation



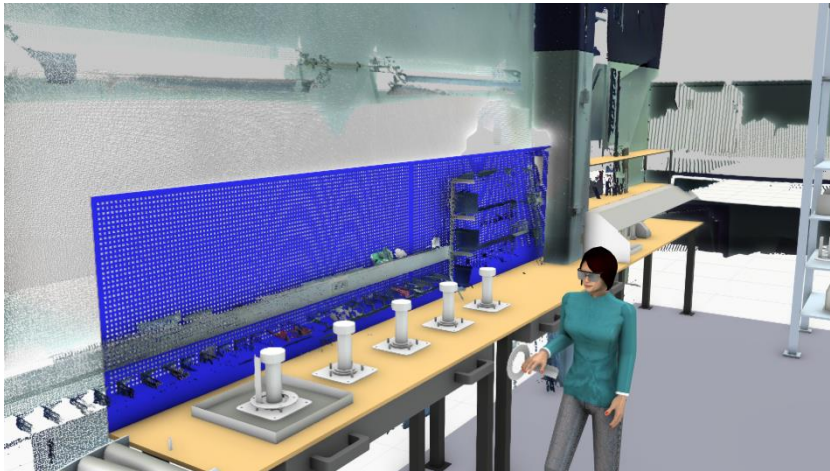
Northern part of the facility



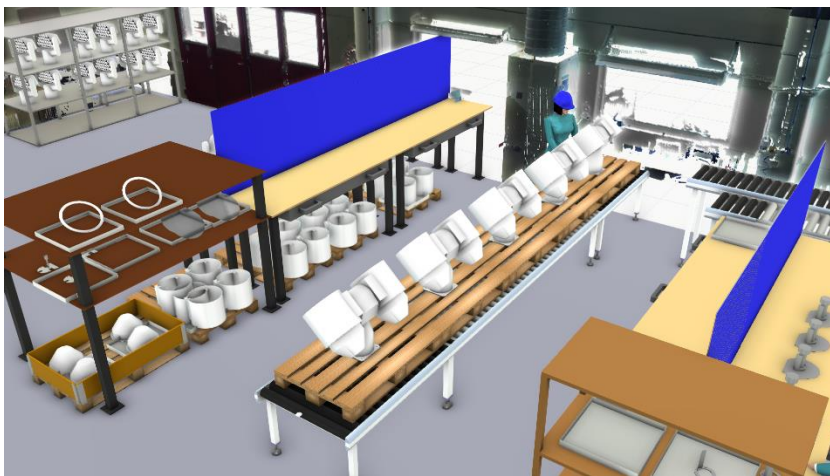
Southern part of the facility



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Station A, pre assembly



Station B, final assembly