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Layout Design of the Assembly Factory

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Abstract

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The purpose of this bachelor's thesis was to design a new layout for the case company. The need for a new layout arose from the expansion of the case company's existing production premises. These production premises consist of cells from different product families. The aim was to create a more functional and efficient layout by integrating the new, expanded space into the old space.

The thesis examined the design of the layout through both theory and study. The theoretical section of the thesis examines different topics such as layout, different layout types, and 2D modelling. In addition, the thesis includes the theory of Lean, the tools of which are 5S and Kanban.

The study started with the mapping of the factory area, after which it was possible to proceed to the actual layout design. As the study progressed, employee interviews and factory visits were used as methods to collect data. In addition, the design phase was completed by utilising workshop meetings with production employees. The collected data helped to create 2D models of the factory premises. The 2D model was created using Microsoft Visio -software.

The result of the thesis was a new layout for the case company's production premises. The new layout allowed the new, expanded factory premises to be successfully integrated with the old factory premises and provided the desired airiness to the production work.

Based on the study, the case company implemented the final layout proposal on the factory premises. The implementation would take place towards the end of the year. The order of the implementation was discussed with the case company to make the process as manageable as possible.

Keywords: Layout, layout design, cell layout

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Tämän insinöörityön tavoitteena oli suunnitella kohdeyritykselle uusi tuotantotilojen layout. Uuden layoutin tarve syntyi kohdeyrityksen nykyisten tuotantotilojen laajentuessa. Nämä tuotantotilat koostuivat eri tuoteperheiden soluista. Tavoitteena oli luoda turvallisempi, toimivampi ja tehokkaampi layout yhdistäen uusi, laajennettu tila vanhaan tilaan.

Insinöörityössä tutustuttiin layout-suunnitteluun niin teorian kuin tutkimuksen avulla. Tämän lisäksi opinnäytetyössä tarkastellaan insinöörityöhön liittyviä aiheita kuten layoutia, eri layout tyyppejä ja 2D-mallinnusta. Insinöörityö sisältää tietoa myös Lean-ajattelusta, jonka työkaluja ovat 5S ja Kanban.

Itse tutkimustyö aloitettiin tehdastilojen kartoittamisella, jonka jälkeen voitiin siirtyä varsinaiseen layout suunnitteluun. Työn edetessä menetelminä käytettiin työntekijöiden haastatteluja ja tehdasvierailuja. Lisäksi suunnitteluvaiheessa hyödynnettiin workshop-palavereja tuotannon työntekijöiden kanssa. Näiden avulla saatiin mallinnettua tehdastiloista 2D-malleja. Mallinnukset luotiin käyttämällä Microsoft Visio -ohjelmaa.

Insinöörityön lopputuloksena syntyi uusi layout kohdeyrityksen tuotantoalueelle. Uuden layoutin ansiosta saatiin sulautettua uudet, laajennetut tehdastilat vanhoihin tehdastiloihin onnistuneesti, sekä tuotua toivottua väljyyttä tuotannossa työskentelyyn.

Tutkimustyön pohjalta kohdeyritys implementoi lopullisen layout-ehdotuksen tehdastiloihin. Implementoinnin järjestystä käytiin asiakkaan kanssa lävitse, jotta prosessi tapahtuisi mahdollisimman joustavasti.

Avainsanat: layout, layout-suunnittelu, solu-layout

Contents

Glossary

HSE: Stands for health, safety, and environment. Includes processes and systems even tools.

Kanban: Control card or board, which is a practical way to implement pull control.

Layout: How the production area is organised.

Lean: Management philosophy and customer-driven process management model.

5S: The five-step method or methodology for organizing the working environment and keeping it clean.

1 Introduction

In this thesis, the layout of an assembly plant is designed. More specifically, an assembly plant which manufactures smaller controllers. This means a controller measuring approximately 15x15x10 cm. The case company is a company in the technology industry. This thesis was initiated when the capacity of the factory began expanding due to high demand. In addition to expansion and increased workload, the layout is also being designed for safety reasons. The factory premises were therefore extended, thus providing new space for the assembly plant. It then became necessary to start designing a new layout that would take advantage of these new spaces.

The design of the layout was started, and once the final layout is received, the case company intends to implement the layout on the factory premises. Therefore, the aim is to develop a new layout that meets the criteria set by the case company. In addition, it would be safer and more efficient than the previous layout. A layout of this kind can also be called a redesigned layout, as the layout includes not only the new premises but also the existing premises.

The design of the layout will consider the reflections of the production employees as well as the recommendations from the case company. In addition, as the layout has an impact on the whole factory plant, workshop-style meetings were held to discuss these topics. For the layout itself, models were created in 2D using Microsoft Visio. This layout is created in cooperation with a company that does not want to disclose its details, keeping the layout secret. Therefore, the figures in the layout are indicative, and more detailed parts have been left out of the illustrations, focusing on cell production. To make the thesis as coherent as possible and to implement what is required in the layout, much of the thesis is also based on layout theory. The theoretical section will examine different layout models and focus on layout design. The theory also refers to the basic concepts of Lean.

2 Assembly Factory

Assembly is the joining together of different components or devices, either manually or by automation. By manual, it means manual work, which is still to a large extent what assembly is. Assembly takes place in stages in the assembly plant using parts from suppliers or parts manufactured elsewhere. The quantities of products to be assembled are generally larger when referring to assembly plants. It can be assumed that the plants have assembly lines with different stages. These include, for example, part assembly lines or sites and final assembly lines. Each assembly plant is different, and it depends to a large extent on the products which are manufactured in the plant. The most typical example of assembly plants are car factories. (Kauppinen et al., 1997: 111)

The literal meaning of “assembly” is assembling and testing. It is also repetitive and continuous work. Assembly increases the added value of the product at all stages, regardless of whether it is just the connection of the parts. However, in some cases testing the product can be more expensive than the assembly itself. Therefore, more often the design and development of assembly plants focuses on eliminating unnecessary work and developing real work. (Baudin 2002: 5)

2.1 Controllers

The assembly factory of the case company manufactures controllers. In general, the controllers, as the name implies, control a process or different systems. The system to be controlled is based on the transmission of an external signal and responding to it in the correct way. Depending on the controller, it can not only control the process but also measure various process parameters such as temperature and pressure. In addition to this, all controllers are fire-safe, sealable, and efficient in terms of capacity. They would therefore be designed for a long life. As a result, materials are selected so that wear or corrosion does not develop much over the years. (Altmann et al., 2005: 52-62)

In addition, controllers development dates to the first half of the 20th century, but their roots may go back to ancient Rome. There are therefore many different types of controllers, with prices and models varying according to the user's needs. The layout usually includes all the manufacturing parts of the production which the controller needs. In this case, the layout would also include the maintenance units. As periodic maintenance also has a major impact on the performance and longevity of the controller, it is part of cell production and usually has its own cell. Maintenance is also one of the ways to reduce noise and vibration levels. (Altmann et al., 2005: 52-62)

2.2 Controller Manufacturing

In this thesis, the focus is on manual cell production where controllers can be manufactured. The different ways in which the controllers are manufactured also have a significant impact on the layout of the factory area. The layout usually depends on the controllers' size and intended use but also on the factory premises of the case company. In addition to these, the manufacturing process is influenced by the amount of flow pressure that the controller should withstand and control. The controller itself is a system that would perform its function independently of the product and the manufacturing process. (Altmann et al., 2005: 1, 58)

Controller would also comply with associated standards and manufacturing budgets. These affect the size of the cells and the correct positioning of cells in relation to the movement of the material, especially in cell production. The layout affects not only the way in which controllers are manufactured but also various costs such as labour costs. The proper layout can therefore reduce these labour costs in the manufacture of controllers. (Bragg & Roehl-Anderson 2004: 118) In this thesis, the controllers of the case company are smaller in size, manufactured from eight cells to up to 16 different modules and depending on the module, the production time of the controller starts from 30 minutes upwards. Therefore, it is important to be aware that the new layout plan would not be suitable for different cell production or larger controllers.

3 Layout

A layout is built from the arrangement of physical parts, so it can be seen as a layout model for a process or similar activity. In general, the items to be laid out include equipment, machinery, access routes, storage areas, and workstations. Layout is also important because it determines the flow of materials, information, and clients through the process. Even a small change can affect the throughput of the process, and the impact can be transmitted through to the costs. (Slack et al., 2013: 191) Layout is, therefore, a costly and time-consuming process with significant effects on production (Logistics World, Online Material). Depending on the perspective, the layout also affects not only the employees in the company but also the management team. Employees pay attention to the layout because it affects their comfort and efficiency. Management, on the other hand, can evaluate investments and other efforts. (Kahraman & Yavuz 2010: 359) In addition to high costs, incorrect layouts can produce longer lead times and destroy the predictability and flexibility of the process. Layout is, after all, a physical product preceded by a multi-step process. (Slack et al., 2013: 193)

An effective layout can be defined in terms of several characteristics. The most important, however, is to involve the health and safety of the layout, both for employees and for clients or other visitors. Shortness and efficiency of flow, as well as appropriate use of space and flexibility, are also considered effective features. In addition to these, unnecessary movement of production employees would be minimized, while at the same time, every necessary tool would be available. (Logistiikan Maailma, Online Material) In addition, potentially noisy places could be avoided in the positioning of production employees or their workstations (Slack et al., 2013: 193).

3.1 Layout Design

The starting points for the layout design are:

- the structural information of the products
- work steps

- determination of the production mode and technology, but also sizing of the production equipment
- the time span, i.e., how long production will remain on schedule
- manufacturing support functions such as tool maintenance or break room.

In principle, layout design aims for efficient material flows. Clear material flows contribute to production control as well as to the development of operations. It is also important to consider the future, i.e., the potential need for change. A challenge in such situations can be warehouses or large structures that cannot be moved easily. In such cases, changes could be anticipated and, where possible, placed in places where they do not interfere with the development of the layout. (Haverila et al., 2009: 481)

Layout design is considered one of the most important design decisions as it has a significant impact on the efficiency and productivity of production systems (Díaz-Madroñero et al., 2021: 1). It also affects costs, as using the right methods can reduce company operational costs by up to 30% (Kahraman & Yavuz 2010: 360). Therefore, layout design is one of the most used improvement methods, meaning that the layout could be changed at certain intervals, especially if there are changes in production. Improvement methods may include redesigning the existing layout or designing a completely new layout. (Kovacs, G. 2019: 547)

3.2 Layout Types

Layouts are divided into four main or basic types. These are fixed-position, functional, production line, and cell layout. More generally, the choice is based on the layout of production equipment and workflow (Haverila et al., 2009: 475). Another way is to divide the layout types into process and product-oriented layouts (Logistiikan Maailma, Online Material). These four layout types are shown in figure 1 with different colours. The layout types are illustrated through a restaurant, where the features of each layout become apparent. In addition to these four basic layouts, there are mixed layouts that use all four basic layouts to design and implement a layout. These can also be called hybrid layouts. (Slack et al., 2013: 198)

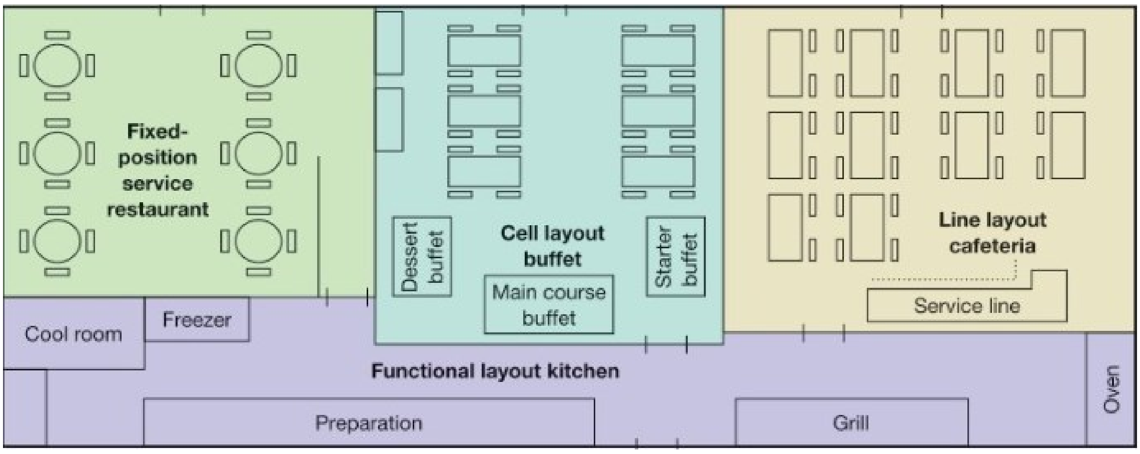

Figure 1. Four basic layout types. [1, p. 6]

3.2.1 Fixed-position Layout

A fixed-position layout is used when the product itself or another resource to be produced cannot be moved. This means that the materials, equipment, or people needed for the process move instead. This is usually influenced by the state of the process. In this case, the object may be too large to move or too risky to be moved, such as heart surgeries or large construction projects like shipbuilding. (Slack et al., 2013: 194) This type of layout also requires careful coordination in terms of the availability of materials. Especially, that they are available at the right time. (Greasley 2007: 28) The detailed design of a fixed layout therefore aims to maximise the contribution of materials to the production of a product or resource at the right time by locating them as rationally as possible. Sometimes the positioning fails, or it has to be repeated several times. This is one of the disadvantages of a fixed-position layout. In addition, the layout can be costly. However, the layout offers a wide variety of tasks for the employees, as well as flexibility in the products. (Slack et al., 2013: 203)

3.2.2 Functional Layout

Functional layout, also named process layout, is based on similarity. This means that equipment, workstations, resources, or processes are placed close together based on their similarity. Either this type of arrangement is practical for the equipment, or it is an attempt to improve the use of resources. (Slack, Nigel et al., 2013:194) The layout is production-technological according to the grouping of equipment, so a functional layout can also be called a technological layout (Haverila et al., 2009: 476).

Hospitals and libraries are good examples of where functional layout is used. Figure 2 shows the layout of a library using a functional layout, where it can be seen how the books, or resources, are placed close to each other. In hospitals, this can be seen as the use of a particular laboratory or X-ray room for different patient needs. A common feature of this type of layout is that clients or users move around according to their needs. In this case, the flow patterns of the layout can be very complex. This is why, research suggests that it is advisable to follow the paths and needs of users so that the results can be used to build a layout that serves users more efficiently and clearly. (Slack et al., 2013: 195-196)

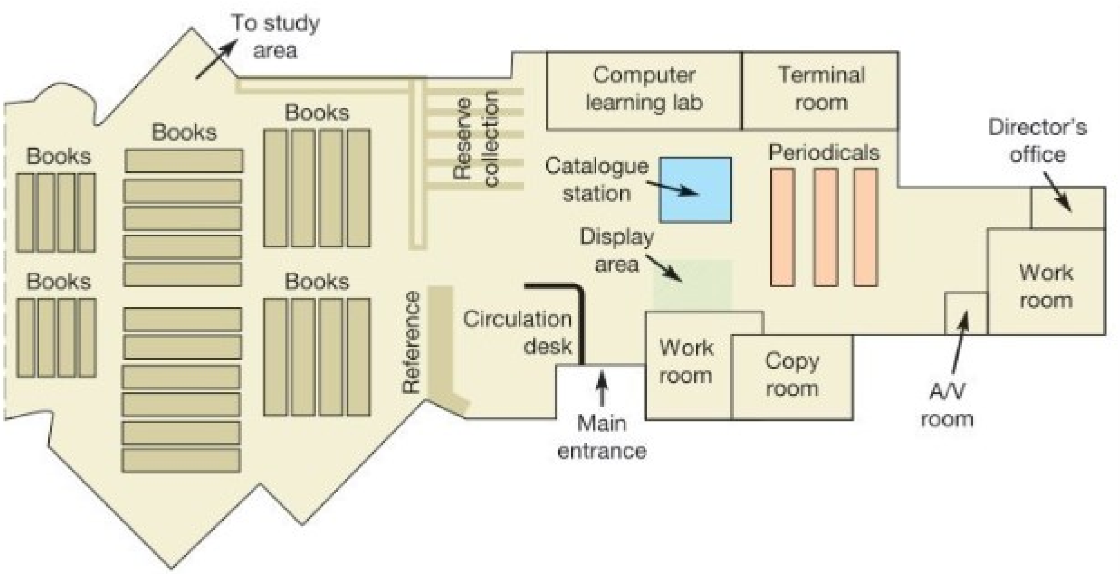

Figure 2. A library that uses a functional layout. [2, p. 7]

While production volumes can vary from batches to one-offs, implementing the layout and controlling the equipment is easy and affordable (Haverila et al., 2009: 476). Nonetheless, there are many ways to implement this layout. The flexibility and adaptability of the layout are also largely used to expand the range of products. Because of the equipment movements and the range of products, the search for maximum flexibility is beneficial in this layout. (Greasley 2007: 28) As mentioned earlier, complex flows can present problems and cause clients queuing (Slack et al., 2013: 203).

3.2.3 Production Line Layout

The idea behind the production line layout is very similar to the functional layout. Instead of designing the process by placing equipment according to their similarity, in this layout type, the equipment is placed in the order of the product workflow. (Haverila et al., 2009: 475) A notable difference, however, is that equipment is transferred according to products, not for their specific needs or resources (Greasley 2007: 30). As a result, production line layouts focus on the manufacture of one or a specific type of product (Haverila et al., 2009: 475). This means that the time spent at each stage of the production line, whether on parts or clients, must be balanced. Otherwise, a backlog or bottleneck will form at a certain point in the production line, usually at the slowest point. (Greasley 2007: 30)

Balancing also affects productivity on the production line layout. Balancing is usually done by means of a pace time which can be used to determine the number of workstations needed. Pace is calculated by dividing the time by the desired output. In this case, to determine the minimum number of workstations, the times of the operations involved in producing the product are added together and finally divided by the pace time. (Haverila et al., 2009: 485) This is one of the reasons why the production line layout is often used in car assembly. Typically, different variants of the same model are made in the same way or undergo at least the same processes. This also creates the idea of a line and a flow, where cars follow the so-called flow through the processes. Therefore, this type of layout can also be called a simple line or flow layout. It has the advantage of being easy to control, but also of specialising the line. In figure 3 the layout of the production line illustrated by a car assembly line can be seen. At the top of the figure is the most common model of a production line layout. However, this has been improved in Japan with a solution such as the one at the bottom of the figure. By rotating the cars around, the production line was shortened by 35%. This resulted in a significant increase in efficiency. (Slack et al., 2013: 197)

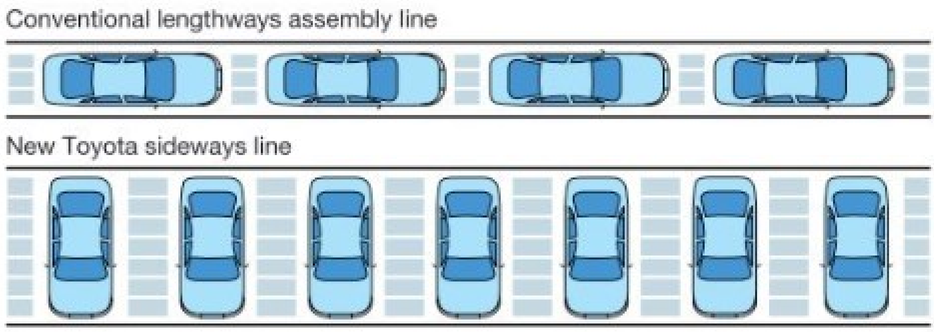

Figure 3. Production line layout illustrated by a car assembly. [3, p. 9]

3.2.4 Cell Layout

The cell layout, as its name suggests, is created by cells. Cells are independent groups in which a particular step or part of a product is produced. The product is therefore moved from cell to cell until it is finished. (Haverila et al., 2009: 477) Cells also contain the parts needed to make the product, or at least they are in the vicinity of the cells. However, the cells themselves can be functional or production line layout type. An exemplary cell layout is the maternity ward of a hospital because often other wards are not needed at the same time, but rather a single cell is used. It is also commonly used in different services. Perhaps a more familiar example of a cellular layout could be linked to grocery stores, where products are grouped into categories such as clothing, home electronics and food. Of these, the food section is grouped into smaller categories for several different products, yet meat and vegetables, for example, are in their own cells. In this way, shopkeepers may have been thinking about the convenience of the shopper, but also about how the shopper would buy more if the products were closer together. In this case, the buyer would also be prone to impulse buying and the shop would make a profit. Figure 4 shows how goods in a department store are sorted as in the grocery store example mentioned earlier. (Slack et al., 2013: 197)

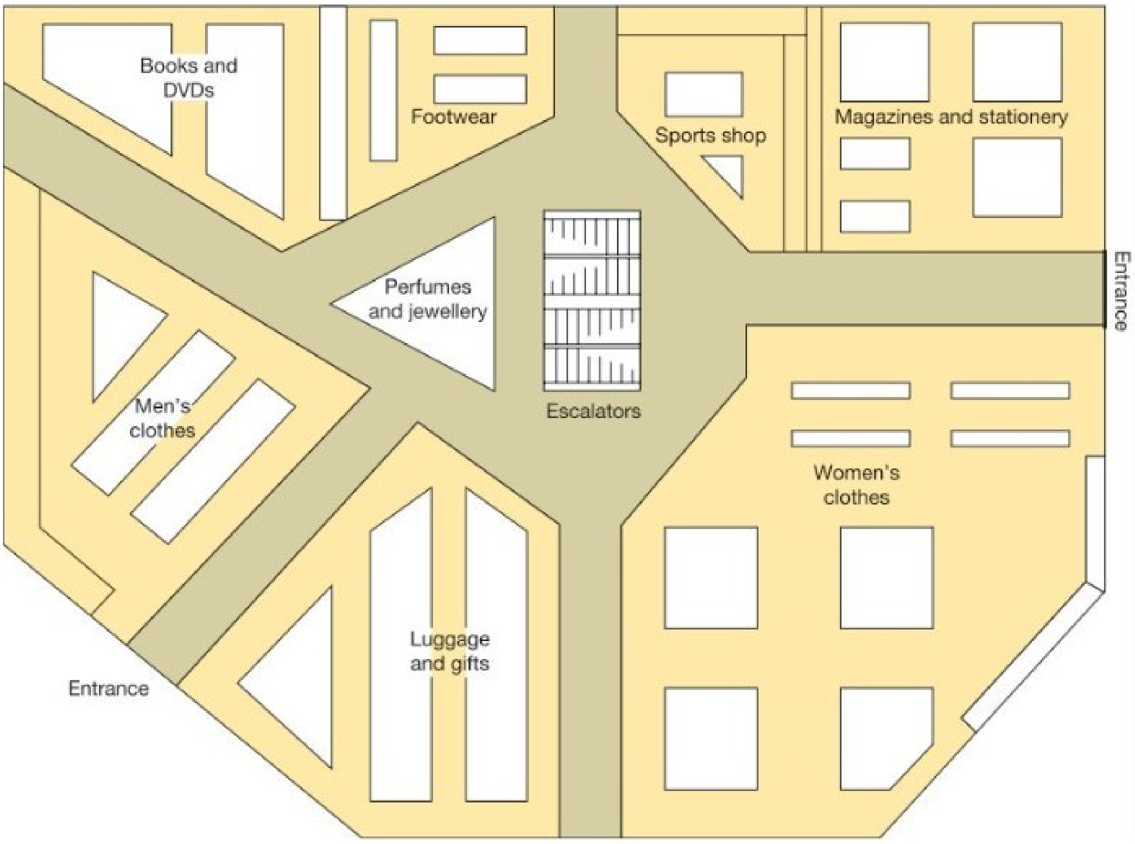

Figure 4. Cell layout in a department store. [4, p. 10]

The cell layout can also use grouping to help combine products. This is called grouping technology. This is how so-called product and client families are created. Groups can be created according to parts, workstations, and employees. The order in which the product is manufactured, and the similarity of the processes in the products or customers also play a role in grouping. Groups allow for greater flexibility as well as smaller batches to be produced. Secondly, grouping helps to reduce unnecessary transport between products. This makes the processes more effective when all the movement happens inside or near the cell. It also helps to diversify the workforce and potentially improve product quality. (Greasley 2007: 29)

In general, the cells are built in a U-shaped pattern as shown in figure 5. In this case, the incoming and outgoing materials are opposite each other. Production employees work from the inside, while the material moves outside the model. This also allows to work around more than just one process, without the need for extra movement of employees between cells. Therefore, in this type of cell layout, it is not recommended to use more than eight employees per cell unit. The U-shaped pattern of the cellular structure is also popular because it provides flexibility in staffing. This can be turned to mutual motivation among the employees, when different processes are learned, and employees become multi-skilled. This also enables an efficient and fast way to produce products at a reasonable cost. However, a U-shaped model like this can be difficult to move when repositioned, and this could be costly. (Baudin 2002: 93)

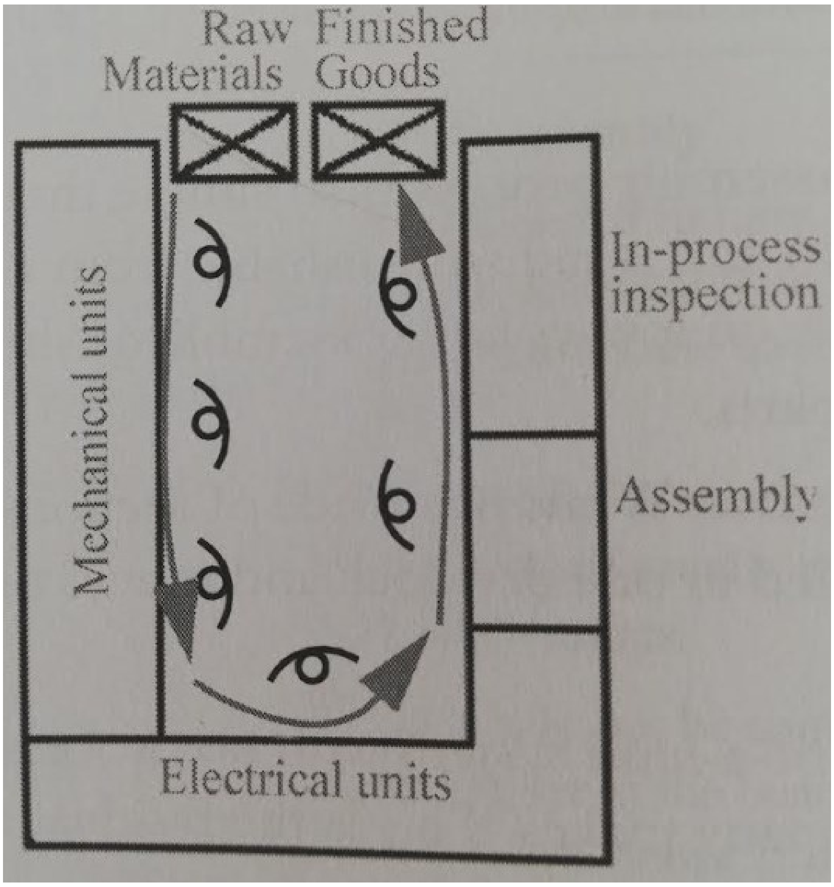

Figure 5. Popular U-shaped cell layout model. [5, p. 11]

3.3 Layout Selection and Layout Type of Case Companys' Factory

The choice of the layout type itself depends on the planned production and its character. This may be influenced by factors such as production volumes and the size of the product range. (Haverila et al., 2009: 479) Figure 6 shows how the four different layout types are positioned for different production volumes and product variety. This figure also considers the importance of regular flow. According to figure 6, the production line and cells have the highest volumes, while the functional and fixed layout types have higher product variability instead of volume.

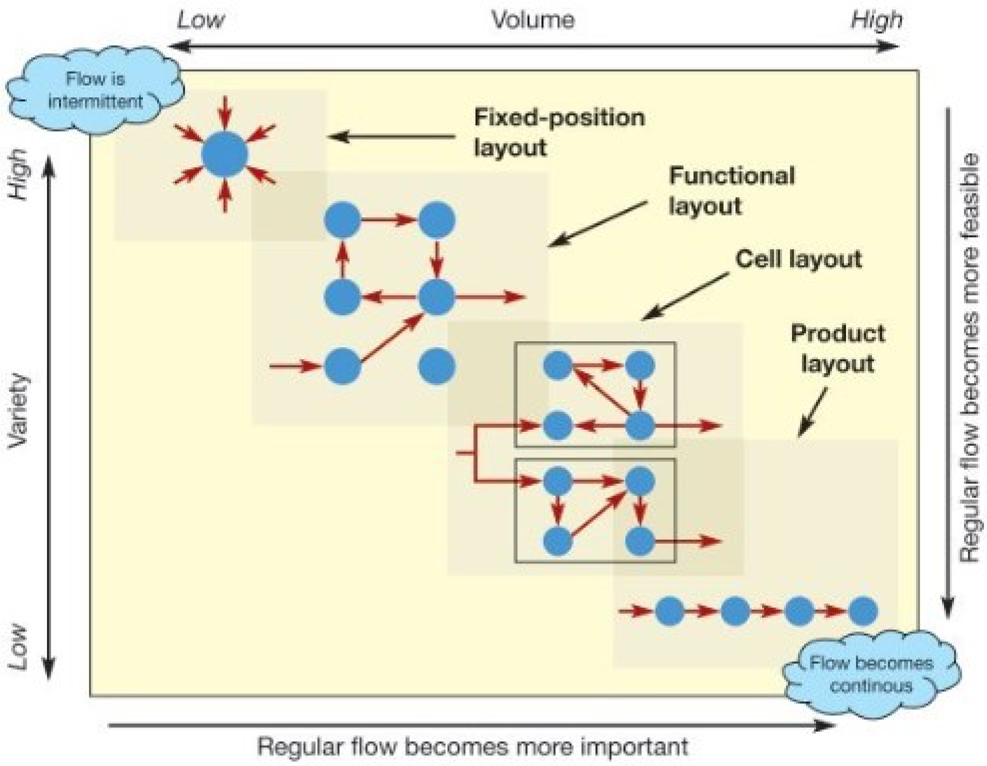

Figure 6. Presentation of production volume and product variety in different layout types. [6, p. 12.]

The decision will be largely influenced by the targets, but the selection itself will also affect flexibility and costs. In terms of cost, the most affordable layout will be sought. However, selection will usually be including uncertainty about the actual costs, which are also affected by the volume levels. In addition, the selection process will consider the feel of the layout and the overall impression that the layout creates. (Slack et al., 2013: 200)

In this thesis, the focus will be on production using a cell layout. The cell layout has been in use at the case factory for some time. One contributing factor to this is the small size of the products, which are the controllers. The case company wanted to keep the cell-based layout in the new layout. Therefore, the layout type selection process took less time than expected. The cell layout is a successful choice when there is repetition in production. Cells also provide more flexibility to the manufacturing of different types of products than a production line layout. However, not as many different types of products are manufactured as in a separate production line. (Haverila et al., 2009: 479) Usually, once the layout type has been selected, the next step is to move on to a more detailed design. For example, this means focusing on the cells' functions as processes, considering what the cell area is and what the cell needs to function. The intention is to combine the resources of certain product groups and design suitable cells according to the needs of the products. (Slack et al., 2013:209)

4 Lean Layout

Lean in layout means designing an efficient flow and resource process, usually on production, according to the Lean principles. In general, flow and resource efficiency are seen as satisfactions that help Lean move forward and achieve its goals in delivering value to clients. In this context, it is about client and producer satisfaction, and maximising it. Applying lean to layout usually helps to optimise material flows and reduce waste. It also helps to minimise excess movement of both employees and material as well as fractional labour. It is also typical to aim for a reduction in the need for space. A positive example of saving transport waste and reducing material is the U-shaped cell layout, where movement between cells is short distance. (Protzman et al., 2018)

Lean is a philosophical way of thinking, based on the Toyota production system. The thinking is based on continuous improvement. (Logistiikan Maailma, Online Material) It began visibly spreading in the 1990s and was significantly impacted by manufacturing companies (Jonsson & Mattsson 2009: 9). The basis of this way of thinking is to have and create respect and value for clients' or overall humans. Thus, Lean is not only a way of thinking, but also an action. Lean is pursued by eliminating waste and improving process flow. (Logistiikan Maailma, Online Material) Lean operations can be seen as production, because according to the needs of the client, it focuses on the continuous pulling of material through production (Jonsson & Mattsson 2009: 9).

However, the goal of Lean thinking is to reduce process lead time. These objectives are identified and influenced by the various Lean tools. In addition to the tools, employees also play a major role in identifying problems and solving them. Lean can be easily misunderstood, so there should be enough exposure to a Lean mindset. Although, for more difficult decisions, it is recommended to consult an expert. Lean tools include for example 5S and Kanban. (Logistiikan Maailma, Online Material)

4.1 Material Flow

The flow would be a value-generating activity once the clients' value is defined. One of the most embraced and well-known flows is the material flow. The material flow includes the movement of the materials themselves, as well as transport, and storage of the finished products. A steady and smooth flow of materials usually results in shorter delivery times and increased client satisfaction. Materials move both from client to supplier and from supplier to client. Therefore, the flow of materials is linked to the flow of information, whereby information is linked to the material and the products that result from the process. Information is also usually linked to layouts with various markers, such as arrows, where the material flow would move. This type of marking can be seen in page 11, figure 5. (Logistiikan Maailma, Online Material)

4.2 Kanban

Kanban comes from Japanese and means card or signal. Directly translated, it means "watch over a board for a period". These cards or signals are used to control production. These can also be objects such as bins, pens, or paper. The idea is that a kanban card or signal triggers the production or movement of a unit, which is called suction control. This can also be done with two cards and two units. Figure 7 shows the Kanban system process for single cards. As summarised in figure 7, material is summoned when it is needed, and the inventory is limited. All the production is in these standard containers. These containers loop to connect work centres with stock points. These also circulate containers from full to empty with stages A and B. In other words, kanban keeps materials moving between stages. Therefore, kanban can be handled individually but also as a two-card system. (Slack et al., 2013: 479)

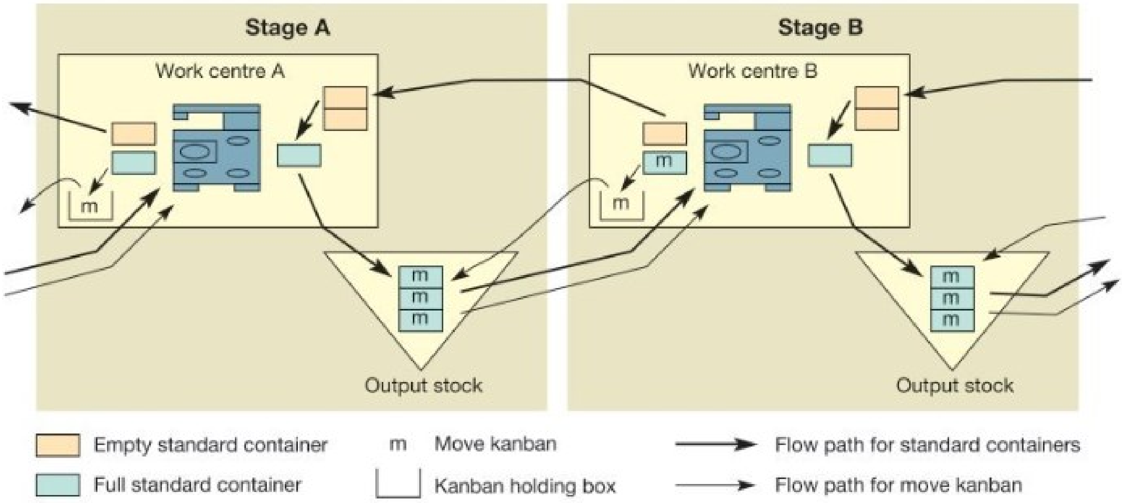

Figure 7. Kanban system with single cards. [7, p. 16.]

However, the most beneficial aspects of kanban are to help overproduction and lack of synchronisation. In this way, the aim is to move material exactly when it is needed, while also minimising the amount of material. Kanban is also usually inventories, so minimising material can prove to be a surprisingly important element even for layout as the aim is to reduce excess material from the layout and give clear cells and walkways to the employees. One example of a kanban is also the two-bin system. This is a box system where the second box, when the first box runs out of parts, slides into the place of the first box. This gives the signal to refill the first box. The boxes are therefore in a row and usually on a downward slope to make it easier for the boxes to slide. These are used to make production more efficient and to clarify the work order for employees in production. (Protzman et al., 2018)

4.3 5S

5S is one of the Lean tools that is seen as a sort of visual organisation facilitator. It is often associated with cleanliness, which would speed up, as well as facilitate, the process. It would also allow predictability and keep the necessary parts in the same place. These are achieved when 5S works according to Lean principles by eliminating waste and creating variations in the process. (Slack et al., 2013: 484) As the name suggests, the 5S consists of five different sub-areas. A sixth sub-area can be added, depending on the organisation, but more generally it is combined with these five sub-areas. The five sub-areas are:

- Seiri, in English *sort*. Sorting the items into necessary and non-necessary. Keeping necessary and then eliminating non-necessary.
- Seiton, in English *straighten*. Organising the components in a way that they are easy to reach.
- Seiso, in English *shine*. Keeping the work area tidy daily.
- Seiketsu, in English *standardize*. Maintaining and improving cleanliness.
- Shitsuke, in English *sustain*. Maintaining standardising activities at the workplace, as well as training and disciplining as part of this sub-area.

5S is also quite an important tool when the layout is implemented. In the layout implementation, if not already in the design phase, 5S can be used to remove excess items from the workstations as well as to find where the waste is originating. For example, daily actions can make a habit of returning parts to their original position. This can also be encouraged through rewards, and audits from time to time. Figure 8 shows an example format of auditing 5S. With this kind of format, it is also possible to track organizations' improvements in all 5S regions. (Protzman et al., 2018)

5 S Daily Inspection

Rank
A = Perfect Score = 4 points
B = 1 or 2 Problems = 2 points
C = 3 or more problems = 1 points
Maximum score in each category = 20 points

Category	Item	A	B	C	Comments
	Distinguish between what is needed and not needed				
	Are things posted on a Visual Display board uniformly?				
Sort	Have all unnecessary items been removed?				
(Organization)	Is it clear why unauthorized items are present?				
	Are materials inside cabinets neatly organized?				
	Are passage ways and work areas clearly outlined?				
	Are hose and cords properly arranged?				
	A place for everything and everything in it place				
	Is everything kept in its own place?				
Stabilize	Are things put away after use?				
(Orderliness)	Are work areas uncluttered?				
	Is everything fastened down that needs to be?				
	Are shelves, tables and cleaning implements orderly?				
	Are all machine guards in their place?				
	Clean and looking for ways to keep it clean				
Shine	Is clothing neat and clean?				
(Cleanliness)	Are exhaust and ventilation adequate?				
	Are work areas clean?				
	Are machinery, equipment, fixtures and drains kept clean?				
	Maintain and monitor the first three S's				
	Is the area free of trash and dust?				
Standardize	Have all machines and equipment been cleaned?				
(Adherence)	Has the floor been cleaned?				
	Are clean-up responsibilities assigned?				
	Are all tools and gages within calibration dates?				
	Stick to the rules, scrupulously				
(Self Discipline)	Are smoking areas observed?				
	Are private belongings put away?				
	Does everyone refrain from eating, drinking and smoking in the workplace?				
	Sub Total	0	0	0	
	Total	0			

Figure 8. Example of an audit and inspections on productions with 5S. [8, p. 18.]

5 Layout Modelling

Layouts are usually modelled using CAD software. This makes it possible to see not only the layout but also, for example, the pipe structures and the entire factory floor in the correct geometry. This also makes it easier to test the different effects of the layout. (Moran 2016: 110) However, this is influenced by the space of layout to be modelled and the resources available to the company. A layout can be designed on paper, if each workstation, piece of equipment and the physical parts of the layout are visible at the right scale. There are therefore many ways to model a layout. For the layout modelling in this thesis, Microsoft Visio was used with the Pro licence. Although, a paper version of the layout was also made, this version consisted of a layout base made with Microsoft Visio.

5.1 Choosing 2D Modelling

The choice of 2D modelling came quite naturally for this thesis. The case company provided the necessary licence and software to start modelling the layout. This was Microsoft Visio. The Pro version of Microsoft Visio was used, as without it the layout would have been too simple. Although most parts of the layout were modelled independently, some necessary parts and features were needed from the Pro licence. This application was also chosen because the layout of the factory premises had been modelled 2019 using the same application. This old layout incorporated the same basis that the new layout would use, so this could be used to design the new layout.

2D modelling for layout design is still the predominant practice, although 3D design has also increased in popularity. Some 2D modelling applications include pre-built 3D models. Microsoft Visio also includes some 3D modelling. However, these are on a small scale. 2D modelling is also a better option when documenting the process further. So, in this case, where the layout was related to the thesis, 2D modelling was suitable. It is also more affordable than 3D modelling. The choice of software and its level of detail can be influenced by factors such as the size of the project and what the case company prefers to use. (Moran 2016: 551)

5.2 2D Modelling the Layout

The structuring of the different versions was started cell by cell. There were eight cells in total. In addition to these, there are other pieces in the space, such as boxes, shelves, workstations, production pallets and walkways. Therefore, when designing the layout, it is recommended to process things in groups of five. This makes the layout design more manageable and the visualisation of the layout more accurate. (Moran 2016: 655)

The 2D modelling phase also largely involved measuring production facilities, different equipment, and workstations. This was done to model all parts of the production in the right proportions so that it would also be realistically possible to fit everything together. The modelling also made use of pre-built models and structures from Microsoft Visio, but most of the structures in the production cells were made up of self-modelled parts. Each modelled table and other parts were labelled in the model to make the layout clearer. The cells were also named with the correct names. Unfortunately, these things are not shown in the following figures. As the cells are only numbered in this thesis due to confidentiality. In addition to these, in the figures the dimensions that formed a major part of the 2D modelling can be seen. The dimensions in Microsoft Visio are in millimetres and allow for the realistic positioning of parts in the factory premises.

2D modelling and detailed measurement helped to detect potential tight and confined spaces in time. During the workshops, many important observations about the movement of production workers emerged. Therefore, it is important to have the layout ready as a 2D model or on paper before the implementation starts to avoid such errors. At the same time, this avoids various costs or unnecessary use of time. (Moran 2016: 13) However, the aim was to produce an efficient and safe layout. Unfortunately, a bad design can end up with an unsafe and congested layout plan with bottlenecks (Díaz-Madroñero et al., 2021: 1). Such issues can also only be discovered after implementation, when it would once again be necessary to make changes to the layout. This was prevented during the thesis by numerous discussions, meetings, individual interviews and even workshop meetings. This just shows the importance of the design phase when modelling is involved too.

6 Layout Study of the Assembly Plant

The initial phase of the study for this thesis was started by consulting the case company. The thesis supervisor from the university of applied sciences also participated in the first initial meetings. In this way, the objectives and requirements based on the layout of the factory were clarified. As in, what the case company wanted from the new layout. After that, the wishes of both the company and the employees were collected through interviews. At this stage, it was discovered that there were quite large differences in opinions and requests compared to the criteria given. This meant that it would be challenging to reconcile them. Therefore, a so-called golden mean would have to be found, which would please both the management and the employees. Ideas were also limited in terms of what was feasible and what was not. As Nyhuis and Reichardt (2015: 409) have earlier noted, when starting to implement a layout from an ideal layout to a real layout, there is a need to consider the flow and constraints. These include the use of space and regulations imposed by the company.

6.1 Targets and Limitations

At the start of the project, there were a few limitations as well as goals related to the layout to be designed. Most of the targets were related to the case company's wishes regarding the layout. The main target was to design a new layout or at least offer new layout design proposals. Other targets were concerned with productivity and employee health because the layout would increase productivity after the new design. The layout would also consider future needs so that these can be set as targets. In other words, the layout would allow for the expansion of cells and their movement if changes to the layout are desired.

The limitations, on the other hand, were related to safety issues and accessibility of the factory, but also to the improvement and acceleration of the manufacturing of products. In this thesis few restrictions regarding safety were closely attached to HSE notifications which are noted in this new layout design. HSE means the concept of health, safety, and environment. HSE notifications can be used to continuously improve operations and prevent similar situations from recurring. (Cvetkoska et al., 2022: 78-79) These HSE notifications were concerned with the forklift and the space it needed. To prevent the forklift from endangering production employees, a safer route had to be found. In addition, there were limitations concerning the equipment in production cells 1 and 2 which the case company wanted closer to each other. This somewhat limited the design work and the generation of different options. Cells and the production area can be seen in the figure 9 below.

Restrictions are individual, depending on the layout and the space available. Sometimes the restrictions may also include energy saving or other matters that the case company and organization feel are important. In this thesis, there were also constraints on investment, which were kept to a minimum. To this can be added the constraints that concerned the layout design phase in the workshop meetings. This refers to the layout of the base, which the production workers were able to influence. Cells 3, 4 and 5 were therefore ready on paper, as these would not be subject to any significant transfers or cell changes compared to the other cells. However, production employees were able to influence the positioning of parts of these cells. This therefore somewhat limited the design of the new layout for the employees.

6.2 Mapping the Baseline Situation

The mapping of the production started quite early in the process. This thesis is based on mapping, which helped to understand the wishes and objectives of the case company. This involved exploring ideas and deconstructing requests. One of the main parts of the mapping process was the creation of layout proposals. To create these layout proposals, it was important to measure factory facilities precisely. However, the first step was to study the old layout model. The basic production information was that the type of production is cell production. These cells and the whole production area can be seen in figure 9. This provided a basis from which to start mapping. It was also necessary to learn about cells and how they work, as some cells needed each other to complete the product of another cell. As seen in figure 9, cells 1 and 6 are part of one product so even if they are their own cells, they need each other. This same effect is between cells 4 and 5. Cell 4 produces parts that are needed by cell 5. This caused some confusion at the beginning of the process when only six cells were mentioned under the various product lines. However, these so-called smaller supporting cells are also equally important in the manufacture of the products. In this thesis, therefore, there will be eight cells to make it easier to perceive these smaller cells as well.

Figure 9 shows that the old layout model allowed to use base that remained at the same scale. The extensions, which are named New Factory Areas 1 and 2, simply took over the spaces of others. However, there were differences in the New Factory Area 2 because it did not include air conditioning like the other factory areas in the layout. All the layout areas, the old and the new areas, remained structurally unmodified for the most part. Only one structural change took place in the layout area, and that was in the New Factory Area 2, where a partition wall was built to separate it from the other factory areas. This can be seen in the yellow highlighted colour in figure 9. Arrows can indicate, in this thesis the white arrows, information about the production passageway along which forklift, people, and material flow (Logistiikan Maailma, Online Material).

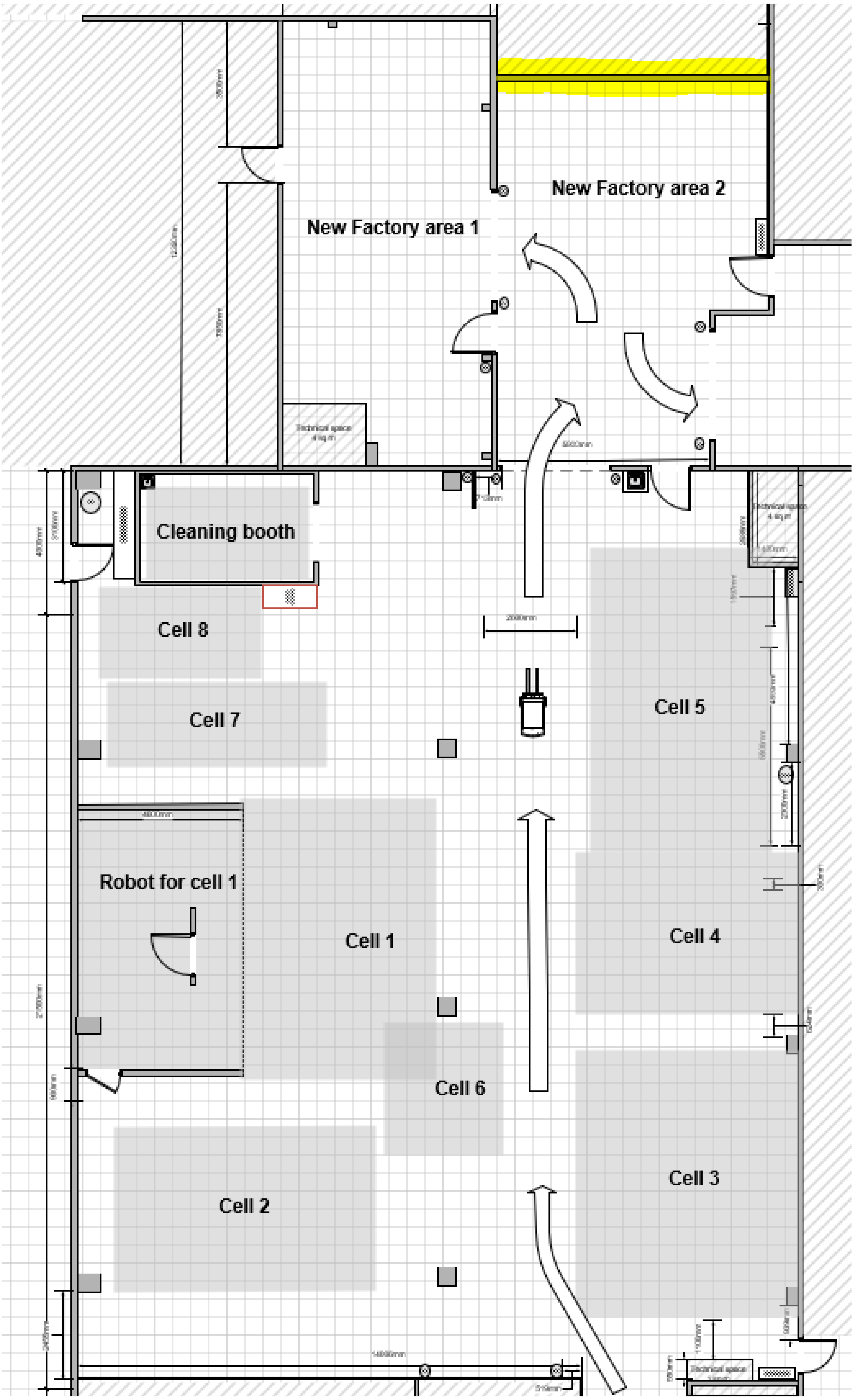

Figure 9. The starting point of this thesis work and how production was placed before the new layout design. [9, p. 25.]

This thesis also includes factory visits and individual interviews. These were mandatory parts for the progress of the work, as the purpose was to create a cellular layout for a manual assembly plant. This was because, in manual assembly work, the employees themselves know best what works in production and how to improve their work. The interviews also helped to identify the physical limitations of the workers, in other words, to remove anything from the layout that would be impractical or difficult to work with. The individual interviews also provided a clearer picture of the opinions and preferences of the different employees regarding the production layout. However, the interviews might not tell the whole truth and in some cases, opinions only emerged during the workshops. In the end, the design of the new layout was influenced by the employees, who committed to the workshops and interviews.

6.3 Design Phase of Different Layout Proposals

At the conclusion of the baseline mapping the design of the different layout proposals began. In total, 14 different versions were designed until a proposal was found that would be suitable for the case company. Some of the cells in the production vary in size, which is why some cells appear in different sizes in different proposals. Some of the production cells went through internal cell changes between proposals that will not be shown in the figures. The layout also included a break room, which is cut from the figures because it did not change in this process. In addition, cells 7 and 8 will be in the same place in all proposals, as this was one of the case company’s early requests. However, their locations were not locked in, and the company would be willing to consider other options for the placement of cells 7 and 8.

The New Factory Area 2 is pictured in every proposal as a storage area for parts. This was due to the air conditioning, which was in significant use during the summer. The placement of the cell there and working in not airconditioned space would not be seen as beneficial to anyone, but also because putting workers in uncomfortable spaces is against a good layout plan. As this thesis focuses on a cell production plant, most of the necessary parts can be found inside the cell.

The idea is to have the necessary parts and tools as close as possible and, at the same time, they would be accessible for the employees. (Slack et al., 2013: 193) However, some parts can also be found outside the cells. These parts are not shown in detail in the layout figures for reasons of confidentiality.

In the first proposal seen in Appendix 1, the introduction of new factory premises is immediately noticeable. In this proposal, the major changes were in cells 2 and 3. Cell 2 was moved closer to the passageway and cell 3 was moved to a new location compared to the original layout. However, this proposal was rejected because the passageway was too narrow between cells 2 and 4, and cell 3 was in front of the emergency exit route. In general, layout design aims to keep passageways at least one metre to one and a half metres wide. However, in this thesis, forklift traffic requires more space for the passageway. The minimum width for a forklift is therefore about two metres. (Protzman et al., 2018) Due to the width of the passageway, this proposal did not meet the organization's safety criteria. The second proposal did not change much from proposal one, as only cells 2 and 3 changed places with each other. This change was due to the case companys' limitations and wishes regarding the layout, as this would bring the devices in cells 1 and 2 closer together. However, once again, space constraints would suffer in cell 2. Cell 2 was therefore moved.

Therefore, in proposal three seen in Appendix 2, cell 2 was moved lower and cell 3 was moved to its original location. In this case, the passageway would also take a different route between cells 1 and 2 than in previous proposals. Here, however, a bottleneck was found on both sides of cell 2. If the new layout creates bottlenecks, the layout has not been successful, as the new layout should eliminate bottlenecks and smooth the flow of material to match the pace of the cell. (Cvetkoska et al., 2022: 98) In addition, for this proposal, there was a significant increase in the number of internal operations within cell 2, as less space was available for the cell than before. Although the cell could be moved and modified, at this point in the design the three beams shown in Appendix 2, marked in grey in the middle, became an increasing concern. Since the beams could not be moved or dismantled, the production layout must be built around them. This was somewhat limiting but at the same time gave new possibilities, because cells could be radically modified. In addition, at the same time, the function of the cell would remain as well functioning as before, if not better. Beams would therefore be considered when new options for the layout are created. To leave room for layout change in the future, these matters were thoroughly considered. (Haverila et al., 2009: 481)

The fourth proposal took a slight step backwards as shown in Appendix 3. Following proposal two, cell 2 was once again moved upwards with major modifications. Major modifications here refer to modifications in the structure and size of the cell. For the most part, this cell underwent track modifications to discover new, suitable shapes for the cell from its original shape. Cell 3 also moved below cell 1. This would allow the cells to fit around the beams and keep the pathway spacious enough. The devices in cells 1 and 2 were wanted close together and this became the case company's requirement for future planning and production. In addition to these, the device below cell 1 also wanted to be included in this as an extra but this was not as high-level a requirement as cells 1 and 2 other devices. In addition, a new design challenge was presented, as cell 6 would need more space. Space was needed because cell 6 would be expanded with the new equipment. Because of this, its location would have to be moved.

At this point, moving cell 1 became an interest. Before this, cell 1 had not been moved because of its robot, until the proximity of three devices became more important. These three devices are the equipment in cell 1, 2 and below cell 1. In the past, the robot was not moved because it would require extreme precision and would be very laborious. The benefits of this layout design were also to find extra space for the mechanic and warehouse worker who have a constant need for a desk and computer because of their work. An example of this space can be found in the bottom right corner of Appendix 3. As these thoughts of moving the robot concluded, layout proposal six was designed.

This proposal differed from the previous proposals, and it can be seen in Appendix 4. Proposal six was designed to make different changes to production than before. There was also a desire to present the case company other possible options to choose from. Moving the robot created some uncertainty for the case company. This was understandable, as it was the most popular product line, and the robot had not been moved in production before. However, this proposal could be applied in the future. After all, cell 5 and, in some cases, cell 4 were planned for extension. Proposal six could therefore be possible years from now if an extension is required in cells 4 and 5. In proposal six even cell 3 would not be in the way of enlargement. However, this proposal was rejected because the expansion would also require a significant increase in production. This could take years, so the focus during the thesis project was on current production and how to improve it through layout.

From all six proposals the case company preferred the fifth one. However, this was not ready as such and required modifications both inside and outside the cells. The major modifications involved refining the layout to show all the items that the factory space would contain. This created a more realistic layout which would be easier to identify for both the case company and the production employees for future reference as well as to spot impossible cell placements in time and thus save time in the process. (Moran 2016: 13) Proposal five is shown in figure 10. The layout did not change much in terms of cell locations. With only cell 2 being moved slightly closer to the passageway from the original proposal five. The main change affected the flow direction of cell 1, which was reserved in this proposal. As a result, the robot would also turn and cell 2 would follow because of its equipment. Similarly to proposal four there were some spaces for the mechanics’ and warehouse workers’ workstations in the left corner below. When proposal five was finalised down to the last detail, questions about the functionality of production arose.

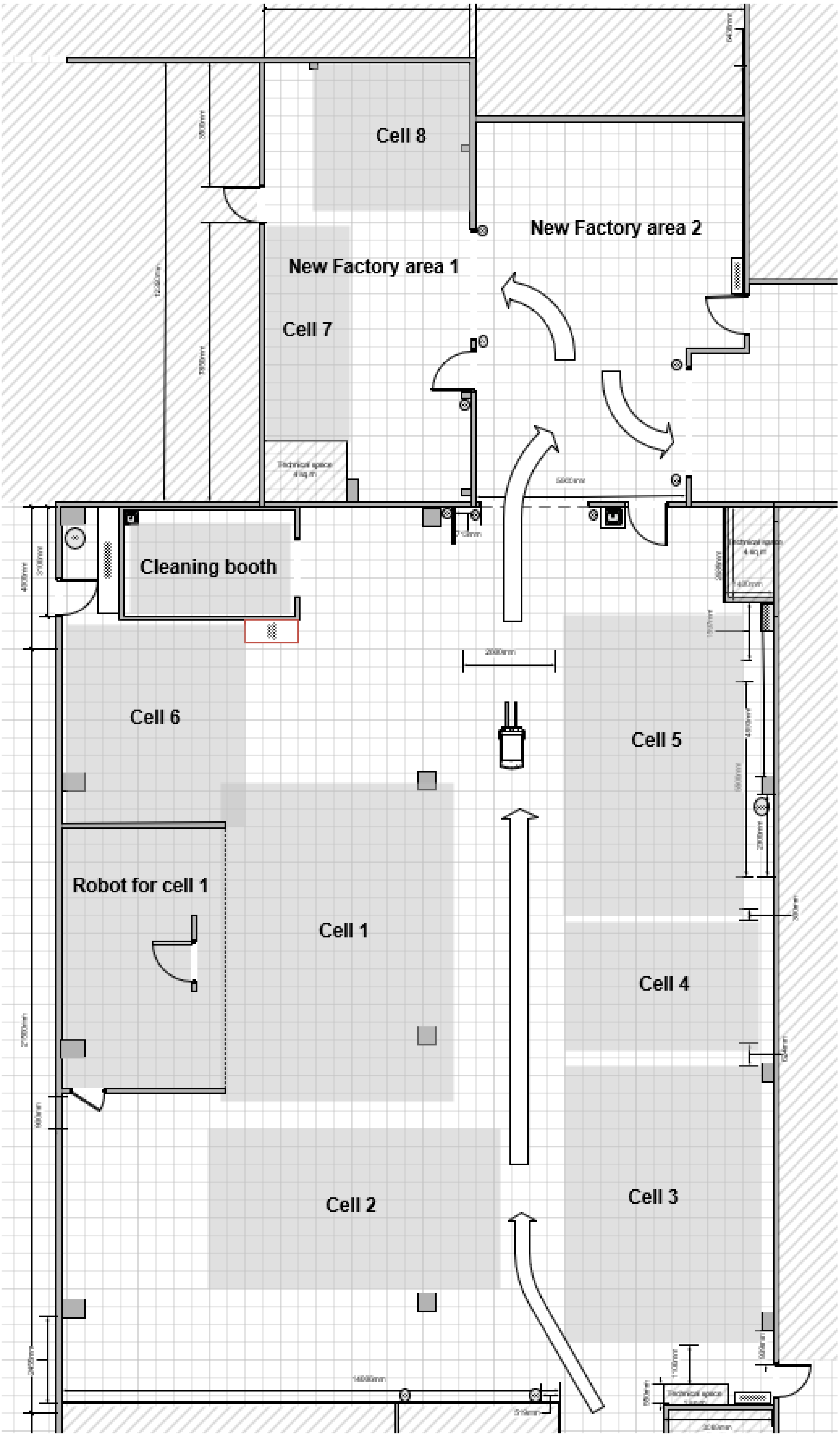

Figure 10. Layout proposal five. [10, p. 30.]

The layout of the fifth proposal was refined and changed to what the case company was content with at the time. When these modifications were finished, and the layout proposal was detailed enough, the next step was to include the production employees in the designing process more than just with the interviews. The layout will expand to new factory premises, and there were some challenges to decide what would be shifted to new premises. This challenge included different product parts and shelves. The extended parts of the layout, the New Factory Areas 1 and 2, would not disrupt the previous flow and flexibility of the factory (Moran 2016: 37). So, uncertain about what would be most functional for production and production employees in the whole factory area, the case company decided to involve them in the design through workshop-style meetings. This allowed case company to obtain their views and allow employees to influence the layout design. This would also be of interest to production employees, as it would affect their output (Kahraman & Yavuz 2010: 360).

6.4 Workshop Meetings

The idea behind these meetings was to provide a blank paper version of the layout, where employees could, as groups, place pre-cut parts of the production as they saw it best. Every part of the production, including the chairs and sub-boxes, was cut into pieces of paper to be glued to an A1-size layout base. The parts were divided into cells using clamps and labelled to know which cell they were. The different cell sections sealed with clamps were also arranged in Minigrip bags, and each was labelled with a different group number. This can be seen in figure 11. This way each group had their bag with the necessary parts to create a layout proposal. These allowed production employees to glue and, if necessary, cut the parts before attaching them. In addition to cutting and pasting, the goal was to get their ideas into the open and possibly implement them together. Four meetings were held, all of which examined the design of the layout in sections. When these workshop meetings were conducted one by one new layout designs and different proposals emerged.

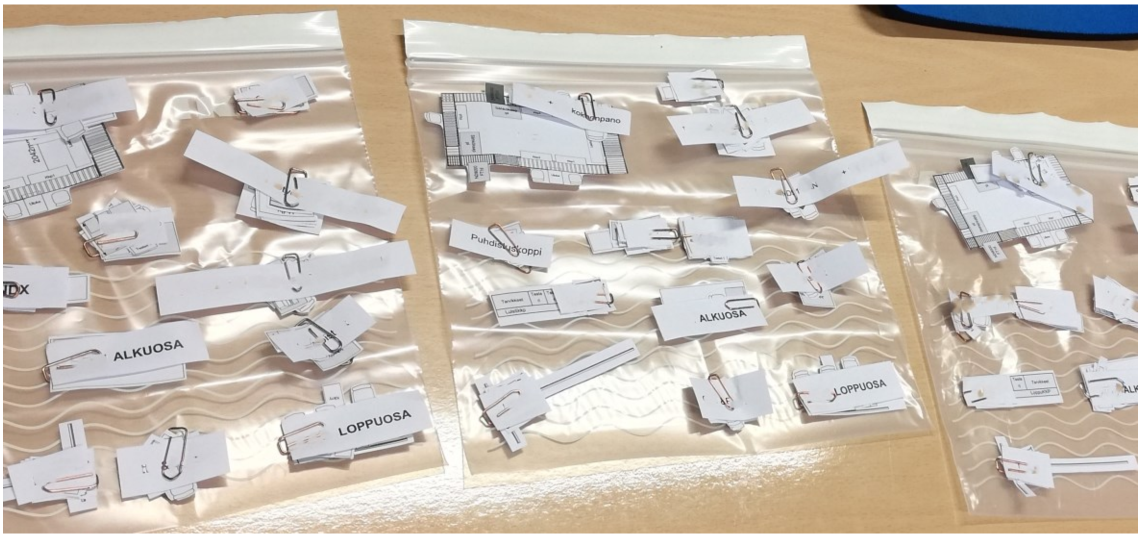

Figure 11. Every cell is divided with clamps and organised for each group with Minigrip bags. [11 p. 32.]

Figure 12 shows in full what was required to run the first two workshops. In addition to these, pens were also needed to write down issues. For the third one, only the A1 size paper sheets shown on the right in figure 12 were needed. While 2D and 3D designs are becoming increasingly popular, paper layout proposals are still created before major layout changes are made, especially before structural changes. (Moran 2016: 13) These paper layouts made it easier for production employees to focus their attention on cresting layout proposals because they could influence the proposals with their handiwork. This made it easier and helped to outline the layout of the factory. However, designing was made more difficult by the amount of material which would be glued to the paper base during the limited time in the workshops.

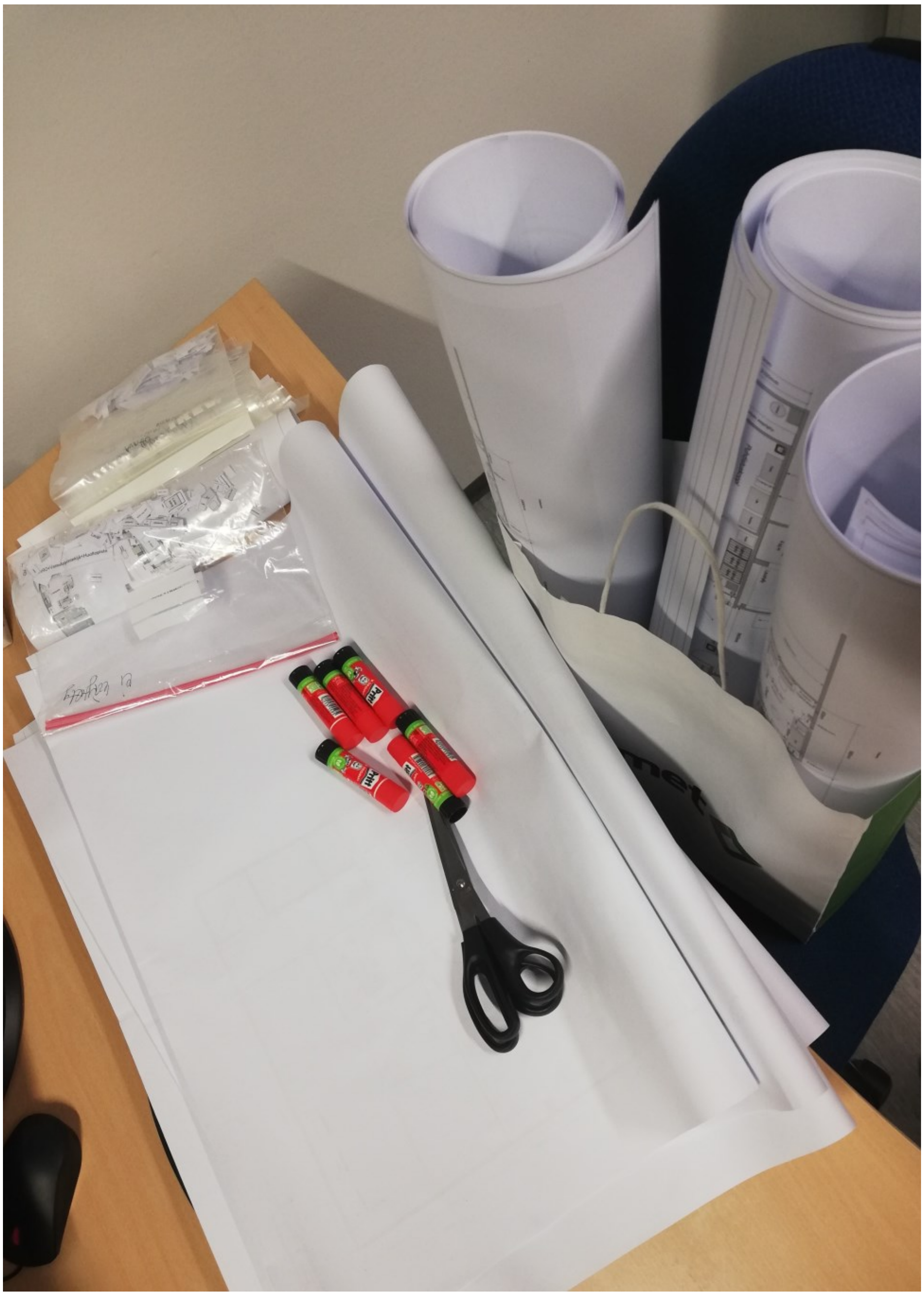

Figure 12. Every part is ready for the workshops and to be used in production employees' proposals. [12, p. 33.]

In the first meeting, seen in figure 13, the aim was to receive different layout proposals from the production employees. These were therefore designed on paper bases with cells 3, 4 and 5 already prepared on the paper. The robot in cell 1 was also ready on the paper. The remaining parts and the remaining cells were placed by the production employees in the places where they felt they could best be placed. To make it easier to start planning the layout, a fifth proposal was brought to the meeting as an example and a contribution. The fifth proposal included two different versions of the New Factory Area 2. The New Factory Area 2 contains production parts and pallets, which in these two examples were moved to different locations. Otherwise, the factory spaces were similar in the examples. These were not much needed because the production employees took the initiative to come up with multiple other ideas.

Figure 13. The first workshop meeting with the production employees. [13, p. 34.]

However, the brainstorming was somewhat influenced by these ready-made proposals, which had previously been sent to some of the production employees by email because of their requests. Nevertheless, this would affect their comfort in production and efficiency in manufacturing, so the workshops encouraged them to consider other options (Kahraman & Yavuz 2010: 359). There are also a lot of different items and equipment in production besides cells. As a result, there is no extra space if the aim is to achieve a type of desired airiness in the production workflow. So, even though there was new space to design the new layout, remembering the limited space was necessity. In other words, space had to be found in the right places without creating unnecessary space. This also limited the flow of ideas in the sense that all the parts had to fit into the layout base, which turned out to be more challenging than expected.

After the first workshop meeting a few ideas came up from the case company. The base idea came from one group, which was slightly modified to produce proposal 7. This was to make a 90-degree turn inside cell 1 so that the cell could be placed higher up in the layout. Cell 2 would move up next to cell 1, and cell 6 would then descend lower. This all can be seen in Appendix 5. While proposal 7 was being considered, cell 2 was modified to a longer version. There were also ideas to shift it to its original model. However, the aim is to make cell 2 and other cells equally efficient and streamlined after the layout change. These ideas were only taken forward to a limited extent, as the proposals from production employees were not yet fully ready and the idea was to use those as a base for the new final layout proposal.

In the second workshop, the plan was to get these unfinished proposals completed. This helped to clarify the ideas of the production employees and to identify whether these were possible to implement. However, only one of the groups finalised their proposal, except for a small tweak. Useful ideas emerged from the other groups as well. Once all the groups' ideas had been discussed it was time to start the reflection of the proposals into proposals which could be implemented. These ideas could also be used as a basis for developing new proposals and to examine in a third workshop.

The third workshop was preceded by case company discussions and a meeting to review the proposals for the third workshop. This included analysing four different proposals to see if they could be addressed in the next workshop. As a result, the case company agreed to present all four of these proposals. All of the proposals were inspired by ideas put forward by production employees. At this stage, it was identified which modifications were not feasible and which modifications were repeated in different proposals. Again, the idea of moving the robot came up with the case company, but this idea was not taken any further.

The preparations for the third workshop were almost identical as for the previous ones. Layout proposals were printed out and made into a PowerPoint presentation. The goal was to present the proposals and explain why the items and cells were arranged in this way, and then let the production employees give opinions on the advantages and disadvantages of the proposals and which one would be the best option. These proposals included the proposals made by the employees in the first and second workshops. The main reason for the third workshop was to obtain last major ideas from the production employees and to possibly start tweaking the last layout proposal or proposals.

Two of the four proposals were rejected at the outset. These were proposals 12 and 13. It became apparent from production employees that the planned modifications to cell 2 would make it more difficult to work in that cell. As a result, the cell would not be modified but would be kept as it is currently. Since cell 2 would now be kept at the same scale, it became clear quite quickly that cell 2 would not fit above cell 1 due to lack of space as seen in Appendix 5, proposal seven already. Cell 2 would then also block the emergency exit, which should have unobstructed access. These issues would be repeated in proposal 12 which can be seen in Appendix 6. This proposal was to be presented at the third workshop, as most of the proposals from the production employees had cell 2 at the top of the production. It was shown that this was not feasible with a red circle around proposal 12. Proposal 13, with the same cell placement as proposal 12, was only distinguished by the relocation of parts and shelves. Compared to the previous proposals, no major modifications in the cells occurred beyond this. Only cell 6 was slightly moved to the centre of the lower production area.

The other two proposals were inspired to a considerable extent by the basis of proposal five. A few corrections were made based on proposals from production employees, precisely for matters that had not been considered from the perspective of an outside observer. So, these were proposals ten and 11, which had differences in part and shelf placement in the same way as proposals 12 and 13. There were differences in part shelf placement even between production employees. This is influenced by the individual working habits of each employee. Therefore, there were not many more cell-to-cell shifts at this stage. Appendix 7 shows proposal ten, which the case company was perhaps the most satisfied with at this stage of the thesis.

In all the proposals, production employees found different considerations that affected the way they moved and worked in production. Furthermore, employees also discussed proposal 12, where enabling cell 2 would not work with this model and scale. In the end, after examining all the proposals, proposal 11 emerged as most suitable for production employees. To sum up, some issues needed to be modified. Some places were too cramped, and others had too much space. Compromises would have to be found between these two. These issues may also have been overlooked because they are not seen in the same way between the employees and case company. This is why the workshops were also successful in the sense that the opinions of the production employees were elicited, but most importantly, problem areas were identified that would affect the efficiency of production. Feedback was also received from employees, which led to further suggestions for production.

Finally, it was decided after the third workshop that two proposals would be made for the fourth and final workshop. The first proposal would be a modified proposal 11. It would be modified based on the ideas from the third workshop. These ideas mostly focused on production details such as the layout of desks, platforms, and part shelves. However, the positioning of the cells did not change. In the second proposal, cell 2 would be above cell 1. In this case, cell 1 and its robot would be moved a few metres lower, to allow cell 2 to fit above at the same scale as it currently is. In addition, the forklift traffic would have enough space to move on production premises. As this was proposal 14, it moved the robot enough to allow cell 6 to fit below cell 1 reasonably. It was preferred to take space from lower areas for above cells 1 and 2 due to their forklift traffic. Proposal 14 can be seen in Appendix 8.

The fourth workshop covered these two proposals in the same way as the third workshop went through the previous proposals. Production employees were divided into four different groups to examine the proposals. However, a significant difference was seen in the generating of new ideas and the evaluation of layout proposals. The silence suggested that there were no further needs for change, and that for the most part, production employees would be satisfied with the production layout proposals. In addition, the fourth workshop was also the last time that such meetings were organised during this thesis project. This was therefore the last time that production employees were involved in examining the proposals and providing ideas. This time, a decision had to be made between the two proposals. The chosen layout proposal could include to a certain extent modifications, but this would not involve any further major changes in cell movements. The production employees voted which of the proposals would be better. Of these groups, three ended up with proposal 14, while proposal 11 received the vote of one group. In conclusion, most production employees chose proposal 14.

In the fourth workshop, cells 7 and 8 were also finally locked in the New Factory Area 1. Cells 7 and 8 had been proposed in New Factory Area 1 for some time and therefore their location was finally decided at the fourth workshop. As these were smaller cells in production, it would mean that the cells would fit perfectly into the enclosed space without feeling overly cramped when working. However, in a previous workshop, production employees revealed that cell 7 is causing harmful noises. This was considered, as noisy places are avoided when locating employees and cells near each other (Slack et al., 2013: 193). Therefore, technical modifications were considered to the cell to reduce the volume. Solutions were provided from the case company’s side. Figure 14 shows the final positions for cells 7 and 8. In addition to this, the New Factory Area 1 contained parts of cells 7 and 8, as well as cupboard space and workstations for maintenance and warehouse worker. The addition of a maintenance station to the layout can also be seen as a factor in production efficiency, as well as an increase in the value of the process (Greasley 2007: 47-48).

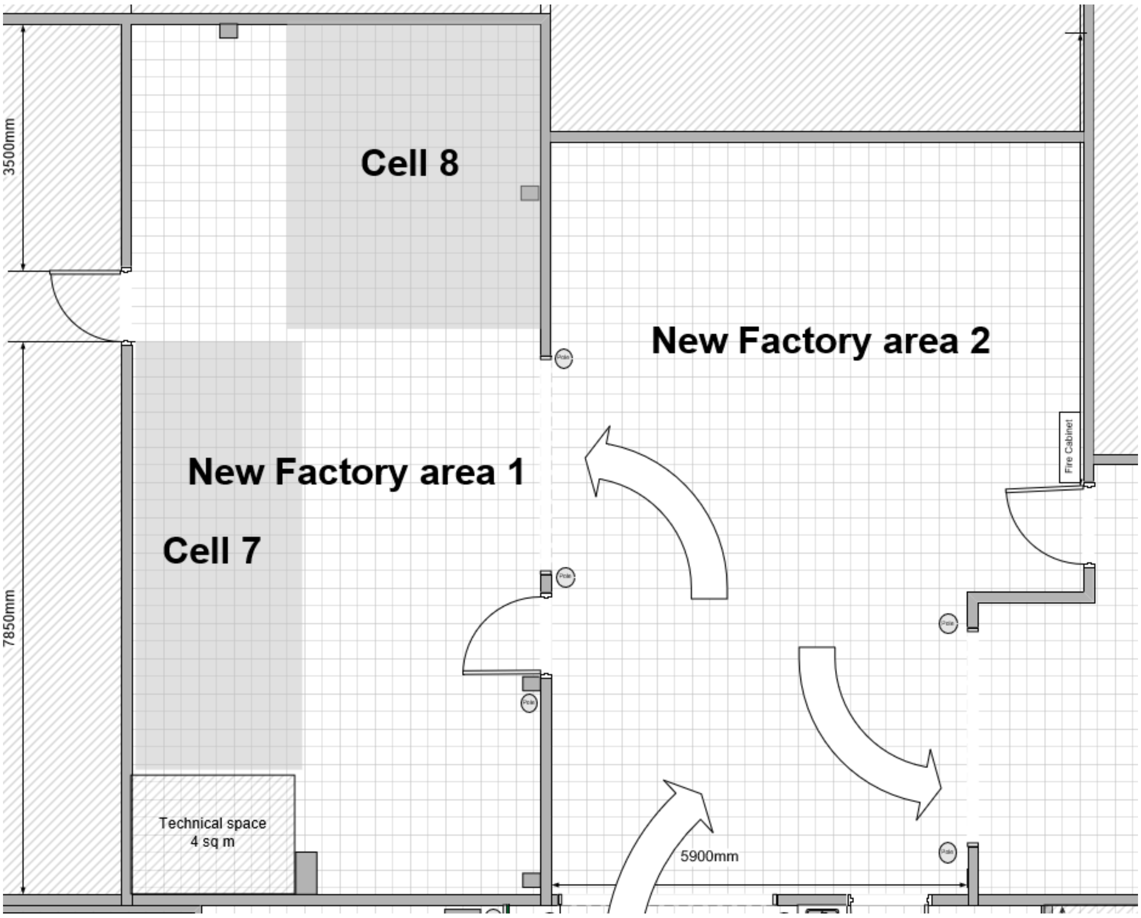

Figure 14. Cells 7 and 8 final positions. [14, p. 39.]

The fourth workshop was concluded with the selection of proposal 14, where cell 2 ends up being above cell 1. Almost immediately after the fourth workshop, little modifications were exposed by the case company as an internal change was made to the workstations in cell 6. This was made to ensure that the equipment needed in this cell would work as designed. Production employees did not find anything to change in the cells except for a single desk transfer outside the cells. Proposal 14 was voted for as it would reduce excessive forklift traffic on production premises. As a result, the forklift would only move next to cell 2, which is a significant change from the original layout. This not only allowed production to be leaner but also increased safety by reducing forklift traffic from most parts of production.

6.5 Final Layout Design Proposal

When these workshop meetings were all conducted, the creation of the final proposal began. Now, the production aspects of creating the layout were known and based on these and the case company's wishes and constraints, final solutions or compromises could be developed. From these last two proposals, one remaining layout was selected in the final workshop, with a few more modifications to the outside parts of the cells. This was proposal 14. Proposal 14 was further discussed with the case company in a meeting. The purpose was to get the company's final opinion on proposal 14 and to ask if this was the proposal that would be used to implement the layout.

The meeting revealed a few things that could still be modified, but these only concerned the layout of the production parts. These things included one of the desks outside the cells that was moved as it was seen as the best option, but also a few adjustments were to make the layout even better. These minor adjustments meant rearranging the shelves of most parts between production and the New Factory Area 2. Even if the layout was designed to be perfect, it was remembered that roughly 90-95% of the layout could be completed on the first try. The remaining percentage evolves and changes as part of production. Therefore, the intention was not to finalise the proposal to its final form as this would be impossible, because the production parts and such factors could still change during and after the implementation process. In addition to this, one of the objectives was also to provide the case company with a proposal that could be implemented after the given time limit of this thesis and which the company would be ultimately satisfied with. (Protzman, Charles et al., 2018) Fortunately, proposal 14 contained most of the factors that could be implemented in production and were successful in the eyes of both case company and production employees.

To sum up, the decision on the layout is one of the most important aspects of production. It has a direct impact on the efficiency of production, but also on the costs of production. (Díaz-Madroñero, Manuel et al., 2021: 1) At the end of the meeting, the case company finally decided on proposal 14 as the final layout proposal. This would be the one that would be implemented on the assembly factory premises. Layout proposal 14 would be presented to the production employees, as it still underwent the mentioned few changes after the last workshop. The case company printed the layout at the production premises. This way the production employees could familiarise themselves with the new layout and future changes at their leisure. There was, however, no longer a possibility to influence matters, as proposal 14 had been decided by the case company. With the layout plan now complete, it was time to move on to the implementation schedule and planning. The case company requested the creation of some sort of implementation plan, which would record the implementation process cell by cell. Implementation plans are usually made to facilitate implementation. This means that the implementation is carried out in a controlled and step-by-step manner. This also avoids various unexpected issues associated with implementation. (Slack et al., 2013: 665)

7 Assembly Factory Layout Design

As the baseline was ready, meetings, and individual interviews as well as workshops were progressing, and the study started to evolve at a promising pace. One by one, as these individual interviews and layout proposals developed, things that would not be successful were rejected. Once the workshops had been conducted and a joint decision on the layout was finally reached with the case company, the layout was ready for this assembly plant and its expansion. It took multiple discussions with the case company and various modifications to the layout, but it was finally finished.

7.1 New Layout Proposal

There were more than ten new layout proposals, but only one of these met the case company’s needs. After the workshop meetings and changing the layout proposals alternatively, a conclusion was made to have one layout which was the best option for the case company. This layout would be something that the company would want to implement on the factory premises. This layout was proposal 14 seen in figure 15. Figure 15 shows the final position of the cells. In addition, the movement of the forklift is represented by a green arrow, up to which the forklift travels in the production area. There is therefore no longer a demand for a forklift in the lower part of the production area. In addition, some parts of production have been relocated to the New Factory Area 2, and cells 7 and 8 are in their intended location.

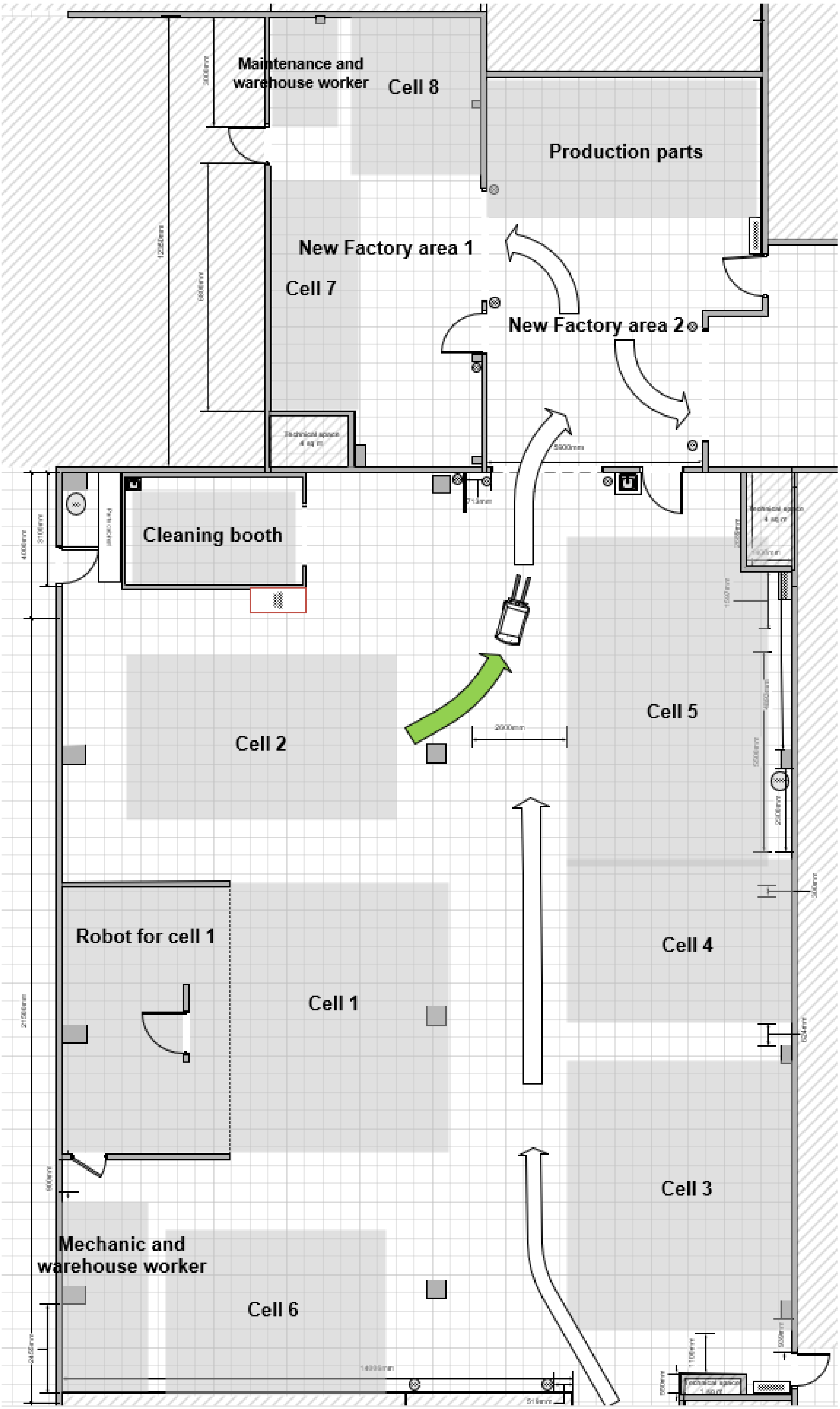

Figure 15. Final layout design for the assembly plant. [15, p. 43.]

In addition, cell 2 will eventually be located at the top of production to reduce forklift traffic. Cell 2 was accommodated by moving cell 1 and its robot lower according to figure 13. The cell was moved by a few metres and the intention was that the forklift would be able to move close to cell 2 without difficulty. Most importantly, the forklift would not endanger or disturb the production employees. In addition, cell 1 would be moved as close to cell 6 as possible to leave clear space for an emergency exit near cell 2. Cell 1 did not undergo any major modifications apart from the translocation apart from some table modifications and component repositioning. Parts of cell 1 also made extensive use of the New Factory Area 2. As cell 1 moved lower in production, the space in the old location of cell 2 was compressed. This smaller space below cell 1 could be used to accommodate cell 6 with its new equipment. Although, this new equipment demands more space, cell 6 would be differently variable compared to other production cells. Part of the reason is that cell 6 is still considerably smaller than the other cells. A mechanic and a warehouse worker with their workstations can also fit next to it.

Finally, cells 3, 4 and 5 did not migrate or experience major changes. Cell 5 underwent intracellular modifications, becoming slightly wider with the changes. The cleaning booth also remained unchanged, and the passageway remained almost in the same alignment as before. Nor did the factory site itself undergo any structural changes, except for the construction of the partition wall of the New Factory Area 2. All the other cells and the placement of production components underwent different changes because of the layout.

7.2 Layout Improvements

Based on the case company's objectives, the thesis was able to create the necessary modifications to the new layout to achieve improvements. Improvements were made from side to side, although compromises had to be made during the thesis. In the new layout, the improvements and modifications can be seen quite clearly. It might be easier to see the improvements by comparing the original and the new layout. Some of the improvements are what the case company requested in the beginning of the thesis.

A new layout plan would generally guarantee the possibility of redesigning the layout in the future with flexibility. In addition, the new layout plan would always minimise any health or safety risks. (Díaz-Madroñero et al., 2021: 1) These issues were reflected in the new layout plan in the introduction of airiness and the reduction of forklift traffic. As an improvement, all the cells and parts were placed in the factory so that there was enough space to walk around and work. In other words, it was possible to bring a certain amount of freedom and flexibility into production for the work itself. Another major improvement was the reduction of forklift traffic in the production area. Forklift traffic would therefore only remain at the top of production, as shown in figure 13. This would also make production employees less vulnerable to incidents. In addition to this, reduced forklift traffic can be seen as an improvement for visitors when they are visiting the site. Visitor safety would also increase in this regard.

While the aim was to create more space to work in production, the aim was also to reduce extra movement around the production facilities. Excess movement was and will continue to be affected by the placement of parts in production, even after implementation. In cell production, it is typical to keep the parts needed in the cell or close to the cell (Slack et al., 2013:197). This principle was utilised to keep the parts as close to the cells as possible and the new layout plan allowed this to be achieved for the most part. However, some production cells' parts would be in the New Factory Area 2, but these parts were retrievable by production employees once or twice a day. This can be seen as a compromise in the process, but also as an improvement in terms of airiness. However, the relocation of some parts would not affect the efficiency of production or the cells. In addition, one of the main goals of the thesis was to place the equipment of cells 1 and 2 close to each other. In line with the objectives, cells 1 and 2 were placed close to each other because of their equipment. This enabled the customer's wishes to be fulfilled, as well as making it possible to increase production efficiency.

When it came to designing the new layout, it was quite clear that the objectives of the thesis could not be achieved without making significant modifications to the layout. The modifications included both internal cell changes and cell repositioning. Major intracellular changes were avoided due to the repositioning of the cells and the expansion of the factory premises. Once the layout has been implemented, production employees may begin to experience what is known as change resistance. Modifications to a new layout may be seen as making work more difficult when it may be a matter of getting used to the new layout. This shows how important it was to involve employees in the design phase of the layout, and to familiarise them with the layout so that the employees are able to anticipate modifications. It is also advisable to provide some guidance to employees after the implementation of the new layout. (Protzman et al., 2018)

7.3 Implementation Plan

Implementation would take place later cell by cell and it was discussed with the case company what would be the best method to implement the layout in production. The implementation should be precise, as the devices that keep the cells running would still work after the implementation. Moving a millimetre in the wrong direction could negatively affect cell function. Therefore, the implementation would be done at a steady pace and measurements would be taken at certain intervals. The structural modification that was made to the plant by adding a partition wall to the New Factory Area 2 also had to be considered here. However, this partition wall does not extend to the ceiling, thus affecting the temperature in the area. The other areas of the factory have air conditioning, as previously noted, but this also affects conditions in the winter in addition to summer. The New Factory Area 2 is therefore cool in winter. Therefore, parts to be moved there would be such that they do not need to be picked up continuously but only once or twice a day. This would also minimise excess movement in production areas, in line with lean principles (Protzman et al., 2018). This was also the subject of the fourth workshop meeting, where the idea of a not airconditioned and unheated facility was raised with production employees. As the implementation would take place later this year, it would start from cells 7 and 8.

The implementation could start from New Factory Areas 1 and 2. These were cleaned and cleared from the previous users to allow the cells to fit inside. After these changes cells 7 and 8 would be placed first. During the movements, parts and other production items would also move behind cells or temporarily to areas where they could remain for a while. However, the aim was to arrange the parts as quickly as possible and take advantage of the New Factory Areas. The repositioning of parts was cautiously predicted before the start of implementation and after the new storage shelves became available in the New Factory Areas. Therefore, New Factory Area 2 was subsequently filled with production parts after the placement of cells 7 and 8.

This would be followed by the internal modifications on cell 5. As the cell becomes wider, parts of the cell are repositioned. The next step would be the relocation of the mechanics' and warehouse workers' workstations, as well as other relevant parts of production according to the implementation plan. Cell 1 would then be relocated. After the relocation of cell 1, it may be necessary to leave part of the cell unmoved to the last location. This is because cell 2 would be moved to the other side of the production next to cell 1. This may also require cell 6 to be split or temporarily repositioned in the middle of production. Once cell 1 has been located, cell 2 is moved to the other side of cell 1. When cell 2 is moved, it may also be necessary to split the cell into smaller parts to facilitate the move. Lastly, cell 6 would be moved to its new location. As the implementation and work progresses, the remaining parts will be moved to new locations and later better locations if necessary.

8 Summary and Reflection

The thesis proceeded according to the given schedule and as a result of this thesis a new layout was created for the case company’s assembly factory. The thesis includes the design of the layout up to the implementation plan. In addition, issues that arose during the project were addressed continuously. Through improvements, meetings and discussions, the result was what the case company eventually requested. To sum up, the thesis turned out as expected and was a successful project.

8.1 Thesis Targets and Results

This thesis’s targets were to design and provide possible option or options to the case company. The proposals would include New Factory areas, bringing the layout up to date. In particular, the new layout would better meet the demands of production than the previous one. Additionally, there were plans to incorporate the new design into production if there was time to spare. At the end of the time limit, this thesis included the new layout proposal for the case company and the plan for the implementation process. The plan would include a schedule for each cell according to which the company would implement the layout. The thesis met the case company’s requests, and the study was completed by the objectives.

8.2 Thesis Reflections

The objectives of the thesis were achieved, and the thesis was completed within the time limits. The study took about a month and a half, during which the layout of the entire production area was completed. If this project were to be conducted again, a different perspective would certainly be included. This perspective could be more balanced between the opinions of all employees involved. A more anonymous way of eliciting ideas could have been found to ensure that everyone's opinion was heard. The new perspective could also pay more attention to the timeframe, and how new layout proposals would be created. The perspective of the layout could also have been limited so that the thesis would address the topic more through Lean than through design and cell production.

In addition, as the thesis progressed, different ways of executing the layout proposals could have been experimented with. The layout could have been done with a different software and, for example, paper layout plans could have been omitted and instead fully digital versions could have been produced. Microsoft Visio provided a very accurate version of the layout, including the dimensions of the production facilities. The program was also straightforward and simple to use. The paper versions, on the other hand, allowed for interactive design with production employees. However, the paper versions added additional work to the project, and Microsoft Visio was not as visually fulfilling an image as initially outlined. If the paper versions had been removed, production employees would have needed some digital equipment to edit the digital layout proposals. However, it would have been easier to edit the proposals, and continuous printing would have been avoided. A more visual and multi-dimensional layout would have been achieved with 3D modelling. This type of modelling was mentioned in some of the discussions. The case company would also have liked a 3D model of the final layout, but unfortunately there was not enough time to model this.

For future development, this new layout design has space for production growth and the opportunity to move cells or different objects to another location. A possible increase in the capacity of cell 4 was also included in the plan. New equipment acquisition will therefore not implement a new layout or cell change. For this reason, it is important that the layout planning is thoroughly done from the beginning. The baseline study helps to get more familiar to the case company, as well as to the production. It is therefore helpful to understand what sort of base the layout will be made on. Once the layout base is familiar enough, relational modifications can be made and, if necessary, solutions for the future can be found. Additionally, without a proper baseline study, the layout could not be planned to the end, as a lack of thorough baseline study could lead to communication problems, as well as incorrect assessment of the situation.

In conclusion, in the future, the layout can still be modified after the implementation. This will of course be affected by how the cells expand and whether there are changes in demand for products. The capacity of cell 4 can be expanded by new equipment purchases, and cell 5 will already expand but can keep expanding due to demand. Given the expansion of cells 4 and 5, these could be the next steps for this assembly plant.

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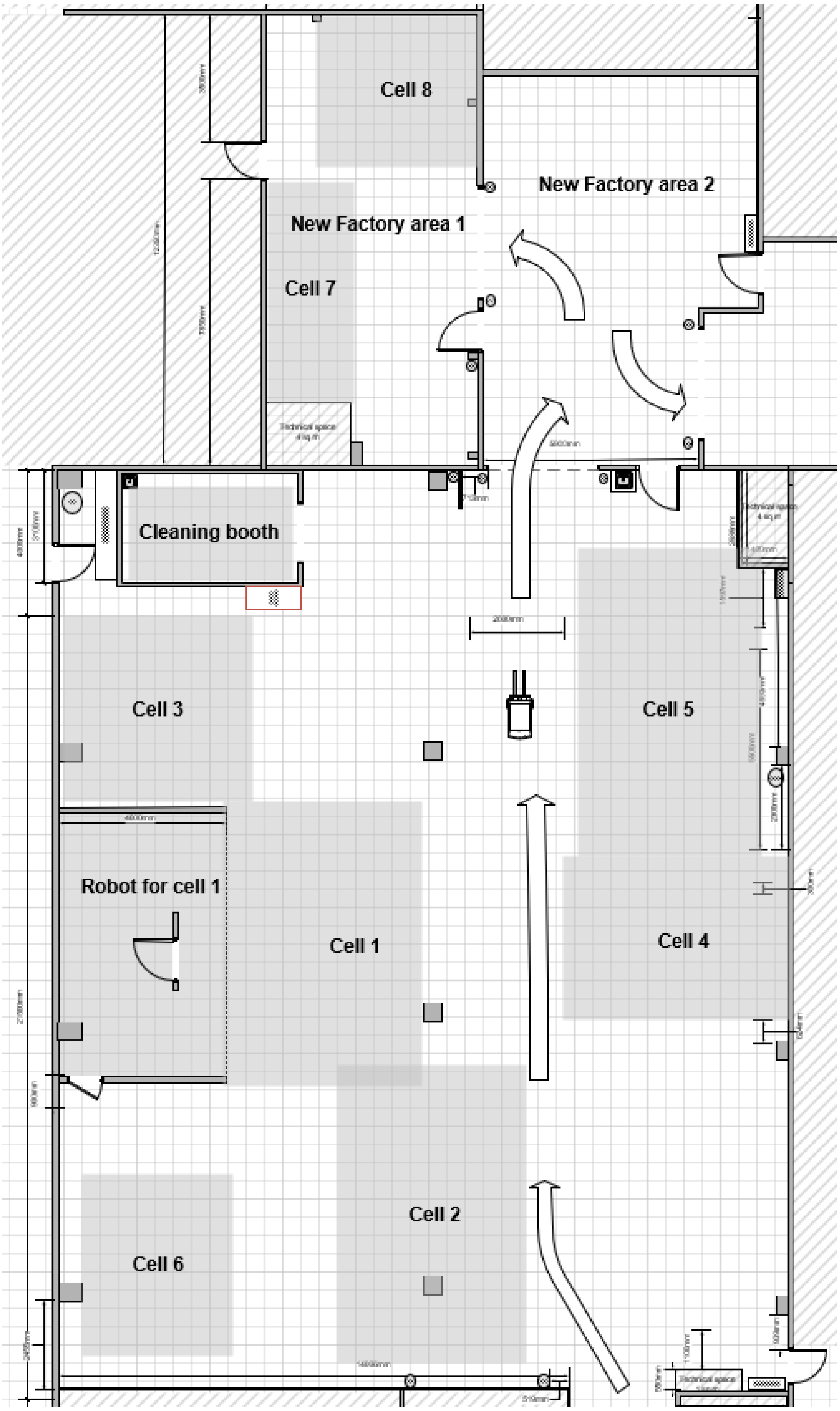
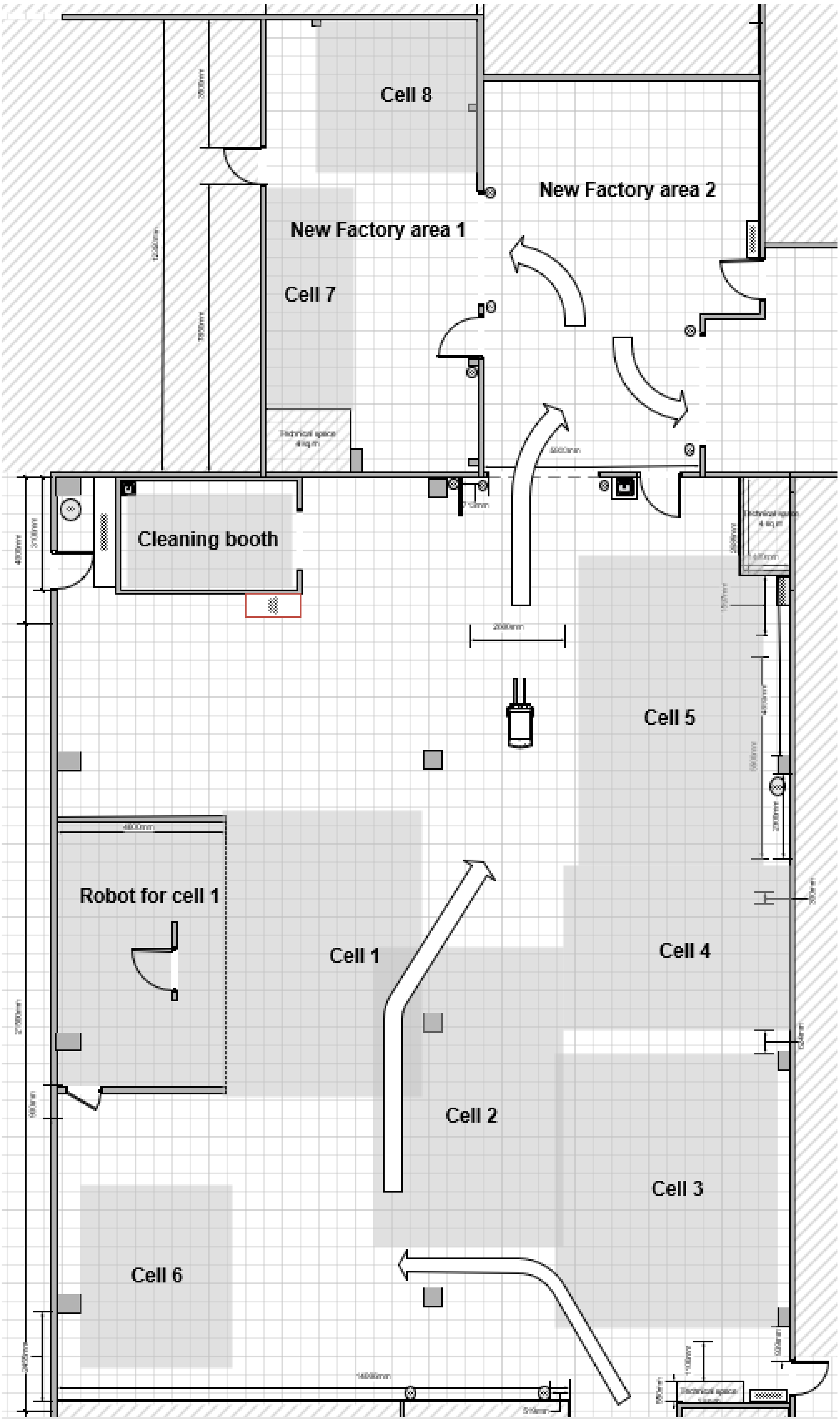
Appendices

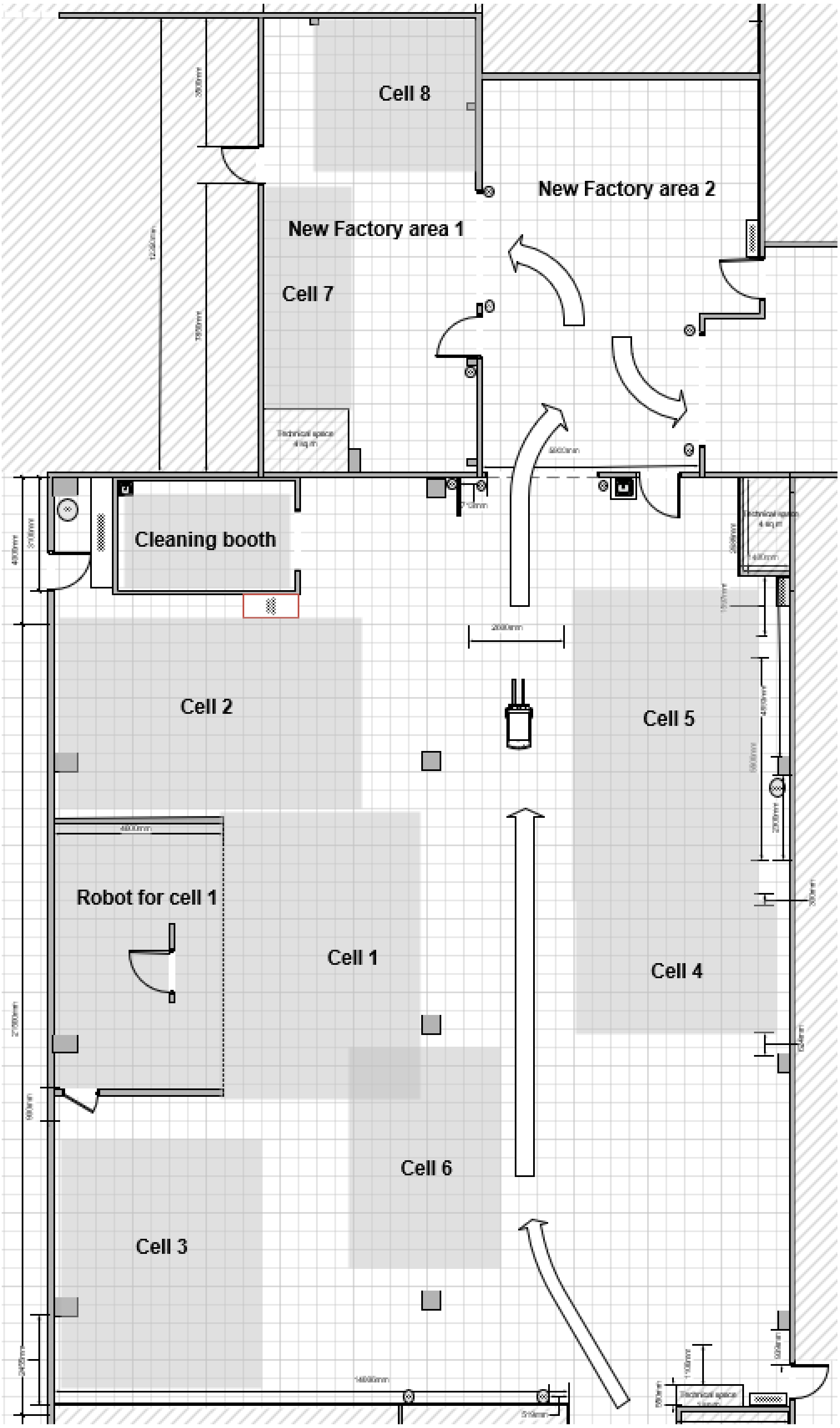
Appendix 1. Layout proposal one.



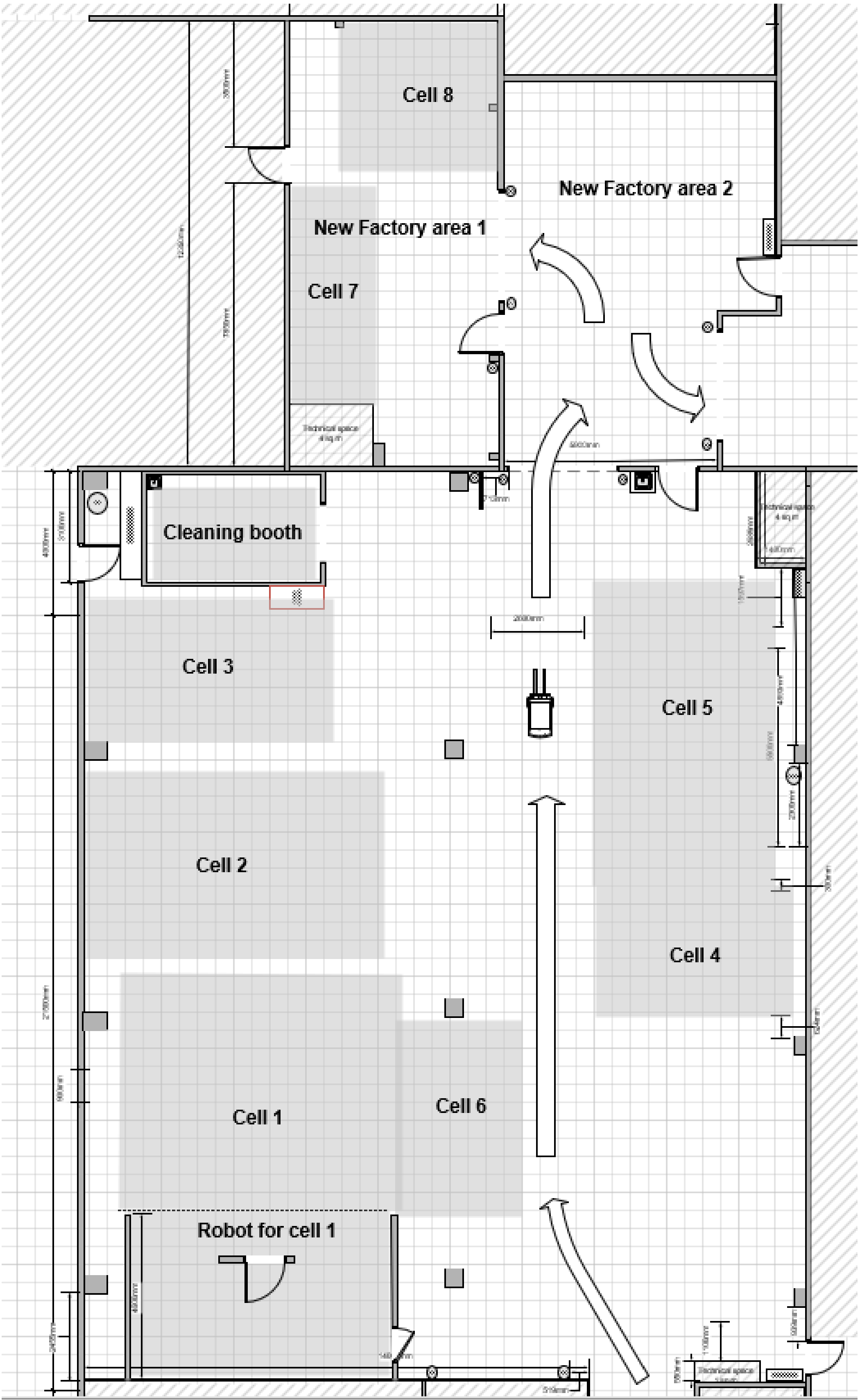
Appendix 2. Layout proposal three.



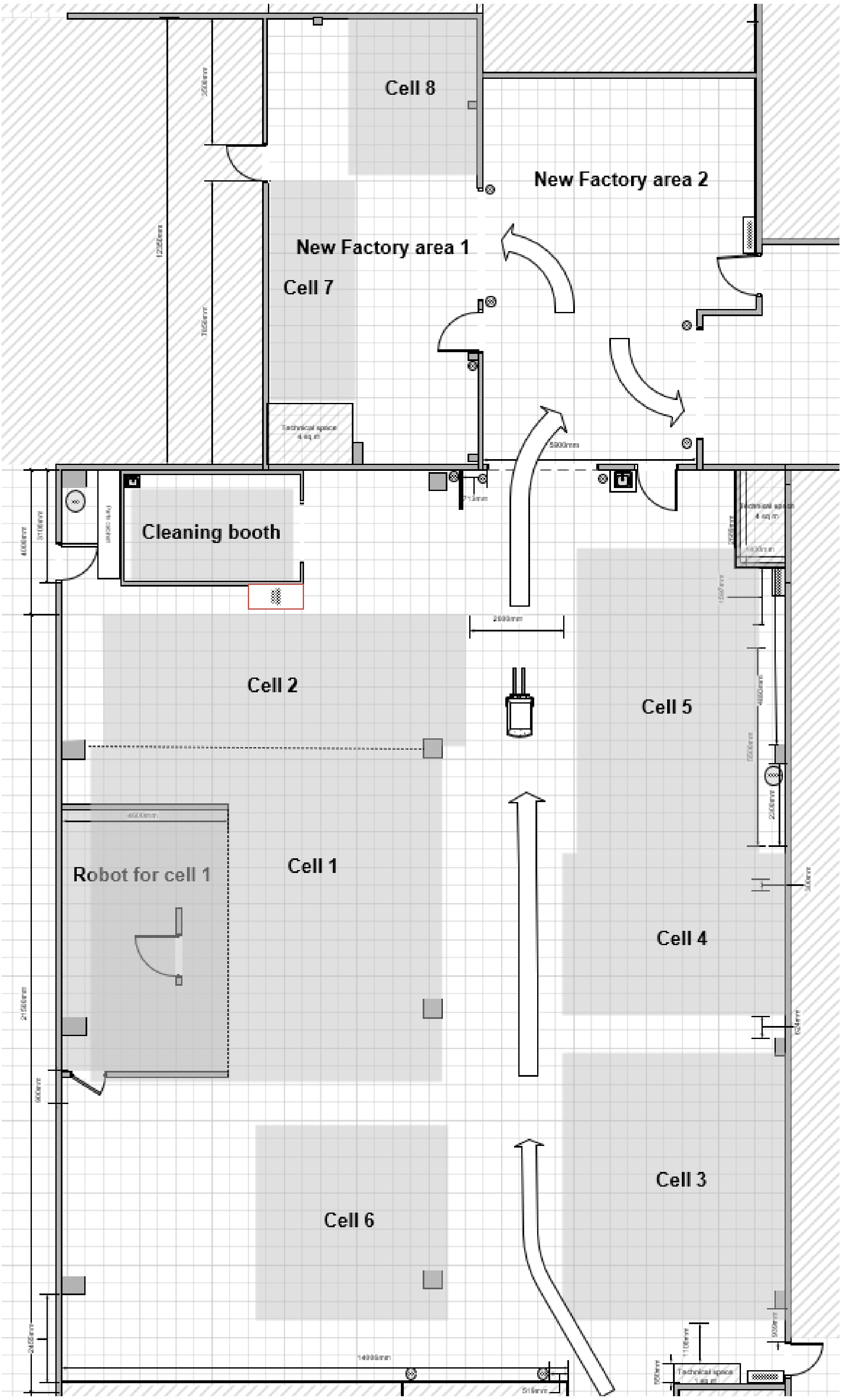
Appendix 3. Layout proposal four.



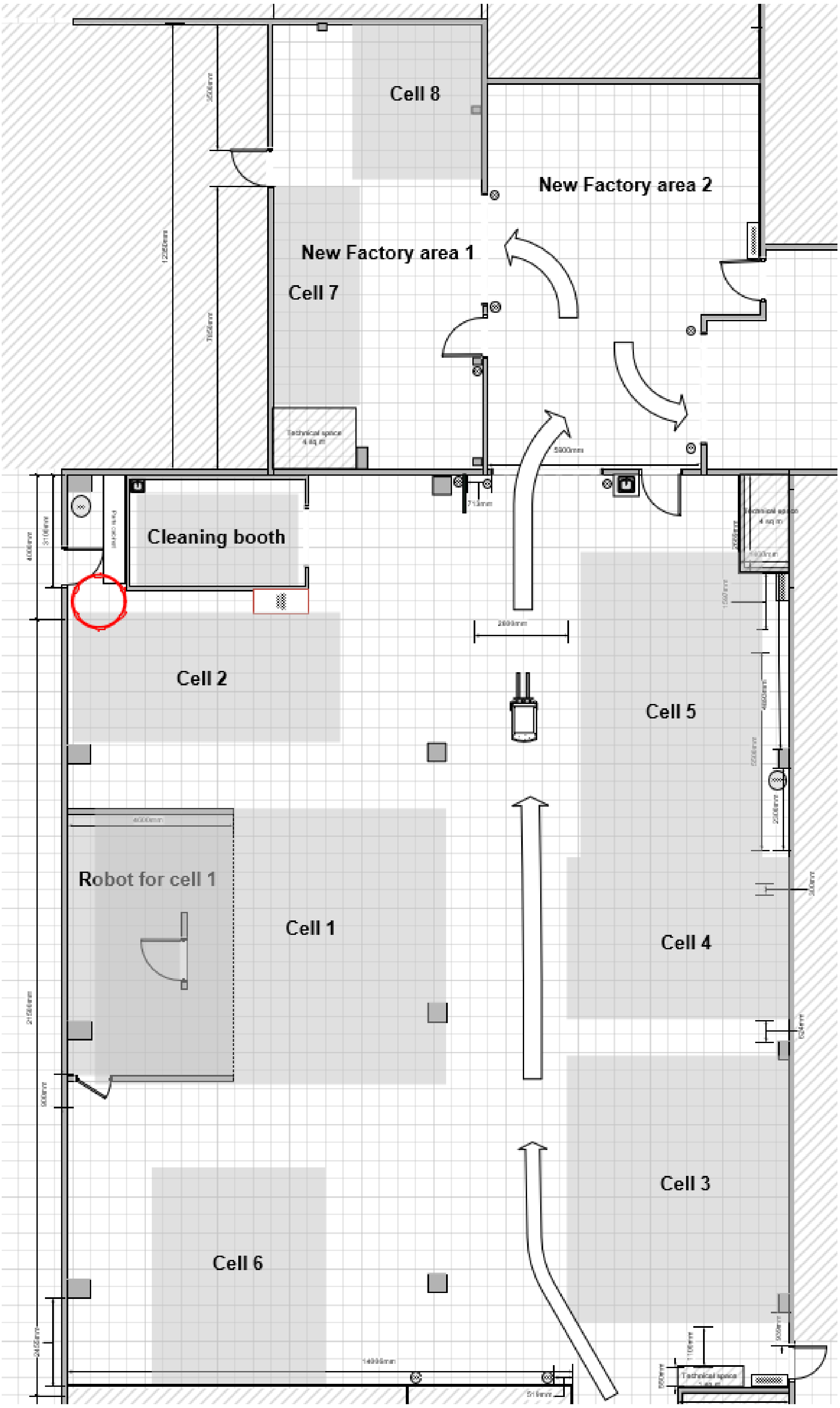
Appendix 4. Layout proposal six.



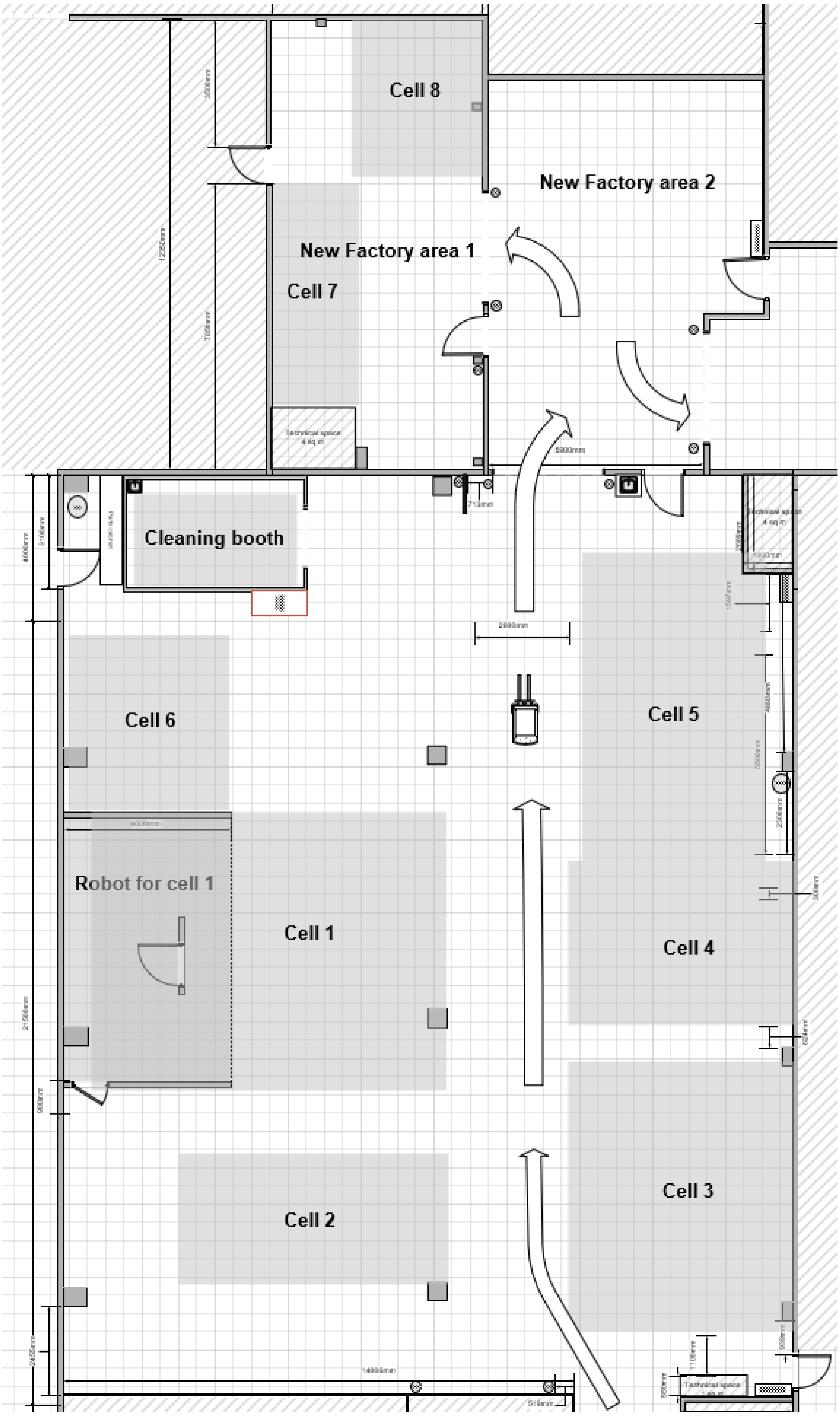
Appendix 5. Layout proposal seven and the first proposal after the first workshop meeting.



Appendix 6. Layout proposal 12 with a red circle to highlight the difficulties of the proposal in terms of the location of cell 2 and the movement of production.



Appendix 7. Layout proposal ten, with the same cell positioning as proposal 11, which was the preference of production employees at the second workshop.



Appendix 8. Layout proposal 14. Another of the last proposals which was shown at the last workshop.