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Developing a model to improve production layouts in the heavy steel industry

Master of Science Thesis in Supply Chain Management

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Abstract

The importance of efficient methods for developing the production layout has grown tremendously over the last decades and is likely to continue to do so.

Although several new technologies and models are developed in the field of layout planning, there are still many areas that lack the attention from specialized research.

The aim of this thesis is to develop and test a model for re-layout planning intended for the heavy steel industry.

The creation of the model and identification of proper tools was entirely research-based. This means that all parts of the model are previously well established academic approaches. These were chosen so that the final model would be well adapted for the intended environment.

The evaluation model was built so that it permitted several parameters to be evaluated against each other. Even though the model was built to consider a tight investment budget, a capacity increase of 7.7% proved to be possible. Furthermore, nearly two hours of operator time could be saved per day and the production bottleneck up-time could be decreased with 1.1%

The final model proved to be well applicable for the case company and the final layout solution that was generated showed that improvements were possible.

Keywords: Layout, Production Flow, Systematic Layout Planning (SLP), Procedural Approach, Process Analysis, Analytical Hierarchy Process (AHP)

Acknowledgements

With this thesis I complete my studies towards a MSc in Supply Chain Management.

The path leading here has been a crocked trail. Along the way I have received help and guidance, for this I wish to express my sincere gratitude.

Many thanks go to my supervisor at Chalmers, Andreas Hagen, who has helped me to turn this research project into a proper, academic, Master Thesis.

My gratitude also goes to my supervisors at Ovako Hofors AB rolling mill, Lars Viklund and Ludovic Gailleton, and everyone else at the rolling mill that has assisted me with information during the last five months.

Peter Jerkrot

Hofors, September 2011

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1 Introduction

This chapter introduces the reader to the subject. The reader is encouraged to study the company layout (see appendix 10.7 and 10.8) and the glossary (see chapter 9), as this would help to create a better understanding while reading the report.

In the highly competitive steel industry, market volatility and uncertainty may cause severe damage to companies that refuse to adapt to the reigning conditions. An efficient flow is no longer a long term competitive advantage. Fluctuations and changes in the conditions may often demand an adaption to stay profitable.

Balakrishnan et al (2003) states that a dynamic environment demands a dynamic layout and material handling. The production layout should not be fixed but instead dynamic and adapted to major changes in the environment. The need to continuously review the production process has over the last decades grown substantially. This creates a demand for simple and easy to use process mapping techniques. In order to map the process, well adapted models and tools must be used that fits the type of production that the model shall apply to.

The Ovako group produces long special steel products in the segments of low alloy and carbon steel. It is delivered mainly to the heavy vehicle, automotive and engineering industry in the Nordic countries and Europe. The group altogether produces 1.3 Mton steel per year, has a rolling capacity of 1.1 Mton and a net sales of 1,100 M EUR. The Ovako Hofors AB rolling mill produces altogether 455 kton rolled steel per year. Out of this amount, 240 kton is processed further in finishing activities (Ovako Webpage 2011).

1.1 Problem Background

Plant layout and material handling is said to affect productivity and profitability more than most major corporate decisions does. If the production layout is enhanced, the entire company profitability will increase (Meyers 1993).

The awareness of the impact of a carefully planned layout has over the last decades increased significantly. Many studies have been presented that claims to have found the superior layout planning method (Gero and Jo 1998, Chien 2004).

Chien (2004) states that many new technologies such as fuzzy logic theory, dynamic programming, genetic algorithm, computer simulation, computer- aided layout techniques etc have been developed in order to assist enterprises in planning a new layout. There has been a massive research effort in this area and highly advanced mathematical algorithms have been developed over the years. Despite this, the old procedural approaches have become proven tools and well regarded in the academia as well as in the industry (Chien 2004).

There is also a trend in the academia to leave the idea of “one universal method” behind. Instead several studies are carried out to develop an optimal model, adapted for just one narrow area. Despite this, the steel industry in general seems to have earned little attention from scholars, and few proposed layout techniques adapted for this environment have been presented (Yang, Ton Su and Hsu 2000, Chien 2004).

1.1.1 Problem Background- Case Company

The factory at Ovako Hofors AB rolling mill consists of two great halls; a rolling operation (hall 7) and a finishing operation (hall 2). After this the material is loaded on either train carriage or rack to be operated by forklift (see Figure 1).

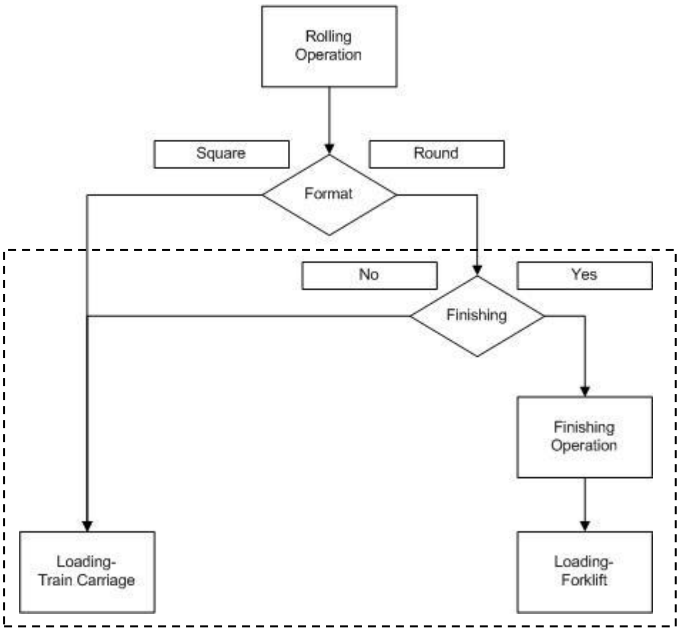


Figure 1. Entire rolling mill operation (dashed line indicates operations in hall 2)

The flow is currently divided in two different directions after rolling operation. These are then reunited in the beginning of the finishing operations (see nr 1 and 2, Figure 2). Together with a third incoming external flow (nr 3) this creates a junction that may cause congestions.

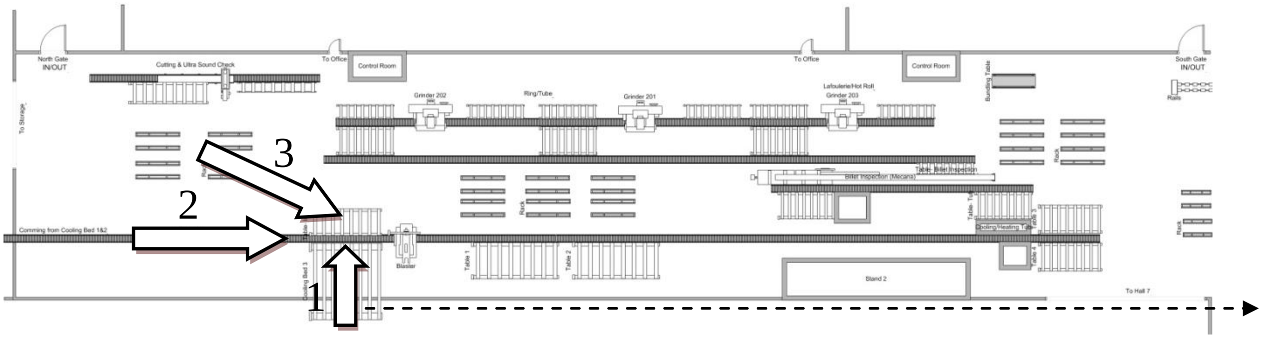


Figure 2. Congestion in the finishing section (after rolling operation)

A forthcoming change in customer demand will make this layout inappropriate. A pre-study has therefore been conducted by the company aiming to change the materials flow in the rolling operation. According to this pre-study, an increased production capacity of 9 percent would be achieved, if one of the flows (nr 1) was to be redirected to the other end of the finishing section (see dashed arrow, Figure 2).

A predicted change in customer demand also forces the company to increase their uptime at certain activities, which the current layout is not adapted for. This together creates a whole new situation for the finishing operation. The finishing operation must after these changes been implemented be able to receive material from two different directions and also to handle increased production rates.

1.2 Problem Definition

Academic- *Out of generic models and methods create a model specialized for the heavy steel industry.*

Proven and accepted methods from the academia must be incorporated into one model that is optimized for these special conditions. The necessary data must be collected and aggregated in an appropriate manner for each step in the model. Each step must then be adapted so that the output from the previous step fills the needs from the input in the next step of the model.

Case Company- *Optimize the material flow in the finishing section and dimension the process for the upcoming changes while considering all limitations.*

The future situation for the finishing section is currently unknown. This new situation must therefore be mapped so that production up-time is established for all activities in the process. The final layout must then be based on this data so that the optimization is made according to the future state, and not according to the current state.

1.3 Purpose

The aim of the thesis is to develop a model for designing new production layouts in the heavy steel industry. The model will be applied on a real case scenario in the intended environment.

1.4 Delimitations

Due to time restrictions, one isolated part of the production layout had to be chosen. This case study was therefore performed at the finishing section after the rolling operation. The actual rolling operation was not a part of the study.

Some machines cannot be moved since this would mean a too great and expensive operation. These machines are the three grinders as well as the billet inspection. The machines are built into the very foundation of the factory floor, and a huge savings potential would be needed to justify such a move. All natural limitations such as earlier factory layout, size and shape of the building etc was also considered.

When all the material which passes through hall 2 is added together this is referred to as 100% of the production. One large part (the square material) does not enter this section of the plant, and therefore this material is not considered in this research.

1.5 Outline

Chapter 1: Introduction

This part describes the Background and purpose of the thesis. The chapter answers the question; why the subject is of importance.

Chapter 2: Methodology

Deals with the knowledge and the reigning opinions in this specific area of research. The design of the study is motivated, justification for the chosen study approach as well as some comments about other possible approaches.

Chapter 3: Frame of Reference

Description of the theoretical framework when it is considered needed for the reader to understand the arguments.

Chapter 4: Empirical findings

This chapter describes in detail the current state of the research area. Furthermore it contains the forecasted future state. Here will the important relations be presented that the analyses in the next chapter is built upon.

Chapter 5: Analysis

The analysis and the results the analyses led to will be presented here. This part contains the analyses of the different flows as well as final layouts.

Chapter 6: Discussion

Discussion around the findings and some thoughts about why the result came to be and which obstacles that stood in the way for further improvements.

Chapter 7: Conclusion

The author's conclusions from the research. Also contains a summary of what this thesis has contributed with as well as recommendations for future research within the area.

Chapter 8: References

All references used in the research

Chapter 9: Glossary

Important words and definitions

Chapter 10: Appendices

Documents and charts important for the understanding of the research

2 Methodology

This section concerns the method that has been chosen and how the data have been collected. Tools that have been used for the gathering of data are decribed in detail and motivated why these tools are prefered to others.

2.1 Choice of Approach

According to Patel and Davidson (2011), logical reasoning can broadly be divided into the two sub groups; inductive and deductive reasoning.

Deductive research is conducted from a general theory down to a more specific theory, also called a top-down approach. A deductive research therefore puts the theory to the test. Normally this kind of research starts with a theoretical framework where the theory makes the foundation for the hypothesis, the observations and finally the result or confirmation (see Figure 3).

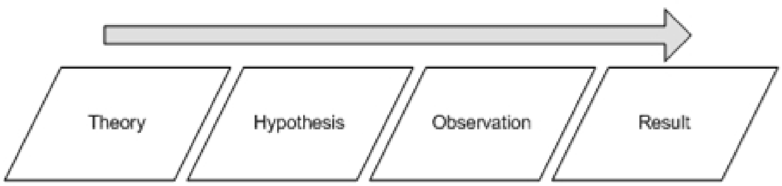


Figure 3. Deductive Approach (Patel and Davidson 2011)

An inductive approach is the opposite. The theory is being derived from the observations made in the research, a so called bottom-up approach (see Figure 4).

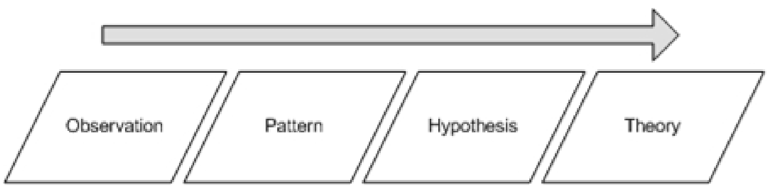


Figure 4. Inductive Approach (Patel and Davidson 2011)

This research is mainly deductive. However, in practice it is uncommon to have solely a deductive approach without any element of induction (Murray and Hughes 2008). When analyzing the data that has been collected with a deductive approach, this will in several stages of the research lead backwards again. If new patterns are appearing that could lead to a change in the theory, this would lead to an inductive approach. This is therefore an iterative process and could be seen as a continuous circle rather than a one-way-latter (see Figure 5), (Patel and Davidson 2011).

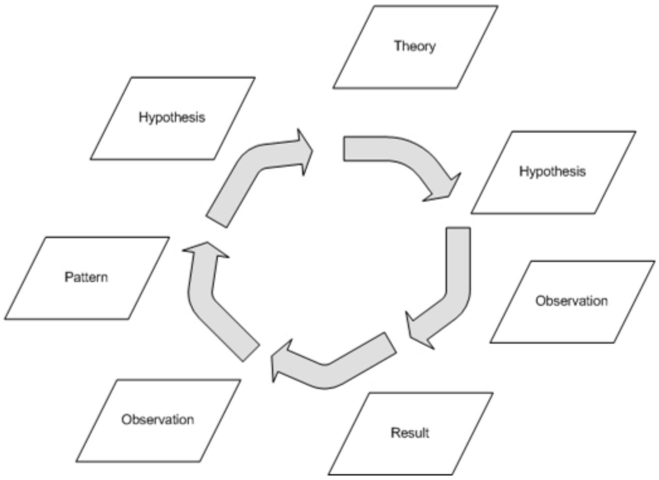


Figure 5. Deductive and Inductive approach (Patel and Davidson 2011)

This thesis will take both a qualitative and a quantitative approach. As expressed by Donald Cambell (1974): "All research ultimately has a qualitative grounding".

On the other hand, Fred Kurlinger is once supposed to have said: "There is no such thing as qualitative data; everything is either 1 or 0" (Miles and Hubberman 1994).

There has been a long struggle about which of the methods that is the most academic correct one, and also if the methods actually are possible to separate entirely from each other. Gherardi and Turner (1987) once contributed to this struggle through their book: "Real Men Don't Collect Soft Data". However, according to Miles and Hubberman (1994) both qualitative and quantitative data collection is a necessity to be able to understand the research.

The gathered data is mainly secondary. This is according to Business Dictionary, BD (2011) "published data or data collected in the past". This data has been extracted from the company's business system.

A part of the data collected has been primary data, which according to BD (2011) is defined as "data collected from first-hand experience". This is the cycle times that have been extracted in real time from the production as well as discussions with operators and managers at the company.

2.2 Research Model

Existing models within the area of layout planning can generally be sorted into two different categories.

One of them is algorithmic approaches which often are based on advanced mathematic algorithms. Many of these techniques also demand the possession of a deep mathematical knowledge from the user of this approach. The techniques are usually focused towards simplification of both design constraints and objectives. Therefore the output from these methods often needs further modifications in order to satisfy more detailed design requirements.

Usually an algorithmic approach only involves strict quantitative data.

The other category is the procedural approaches. These approaches are more open for the incorporation of both quantitative and qualitative data.

The quality of the outcome from the procedural approaches is much affected by the experience from the one conducting the project (Yang, Su and Hsu 2000).

According to Gero and Jo (1998) there are many issues still to be answered, which have been identified in previous research papers. They state that there are three major questions in a layout project. These are: “how to formulate this complex and non-linear problem, how to control the combinatorial nature of the generated solutions, and how to evaluate the solutions based on the multiple criteria associated with the given requirements”.

Yang, Su and Hsu (2000) states that the answer to these questions could be a solution where different models are combined. The two first questions are dealt with in the procedural approach. However, the multiple objective decisions in the evaluation would benefit from an approach more of a hierarchical nature. They therefore suggests that a procedural approach technique could be joined in the evaluation state with Analytical Hierarchy Process (AHP), in order to handle the last issue formulated by Gero and Jo (1998).

The model in this thesis will be based on the procedural approach technique. There are two reasons for why the alternative, algorithmic approaches, are discarded. First, these approaches are not as capable of handling qualitative data as the procedural approaches. Secondly, as previously stated, a deep mathematical knowledge is necessary to develop and manage such a model.

This model will be based on a procedural approach layout technique called Systematic Layout Planning (SLP). Although many different names and variations exist, most of the procedural approaches usually come down to smaller variations of this method (see Figure 6).

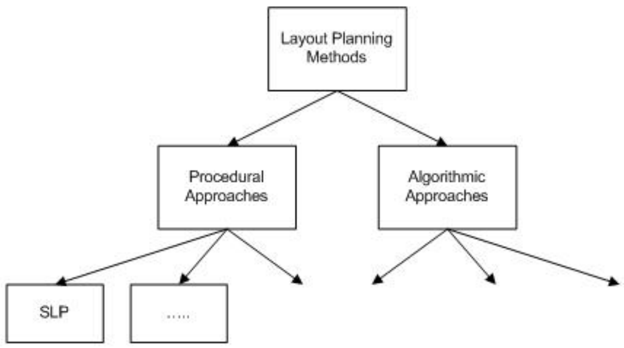


Figure 6. The foundation of layout planning

As described by Muther (1973), the type of production indeed affects which sort of data collection that will be most successful. Given below are the different tools, as presented by Richard Muther. These are all chosen according to the SLP model (see chapter 3.2.1). The tools not chosen are other strong tools for a layout project, but they are less useful in this type of industry (see

Figure 7).

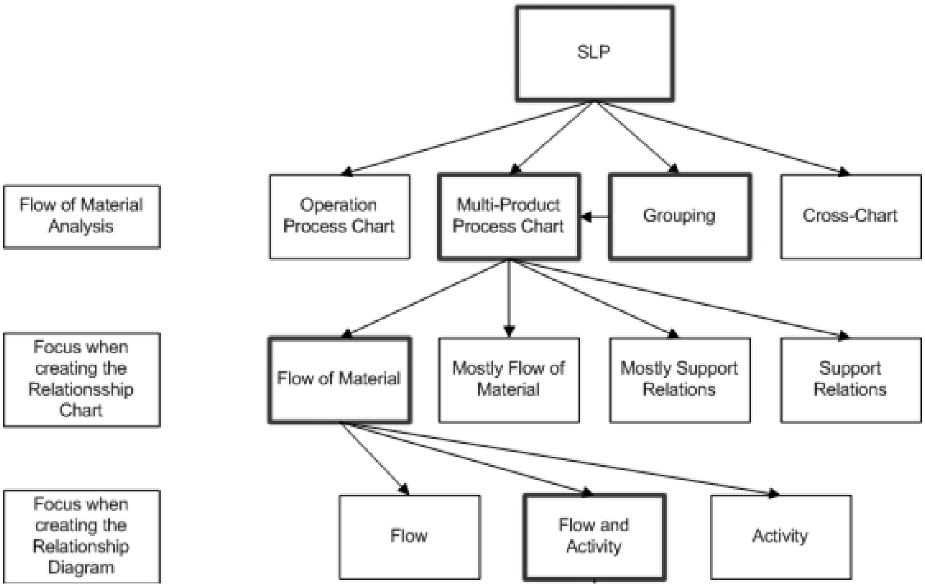


Figure 7. Chosen tools (in bold) optimized for the heavy steel industry (Muther 1973)

2.3 Tools for gathering of data

The input data to make a process analysis, which in fact is the basics for a layout project is according to Muther (1973) summarized in P, Q, R, S, T.

- P = "Product" (What will be produced)
- Q = "Quantity" (How much will be produced)
- R = "Routing" (How will it be produced)
- S = "Support" (What will back up the process)
- T = "Time" (When will it be produced)

These factors are essential for the process analysis and creation of the layout.

2.3.1 Flow of Material Analysis

The tool used to gather data for the flow of material analysis is an, by the author, improved version of the Multi-product process chart recommended by Muther (1973) for this type of production.

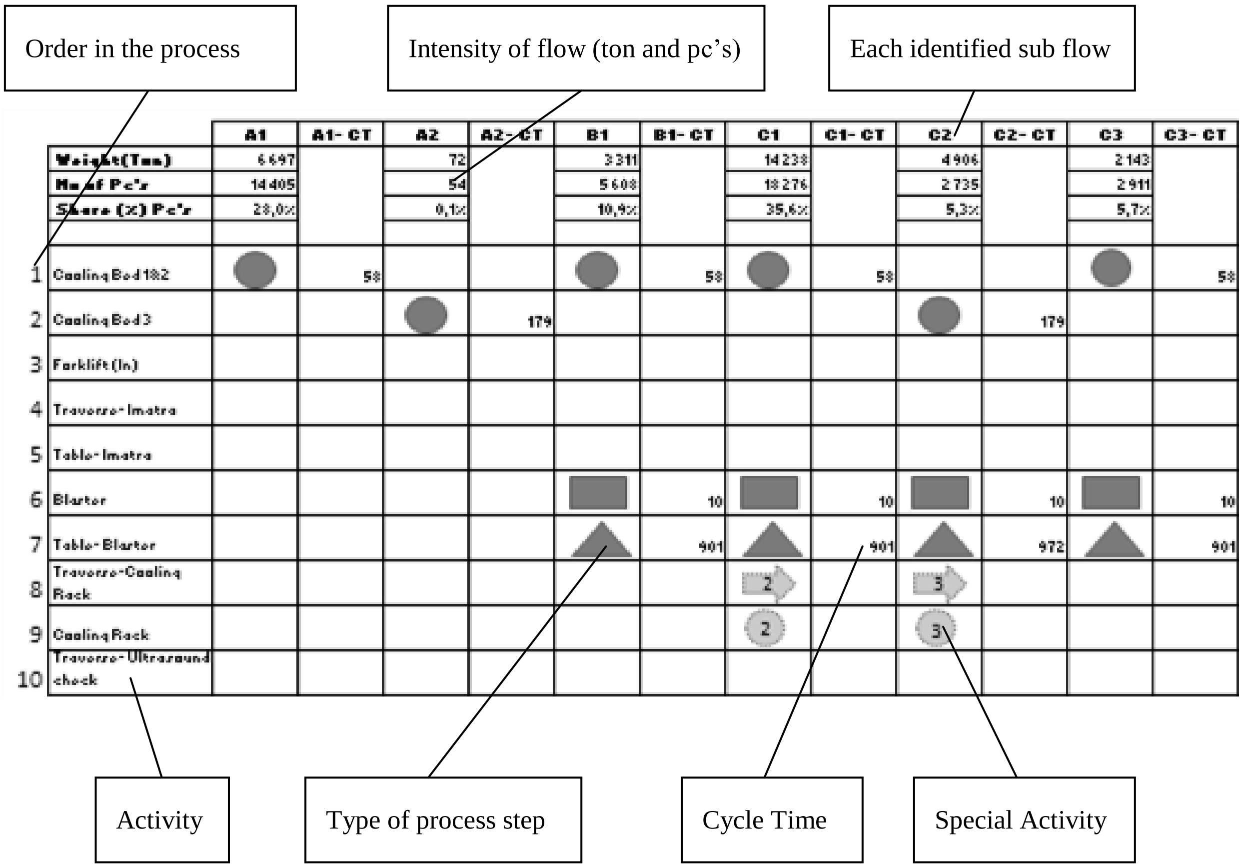


Figure 8. Example of Process Flow Diagram

In this chart following information is gathered and given for each sub flow:

- The order of the activities
- The intensity of the flow given in tons and pieces
- The total share of each sub flow
- Cycle Time for each activity
- Special activities (only performed under special circumstances)
- Total first piece lead time (not visible in example above)
- Total up time for each machine/activity (not visible in example above)

This chart is modified to be applicable in productions with high volumes and many different products that is relatively similar (homogenous) and can be grouped together.

2.3.2 Relationship Charting

This tool is highly associated with SLP.

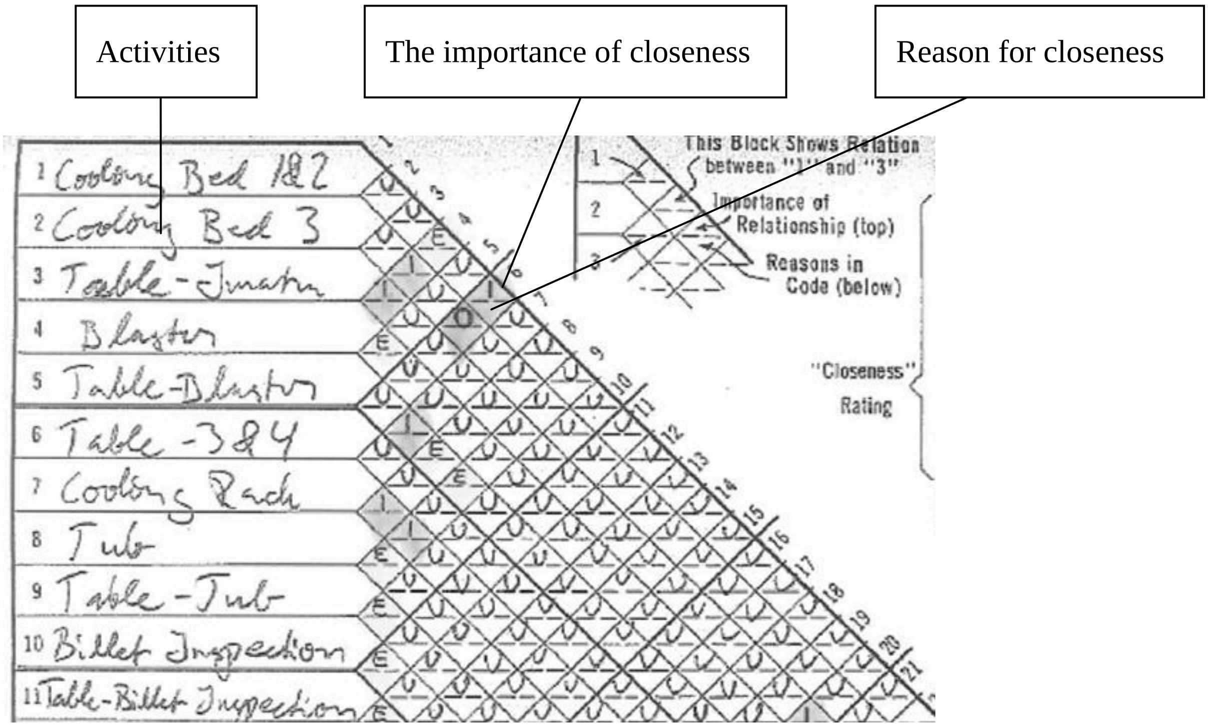


Figure 9. Example of Relationship Chart (Muther1973)

This chart is considered to be a strong tool, where qualitative data is converted into quantitative.

The importance of closeness between each activity and other important factors that should be considered in a layout project, for example doors, toilets etc, is inserted into the top of the square. The particular reason for this (if there are any) is then inserted in the bottom of the square.

As grading, A, E, I, O, U and X is used where:

- A = "Absolutely necessary" (red)
- E = "Especially important" (yellow)
- I = "Important (green)
- O = "Ordinary closeness" (blue)
- U = "Unimportant (white)
- X = "not desirable" (brown)

2.3.3 Relationship Diagram

The information gathered so far is then inserted into one diagram. This relationship diagram contains both the importance of the closeness as well as much of the information given in the flow of materials chart.

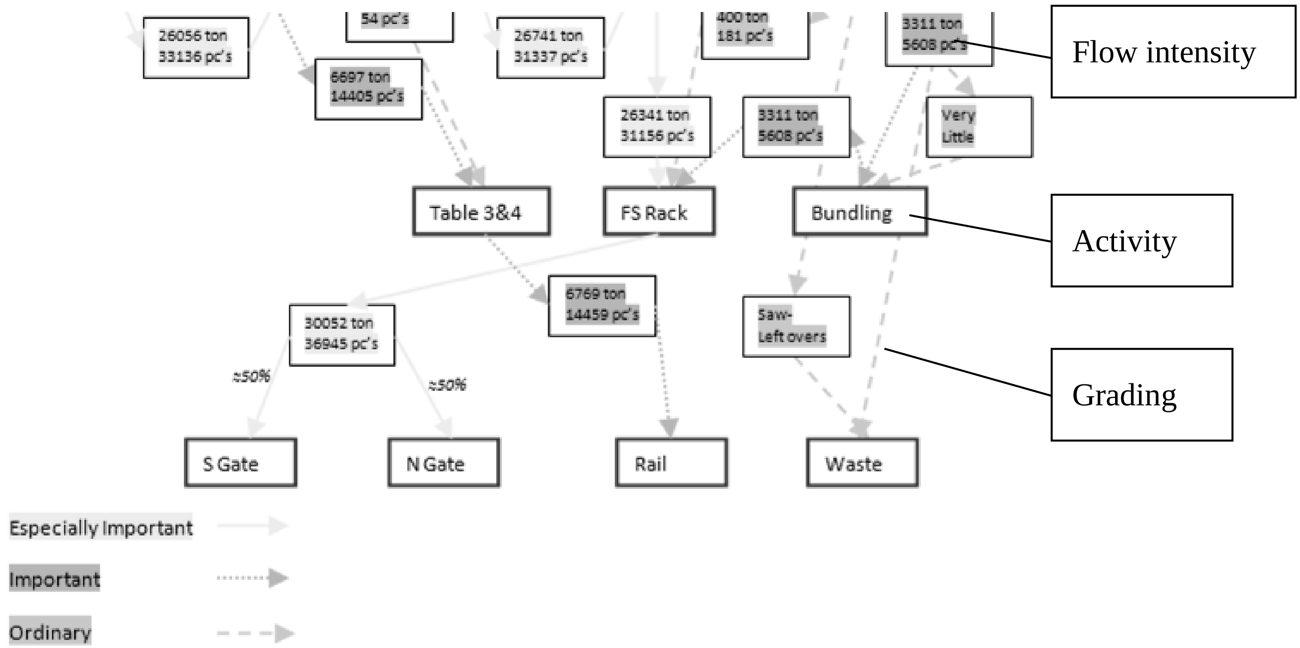


Figure 10. Example of Relationship Diagram

This chart describes all important activities and support functions as well as the intensity between them (grading). This could also be done on top of the existing layout, which would make it a first crude layout suggestion.

2.3.4 Space requirements and availability

So far the model used is, apart from some smaller modifications of the tools, straight forward taken from SLP. The next step according to SLP would be the space requirements and availability analysis. The tools used for these analyses are due to the the scope of this thesis not of significant value. This would only generate a relationship diagram on top of the existing layout. These are mainly tools for creation of entirely new layouts, and not for changing existing layouts.

In this stage, the existing layout must be carefully measured and if new machines are to be invested in, the needed space for these must also be established.

2.3.5 Analysis

The analysis is made in two steps.

First all activities and connections are analyzed separately. This makes the foundation. Here it will be described how each part in the process should be changed so that an optimal layout could be achieved.

The next step is to put this together in a number of layout suggestions. After a pre-evaluation, most layouts will be discarded, leaving a few to be properly analyzed in the evaluation stage.

2.3.6 Evaluation

There are opinions that the relatively unstructured and subjective evaluation methods presented by Muther (1973) are not optimal for a project with complex multi-decision evaluation (Yang, Su and Hsu 2000).

Several different criteria must be weighed against each other. This must be done in an objective manner and each layout suggestion must be weighed against the criteria in the same way. This often presents problems in evaluations with many factors that must be taken into consideration. In some cases, each factor also must be broken down into sub-factors, which makes it almost impossible to make an objective evaluation without an appropriate, systematic, evaluation tool.

To be really useful, the evaluation method must be able to consider the financial aspect. The optimal situation must be based on several different criteria, where the ability to invest is one of them.

Multiple Criteria Decision Analysis (MCDA) is a sub discipline in the area of operation research. This area is entirely focused on methods and tools for multiple criteria decision making.

As suggested by Gero and Jo (1998), Analytical Hierarchy Process (AHP), is a method that fits very well to this kind of problem. AHP is a technique that derives from the area of MCDA and is used to structure complex decisions in order to make the best analysis in environments with many variables.

AHP is according to Morera 2002 “one of the best known decision making processes to help people into the hard task of making the best decision out of a set of possible options”

Other sources such as Yanh and Kuo (2002) and Yang, Su and Hsu (2000), also suggest this approach for evaluation in layout planning projects.

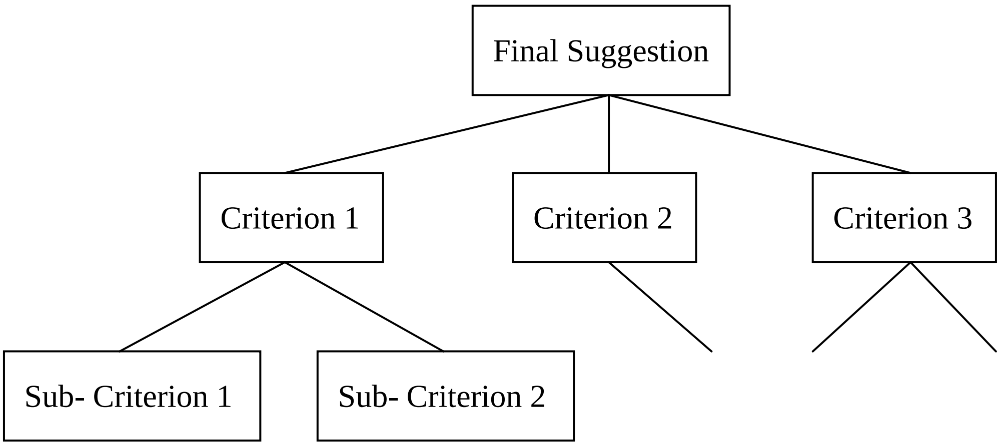


Figure 11. Analytical Hierarchy Process

Each criterion is divided into sub-criterions that are weighed against each other. After that each layout is weighed against each other seen from the perspective of each single criterion. These scores are then added together for each single layout, resulting in one layout scoring higher than the others, which also will be considered the optimal layout (For description of the method, see the frame of references, section 3.3.1).

2.3.7 The final model

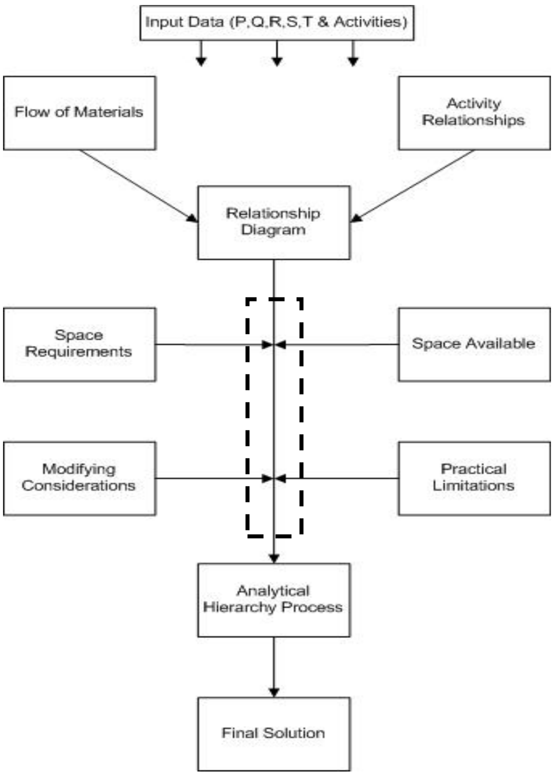


Figure 12. The final model to be used

Figure 12 describes the final model that has been developed for this case study. The model and the tools described are optimized to gather data in the environment that the case company offers. However, it is important to state that in a layout project, there exist no absolute rules that could be followed exactly so that in the end a good layout is received. The model will contribute with methods and guidelines to gather correct and sufficient data, as well as it will help to make a correct evaluation. In between, there will always be the part, which by Muther (1973) refers to as "the creative part". This means to take an amount of input data and turn this into a layout. The result of this phase will always be due to the experience and knowledge possessed by the maker of the layout. This phase, which is referred to as the analysis in the methodology, is indicated by the dashed line in the final model (see

Figure 12).

2.4 **Reliability**

Reliability is according to Colorado State University, CSU (2009) the measure of how accurate the research would yield a similar result if the trials were to be repeated.

All calculations are based on 8 weeks, 41-48, 2010. This is due to two reasons.

First of all, the production during these 8 weeks was very close to the yearly average. This means that calculations on a yearly basis would generate the same results as these 8 weeks did. This was done due to the less time consuming procedure to aggregate the data from 8 weeks instead of 52, as it would still generate the same results and thereby the same conclusions. All figures, unless stated, then also refers to the time span of 8 weeks.

Secondly, this time span was also used for the analysis of the rolling operation (previously referred to as the "pre-study"). The result of this analysis was partly used as input data for this research, which makes it appropriate to base both analyses on the same data.

All secondary data have been extracted from the company business system. To aggregate this data, tools that are optimized for this kind of production have been used.

The largest part of the primary data was constituted by the different cycle times. These were measured 10 times for each activity and the average was then used for calculations, in order to give a credible result. The last part of the primary data was discussions with managers and operators. This data was never used for any calculations, but as an initial method to understand the process.

2.5 **Validity**

Validity is according to CSU (2009) the measure of how well the study reflects the concepts that the researcher is trying to measure.

The model that is presented in this research is adapted for the typical environment of the steel industry. The model and the tools used are optimized for changing already existing layouts in a high volume low variety production. The tools used favor extremely heavy products, and also homogenous products which make them possible to group.

This makes the model suitable for the average heavy steel producing company. However, this is not a guarantee that it will be suitable for every company in this industry. There are always situations that will call for other methods, and slightly changes in the model may prove advantageous in specific occasions.

The model is not only suitable for the steel industry. Emphasis has been put on developing a model that is favored due to following criteria:

- Heavy products with awkward lifts and handling
- High volume / Low variety production (layout by product)
- Big and expensive machines
- Fairly homogenous products that easily can be grouped
- Aim to change an already existing layout

This means that in situations where the criteria above apply, this method would be applicable.

The evaluation method that has been presented is not adopted for any specific industry. This is instead suggested as an improvement compared to older evaluation methods, and would be advantageous to use in any layout project. The strength of this technique lays in the ability to handle complex multi-decision problems. Therefore the more factors that must be evaluated, the more advantageous this method will prove to be.

3 Frame of Reference

This section will include the various academic methods and specific theoretical knowledge that is required to understand and re-fabricate the results achieved in this case study. No information that could be considered as elementary will be presented here, when it will be assumed that the reader already possesses this knowledge.

3.1 Heavy Steel Industry Characteristics

The steel industry is due to its nature associated with process oriented production and huge heavy machines which are hard to move. Because of the expensive machines, this often results in a very homogenous product range.

The heavy and awkward products call for a great deal of automatic transportation on lines and large cranes to lift the steel to and from the manufacturing process.

The different tools and dies used for the production is often expensive and time consuming to exchange. All this together creates a typical High Volume/Low Variety production, some sort of production in batches as well as a typical push environment (Jernkontoret/Stålindustrin 2010).

3.2 Theoretical Method for Establishing a Layout

This section describes how a layout is established according to SLP. This includes tools and focus in the gathering of data as well as a description of how the data could be turned into a layout.

3.2.1 Systematic Layout Planning (SLP)

What could be argued to be the most organized and systematic technique to develop a layout plan is Systematic Layout Planning or SLP. This technique was developed by Richard Muther for over 50 years ago. The method has got various face lifts and improvements but the overall strategies are still the same (Richard Muther & Associates 2007).

According to Richard Muther & Associates (2007) a layout planning must never be a subject to uncoordinated continuous improvements but rather a systematic approach where all factors at the same time are taken into consideration.

Meyer (1993) clarifies that the key of getting this technique profitable is to collect and analyze data. If this is done correctly the final blueprint will only be a graphical representation of this work, and quickly made when the work already is done. He states a common mistake is to start with the actual blueprint, and says this would be just as "reading the last page of the book first".

The part of this case study concerning SLP is based on the techniques as presented by Muther (1973). The same approach could be found in Meyer (1993), Yang, Su and Hsu (2000), Wilde (1990) as well as in several other sources. Additional sources, such as Chien (2004) bases their models on the same approach but incorporates modifications due to the surrounding environment.

A layout process must according to Muther (1973) pass through a serious of phases, a number of steps that through SLP has been standardized and inserted into a framework.

This technique is well used and proven to work countless of times due to its systematic approach. But the technique could also be said to be nothing more than a standardized process analysis. Every time a process is deeply analyzed, certain steps must be covered to gain understanding for the process. Before there is any possibility to know where to go too, one must have a deep understanding for where to go from (Net MBA/Process Analysis 2002). This includes following steps;

- Define process boundaries
- Map the process flow with all its activities and interrelations
- Calculate capacity and intensity for each step in the process
- Identify bottlenecks and evaluate further limitations to consider
- Improve the process based on the previous analyses

While going through this method, a lot of different diagrams and charts have to be used to keep a lot of data in an analyzable manner. To go through these systematic steps is what the very core of SLP is about, a systematic and standardized approach.

The Basic Elements of SLP

The basic elements of which a layout problem rests on are Product, Quantity, Routing, Supporting Service and finally Timing. That means, “what is actually produced”, “how much is produced”, “what does the routing schedule look like”, “what support backs up the process” and “when will the items be produced”.

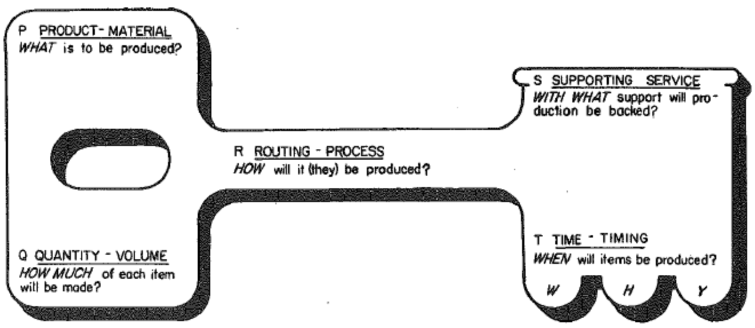


Figure 13. A visualization of the key to unlock the ultimate layout plan (Muther, 1973)

The Product-Quantity Curve

A method for developing a layout plan could never be achieved as a single method that always is performed exactly in the same way for any given situation. The situation for example a steel mill, with usually large quantities and few process steps and a low product variety is very different from the company with a complex assembling, high variety, low volume products etc.

Therefore the base for a layout plan must be adapted after the type of production. What the P-Q Curve describes is roughly the type of production dealt with, and therefore represents the starting point of a layout project.

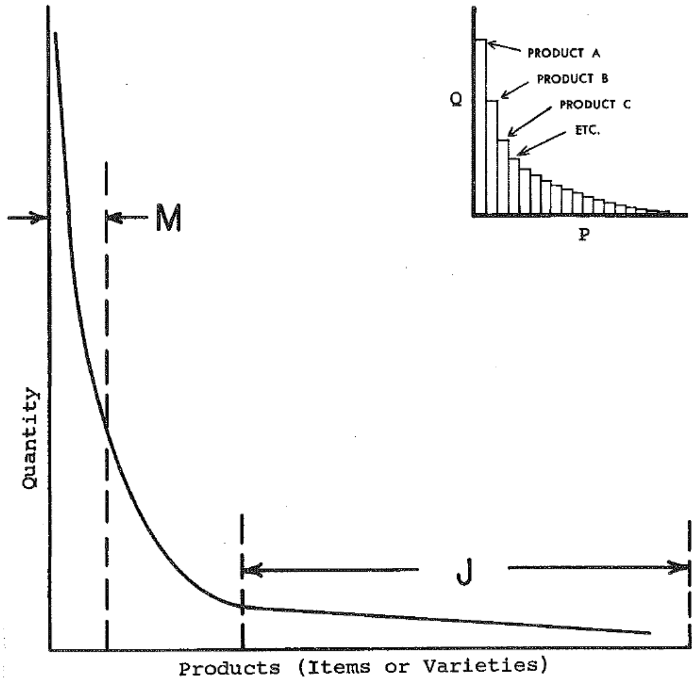


Figure 14. The P-Q Curve. (Muther, 1973)

The position on the Curve tells something about what factors are important to prioritize for our plan. Eg, far to the left at the curve shows high volume/low variety (HVLV) products which will increase the importance of the actual main flow, whereas far to the right, with low volume/high variety (LVHV) products other factors such as supporting services etc will increase in importance.

This means also that a slightly flatter P-Q Curve, that means not a very extreme difference between the different production processes, will favor a solution where all the products could be manufactured in the same system where a balance between layout by products, such as line production and layout by process, like eg job shop methods could be found.

An extremely “deep” P-Q curve, on the other hand, will often favor a production where layouts are split between product groups and specialized for this particular manufacturing. An example of this could be that the product groups far to the left will be produced by some sort of mass producing line. The other, less produced product groups could be manufactured in a job shop that could handle more diversified processes.

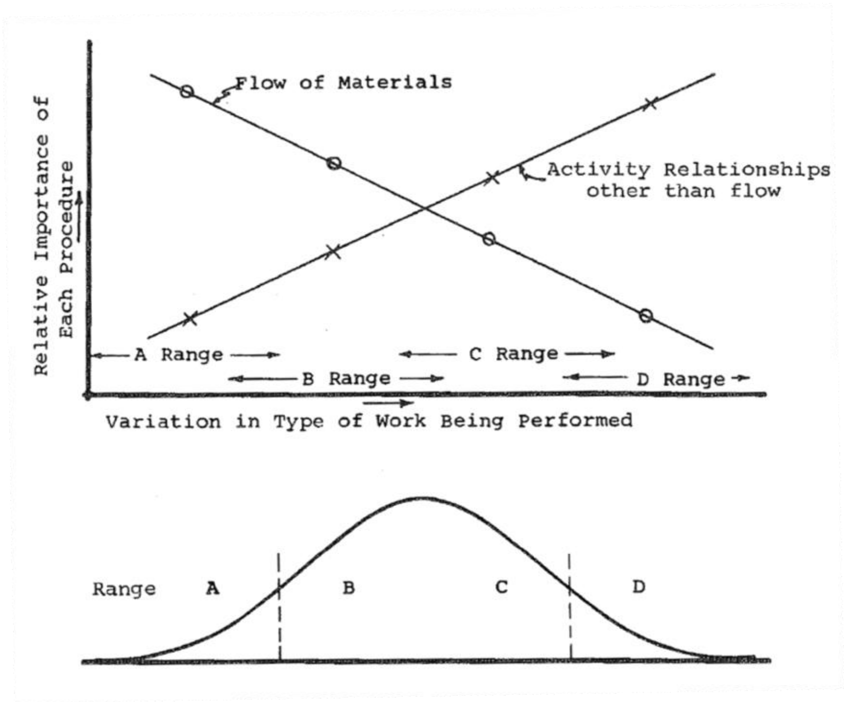


Figure 15. Importance of factors due to the P-Q Curve (Muther, 1973)

The SLP Framework

The approach is divided into four phases:

- Phase1: Location- Which areas should the layout consider
- Phase2: Overall Layout- Establish flow pattern and areas allocated
- Phase3: Detailed Planning- Planning of each machine and the different activities
- Phase4: Installation- Physical implementation and installation of the layout

A layout plan always rests on three fundamentals.

- Relationships- Relative closeness desired and required
- Space- The necessary area that needs to be allocated
- Adjustment- Rearrangement of the plan into a realistic solution

The contribution of SLP is, as a standardized framework, offer a systematic approach to solve these questions, based on the data given for each situation.

This framework looks the same for every layout project. The methods and tools for gathering of data and to make the analyses differ however greatly.

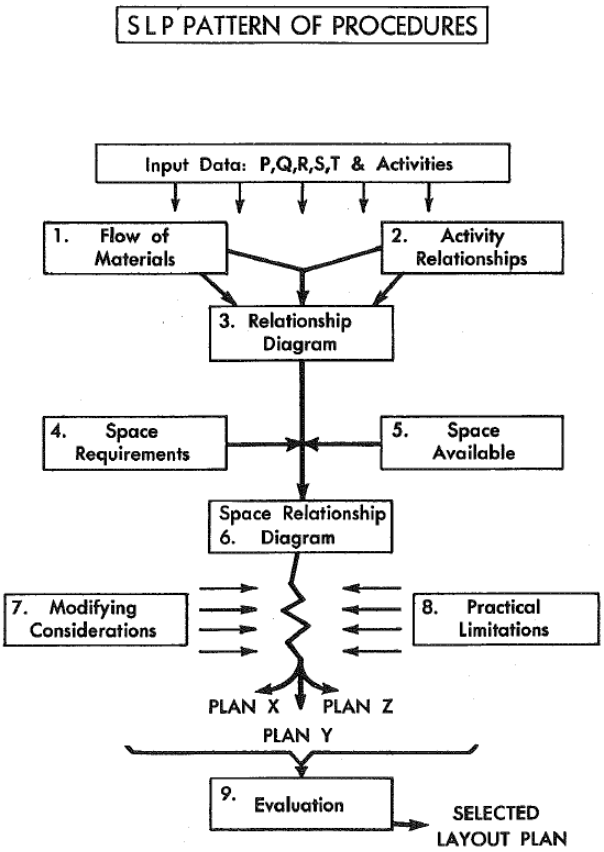


Figure 16. SLP Pattern of Procedures (Muther, 1973)

Flow of Materials

In this part the aim is to map the process carefully, and by use of different operation-process charts create a picture of exactly which activities are parts of the process.

When this is made, and the intensity (quantity) of the flow has been established, the actual need for this activity could be analyzed.

Could this step be eliminated, does it contribute with any value to the product? If so, could it then be combined with another activity and by that save time and personnel? Another question here is whether the activity could be rearranged for better fit, or if the manufacturing process demands it to be just where it is etc.

Activity Relationships

Next part is to establish the relationships between the activities. Exactly what is done where, what kind of relationship does this create between the activities and then also between the different machines in the activities.

As already mentioned, there is more than merely a production flow to consider here. As seen in Figure 14, the P-Q Chart indicates which activities to primarily focus on. In for example the heavy steel industry, the flow of materials will be the base of these analyses. Here lots of heavy and awkward transportation of the products has to be done in an as efficient way as possible. On the other hand, in many other industries, other relations may be more important to consider. An example of this could be interacting supporting services like repairment, toilets, offices etc. Also for many industries there is no reason to prioritize the flow of the products. For example a jewelry manufacturer will probably have a lot of other more important factors to consider than the actual flow of the products.

Relationship Diagram

In this stage the data gathered is put together in a more graphical way. This could be said to be the very first draft of something that looks like a layout. Sometimes this is even mapped on an existing layout, giving even more the feeling of a finished plan. It is however in this phase far from a finished layout. This is merely a graphical picture of the different activities where both the intensity of the flow and the relation is specified.

Space Requirements and Availability

The space requirements of the new machines have to be established and the available space that exists in the production area has to be calculated.

Space Relationship Diagram

All these five first steps will then be put together into what would even more look like a finished layout. This is a further development of relationship diagram, so that it now also contains both the available space and the necessary space for the new machines.

Modifying Considerations

Until now the procedure has been relatively much focused on the gathering of data and put it together in a systematic and easily understandable manner. Now comes the part that Muther (1973) describes as “the really creative part”. The space relationship diagram is a sort of layout, but probably not a very good one. What is the next part is to consider modifications to make this into a truly good layout. What were analyzed in the relationship diagram were all different activities in, or around the actual process. There will be lots of conflict in this data. Activities that were found to be closely related with some activities may also of some reason be best placed far from another activity that unfortunately also this was closely related with the first activity. Here there are no obvious answers, but instead there has to be small modifications to get the best balance. Other modifying considerations could be how to place buffers, incoming goods into the process, were and how to put the finished stock with all other activities taken into consideration etc.

Practical Limitations

The limitations are of course many when planning a new layout for an existing building. Even more limitations will exist in those cases where only one part of the process has to be re-modeled. In most cases walls and ceilings are not movable. Some machines may be impossible to move or at least not economically viable, since it will probably take huge savings potential in a layout for to start rearranging all heavy machines in a plant.

Evaluation

At this point, with all limitations taken into considerations, the potential future layouts will probably be down to a few. Now these have to be evaluated, for in the end be down to one best layout proposal. This evaluation could be done in many ways.

Muther (1973) describes three basic methods:

The first one and maybe the most subjective of the three are to weigh advantages and disadvantages against each other. This is merely two columns, one with pros and one with cons, which are then compared against each other.

The second one is “Weighted factor analysis”. This is a technique where all the most important elements are broken down and analyzed separately. Practically it is done by taking these identified factors and then assign a numerical value to each one. These numerical values are then added together and the design with highest scores in the end will be the final layout.

The third evaluation method is cost comparison or financial analysis.

This is often used to justify a project. If it’s not economically feasible to implement these changes, they will in most cases not be implemented. In cases with a brand new production to be build, a total cost analysis will be necessary to contribute with a picture whether this layout will be economically feasible or not. On the other hand, when it is a re-layout, often a comparison between the old layout and the new concerning those parts where something is changed will be sufficient.

Of the four different phases mentioned above, only phase 2 (Overall layout) and 3 (Detailed planning) could be said to be an actual part of the creation of the layout. Both these phases are based on the framework given above, where first all the steps are gone through to plan an overall layout, and then repeated once again for each activity in the detailed planning.

3.3 Basic Calculations: Theory & Technical Terms

This part contains a description of how certain calculations are made as well as some basic mathematic arguments.

3.3.1 Analytical Hierarchy Process

AHP is a technique that is used to structure complex decisions in order to make the best choice in an environment with many variables.

The method demands the actual problem to be divided into sub problems, a number of elements on which the decision should be based. These elements must then be weighed against each other, so that they each receive a numerical value due how critical they are for the process.

Each individual from the population, from which the decision should render in one best choice, is then evaluated against these sub problems or elements and against each other.

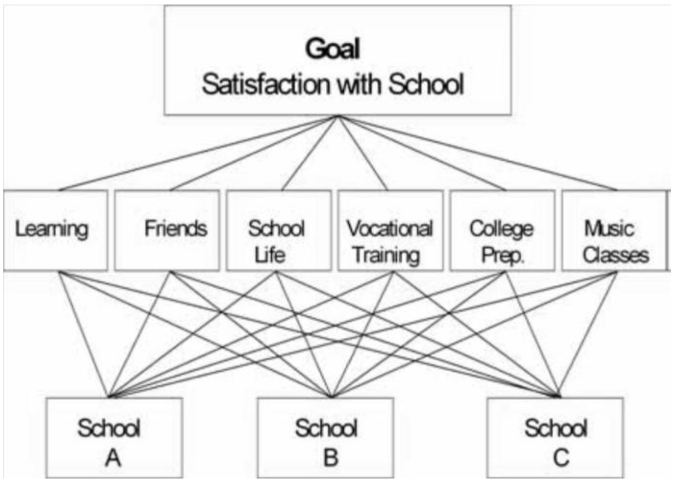


Figure 17. Example of sub problems in a school environment (Saaty 2008)

A matrix is created containing each of the choices, weighed against each other. The eigenvalue of each of the choices are then calculated, which will present a measurement of how good each of the different choices is according to that particular element. After analyses like this are made for each sub problem, they are put together and the alternative with the highest score will be the final choice (Saaty 1990).

The eigenvector is a phenomenon from the linear algebra. It describes a non-zero vector of a matrix that still when multiplied with the matrix remains proportional to the original vector. This means it changes in magnitude but not direction.

The non-zero vector v is an eigenvector to matrix A if there is a scalar λ such that:

$$A\nu = \lambda\nu$$

(*where λ corresponds to the eigenvalue)*

Mathematically the eigenvalue could be found through:

$$\det[A - \lambda I] = 0$$

(the determinant of the matrix minus lambda times the identity matrix equals to zero)

(Howard and Busby 2002)

3.3.2 Tact Time and Cycle Time

Due to common misconceptions and misunderstandings considering Tact Time and Cycle Time, a section has been included to define the both terms.

Tact Time is defined as "the rate at which a customer would pick up a product if he picked up products uniformly during the day, while you produced it".

$$Tact = \frac{Available\ Production\ Time}{Customer\ Demand}$$

This means that if production is correlated to Tact, there will be no waste in the shape of overproduction, the in lean environments often called, “greatest of all wastes”.

This relates to Cycle Time that is often defined in at least two different ways. Production Cycle Time is the interval between two consecutive units at the end of the process. Process Cycle Time on the other hand is the time a product is being worked on in any given activity in the process.

$$Cycle\ Time = Tact\ Time * OEE$$

OEE is here defined as Overall Equipment Effectiveness. This illustrates a compensation for machine breakdowns, discarded products etc.

$$OEE = Availability(Time) * Quality\ Yield(Salable\ Products) * CT - Performance$$

CT-Performance is here defined as Total units produced divided by volume that should have been produced during the actual uptime (Wilson 2010).

3.3.3 Buffer Calculations

The size of needed buffers is often decided by considering the standard deviation of a historical population of data (Wilson 2010).

$$\sigma = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(x_i - \mu)^2}$$

The standard deviation shows the dispersion of the population from its mean value. If the population is normal distributed, the normal distribution curve given below can be used for deciding the probability that one individual in the population will be inside of the standard deviation (Forsling and Neymark 2004).

According to Net MBA/Normal Distribution (2002), in process and operations management, variations are usually considered as normal distributed.

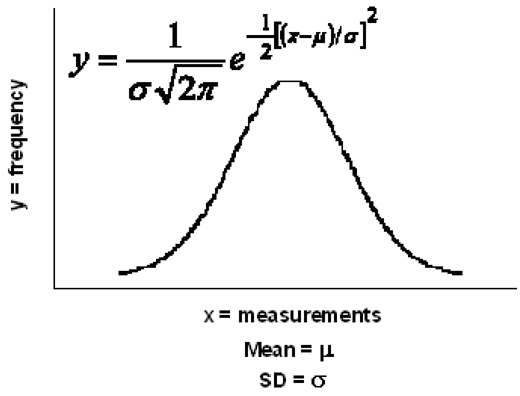


Figure 18. The Normal Distribution Curve StatTools (2007)

This means that when a probability has been decided for that an individual shall be inside a certain limit, it is then possible to calculate how large e.g. a buffer needs to be in order to coop with a certain production environment.

3.4 Processing Activities and Material Properties

This part describes the processing in each activity and some material properties. This part is important when the understanding of some reasoning in the thesis demands knowledge about how the operations is done as well as how the material responds in different scenarios.

Grinding

A cutting processing technique where the cutting operation usually is rotating. The grinding wheel is based on a large number of grains tied together with an adhesive fluid (Karlebo, Lindström 1991).

Blasting

A processing technique where the working piece is shot with a large number of grains, often similar to the ones that a grinding wheel is made of. It is an advantageous operation for cleaning surfaces, e.g. removing mill scale from hot rolled steel (Karlebo, Bagge 2006).

Ultrasonic Inspection

An ultrasonic beam is aimed towards the material. If a crack exists, it will reflect the beam differently, thus showing the existence of flaws both at the surface but also deep into the steel core (Kalpakjian, Schmid 2006).

Magnetic Particle Inspection

This technique is possible due to the change in a magnetic field created by discontinuities in the steel core. If a bar is magnetized, a field will be created around the opening of the cracks, making this part more magnetic than other parts of the steel bar. When fine ferro-magnetic particles are added, these will flock around the cracks, visibly showing where cracks could be found in the material (Kalpakjian, Schmid 2006).

Phase Shifts in Steel

Pure Iron (Fe), can exist in three different phases that all affect the materials ductility, strength, hardness etc. These are (Alpha)- Ferrite, Austenite and Delta- Ferrite. When iron occurs in alloys together with other elements, such as coal, manganese, chromium etc, other phases that have a huge impact on the steels properties may be created. When alloyed with for example coal, steel can depending on the treatment occur in phases such as cementite, and martensite, two phases that both creates an extremely hard but brittle steel (Jernkontoret/Järn- och Stålframställning 2000).

Cooling

The cooling procedures in steel production is quite complex. All alloys react differently from each other when exposed to a colder medium. When carbon steel is cooled rapidly from a high temperature (in the austenitic phase), martensite is created. Even if only a small layer on the outside of the steel bars contains martensite, this will create a very hard but brittle surface that may crack in handling (Kalpakjian, Schmid 2006).

Hydrogen Embrittlement

The presence of hydrogen at some stages of the production may give cause to reduced ductility with cracks as a result, so called hydrogen embrittlement. This is a phenomenon that mostly occurs in high strength steel. Hydrogen may enter the steel during melting, rolling (FERA 2006) but also during use of chemical reactions such as electrolysis (Kalpakjian, Schmid 2006).

High temperatures allow the hydrogen atoms, due to increased solubility, to diffuse into the steel. Inside the atoms start to combine into molecules, increasing the pressure in small pockets inside the steel. This pressure may increase until the ductility limit is reached and the material starts to crack (Kalpakjian, Schmid 2006).

These cracks may start to appear from just a few hours after operation until several years (MAI 2010).

4 Empirical Study

The empirical study will focus on presenting all data gathered that is needed to do the analysis in the next chapter. Here will also the forecasted future scenario be presented, that means the production that the layout has to be adapted for.

4.1 The Current State

This part will be divided into two different states of the production. First the current state will be presented. This is the essential raw data that has been extracted from the process, upon which the following analysis will be based. This is the entire process divided into several sub-flows. This is done in order to describe every flow in detail and present a complete set of data to provide a strong base for the calculations.

The second part describes the empirical findings for the situation after that forecasted changes has taken place. This is what the situation would look like if no layout changes in the flow in hall 2 are carried out. However, since these forecasted changes also includes the layout change of rolling operation, which means flow of billets 190-230 will arrive in the second hall via cooling bed 4 at the south side of the building, this lift has to be taken into consideration.

The empirical study will contain all the "hard" data that has been used for the analyses, as well as all important relations between activities within the process.

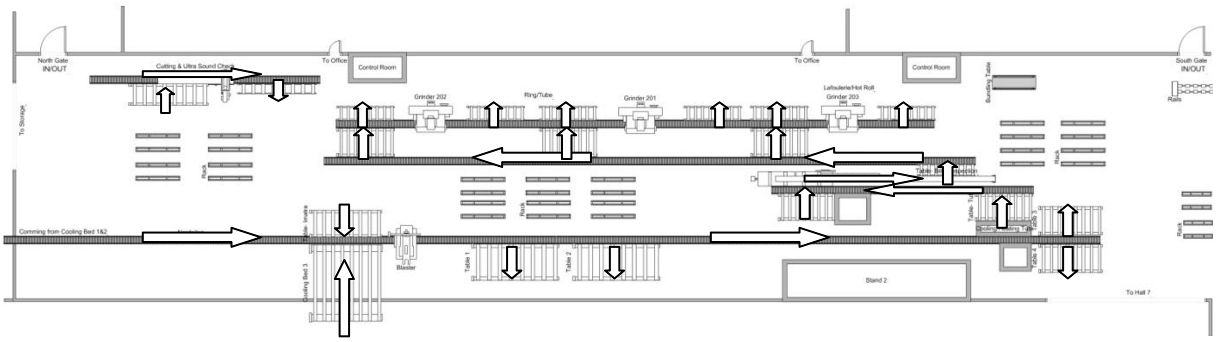


Figure 19. Current layout with arrows indicating the flow direction

The layout above illustrates the direction of the flow. Later in chapter four the lifts are illustrated so that the reader can get an understanding for the entire flow. As a clarification, there is no continuous flow from Nordpilen to the Tub. These pieces are instead lifted from table 1&2 to the tub with traverses.

(For a detailed map of the flow, see the process flow diagram appendix 10.2)

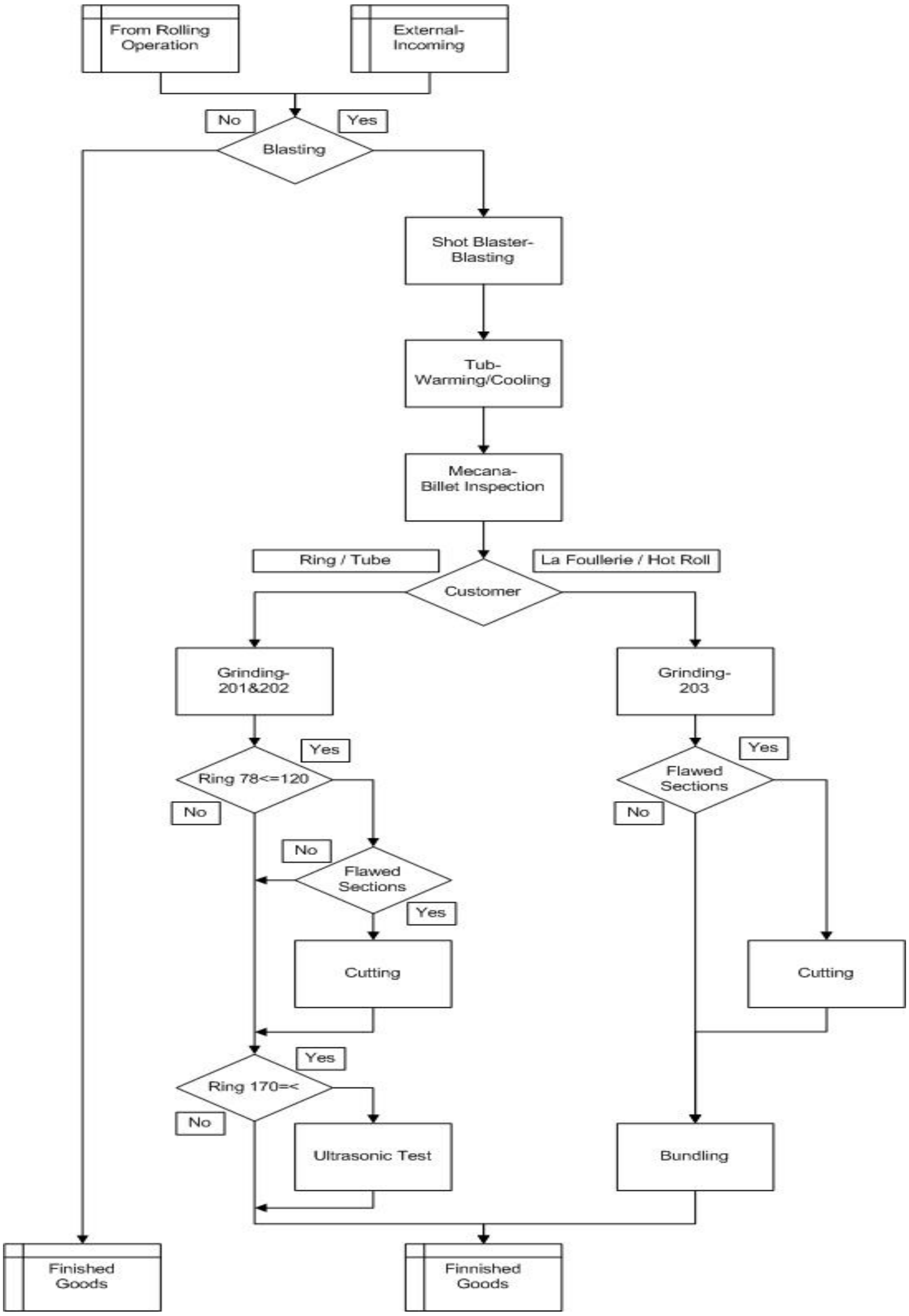


Figure 20. Entire process of Hall 2

Input Data

Described below are the different sub-flows that have been identified in order to analyze every part in detail. In all 10 flows has been identified. Considered here were also future changes in the production, which means the reason for the split into sub-flows may not be visible in the current state mapping.

All flows are split due to three factors. Where they are coming from, where they are going to and finally what dimension has the produced part. The dimension is important due to the difference in cycle time that exists in some activities depending on the diameter of the steel bar. Optimally these different dimensions would be treated as single flows. However, when around 15 different dimensions are commonly produced, these had to be divided in two groups. More would have been rendering in too many sub groups to handle. The difference between cycle time in operations due to dimension is also relatively small, in many cases less than the process spread which makes it hard to determine the actual difference between two nearby dimensions.

Destination (Customer) and origin (Bed) of the products has to be divided into different sub-flows, when the flow is entirely different dependent on these variables.

Flow	Coming From(Bed)	Going To(Customer)	Sizes
A1	1&2	Hällefors	78-160
A2	3	Hällefors	170-230
B1	1&2	La Foulerie & Hot Roll	78-160
C1	1&2	Tube	78-160
C2	3	Tube	170-230
C3	1&2	Ring	78-160
C4	3	Ring	170-230
C5	Imatra 280T&285K	Tube	78-160
C6	Imatra 280T&285K	Tube	170-230
C7	Imatra 803F	Tube	78-160

Table 1. The different sub flows in which the production was divided

The P-Q diagram (see Figure 14) describes the two first parameters to consider in a layout project. These are product and quantity.

As seen there is not one dominant product or product group, hinting that a common production strategy for all products would be advantageous. Considering also that these are big, heavy products manufactured in the same manner to 95 % and in extremely expensive machines, it becomes quite obvious that some sort of line production is a necessity for this kind of manufacturing.

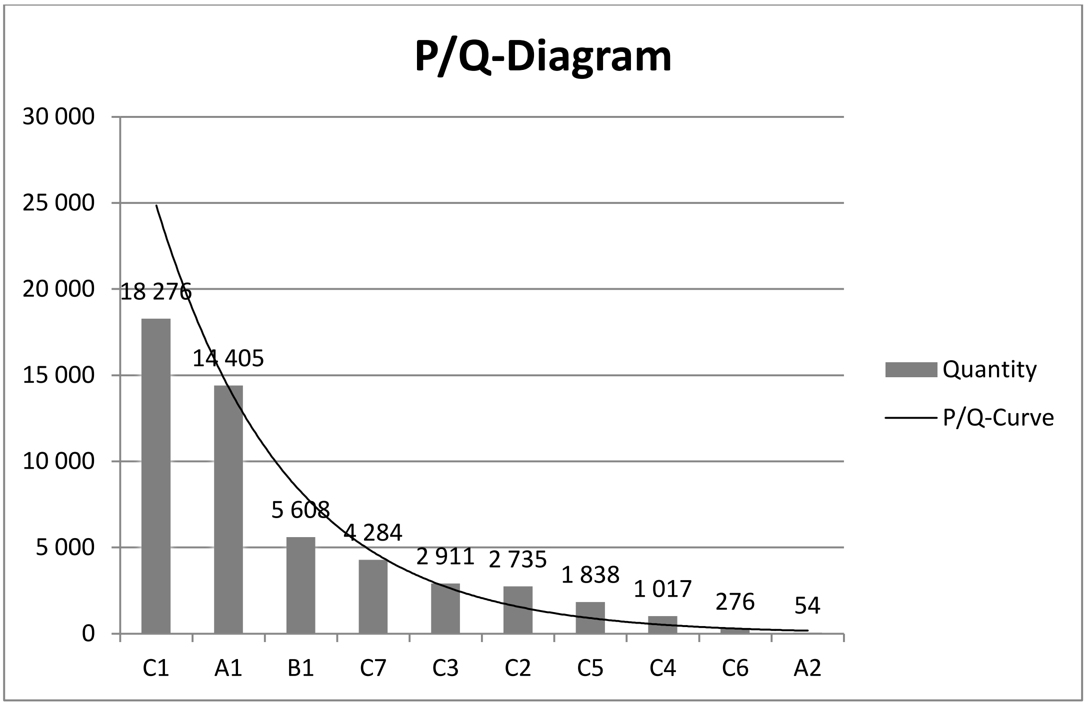


Figure 21. PQ- diagram, describing the product groups in relation to the produced quantity

The many product groups and well spread production results in a relatively softly bent P-Q curve. These should in this case not be seen as totally different products, with clearly differing routing schedules but instead small variations of the same product.

This is a typical HVLV production scenario.

4.1.1 Flow of Materials

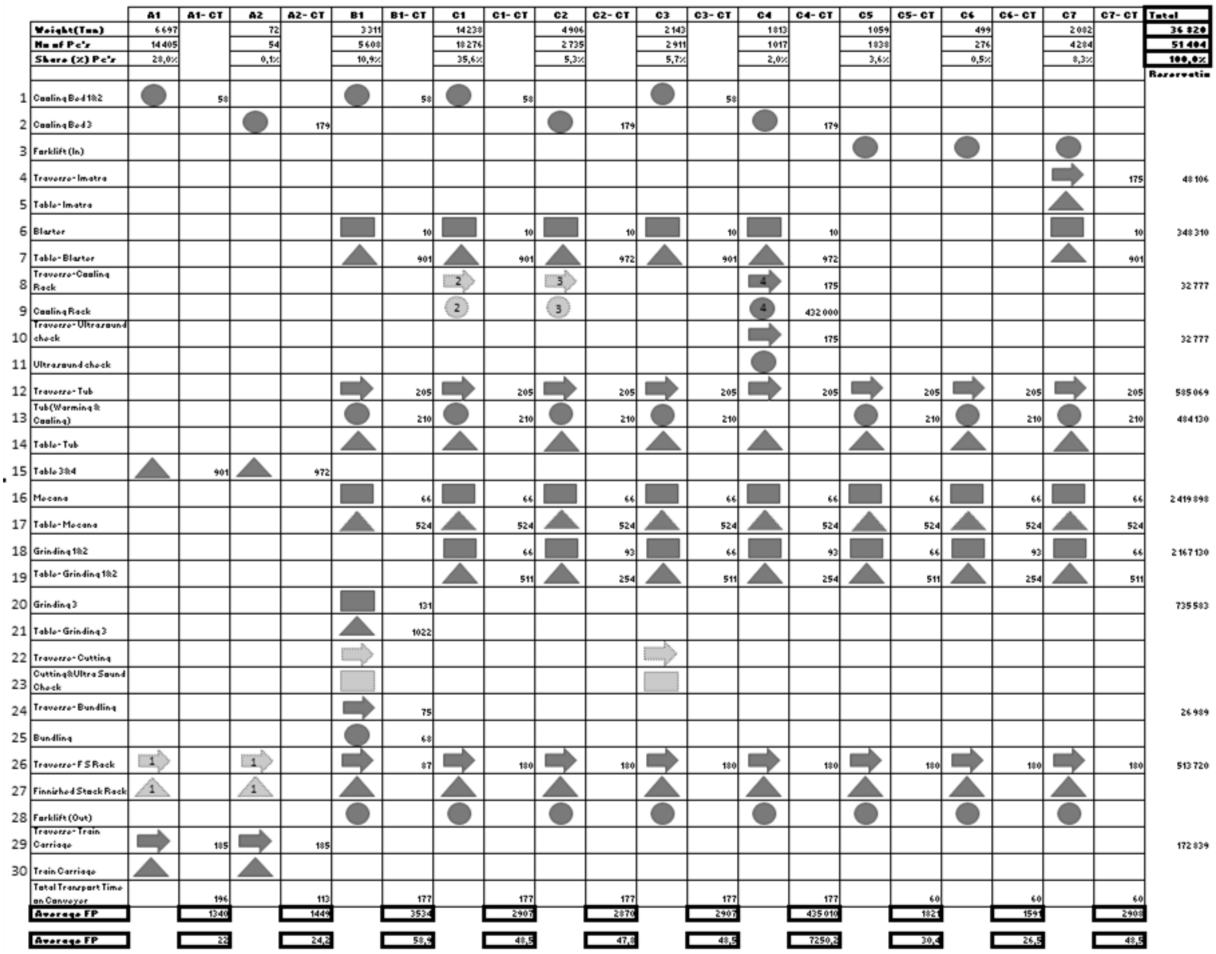


Figure 22. Process-Flow Diagram (Current State)

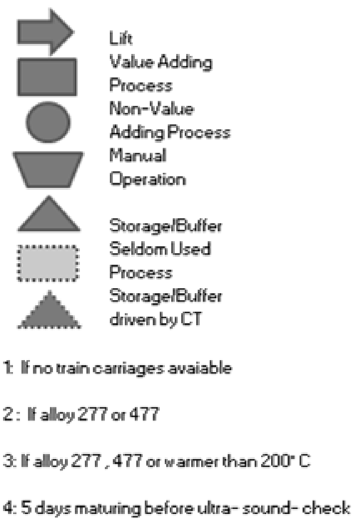


Figure 23. Legend (Process-Flow Diagram)

The Process-Flow diagram (see Figure 22) covers in detail all activities in each sub-process including intensities, first piece lead time, and machine load. (For a larger version, see appendix 10.2).

The information from flow A1 will be given below as an example of what information could be extracted from the process flow diagram.

Flow	A1	
Diameter	78-160	
Destination	Hällefors	
Intensity (ton)	6 697	
Intensity (pc's)	14 405 *(28.0% of total)*	
Value Adding Operations	Non	
Non Value adding Operations	Cooling Bed 2	*Cycle Time: 58 sec*
Storage and Buffers	Table 3&4	*Average lead time for batch: 901 sec*
	Finished Stock Rack	*Cycle Time: Not stated (exception)*
	Train Carriage	*Cycle Time: Not stated(leaves when full)*
Lifts	Traverse - F S Rack	*Cycle Time: Not stated (exception)*
	Traverse - Train Carriage	*Cycle Time:* 205 *sec*
Average First Piece Lead Time (sec)	1 360	
Average First Piece Lead Time (min)	23	

Table 2. Example of information in flow A1

In words this means that steel bars comes from cooling bed 1&2 in average each 58th second and goes directly to table 3&4.

Here it is consolidated in average 901 seconds before it is lifted to the train carriage, a lift that will take around 205 seconds.

If no train carriages are available at the time, the exception mentioned above will result in that the bars are laid in finished stock racks. How long they will lay here is not given (depends on when the next train will arrive).

As seen, the sub-flows are relatively equal. The high intensity flows are treated in the same activities and a few less intensive flows are sometimes handled a little differently.

The flows with the by far highest intensity are C1 with 18 276 pieces and A1 with 14 405 pieces. A2 and C6 has so low intensity that they won’t make that big difference while the other 6 sub-flows count for between 1000 up to around 5000 pieces.

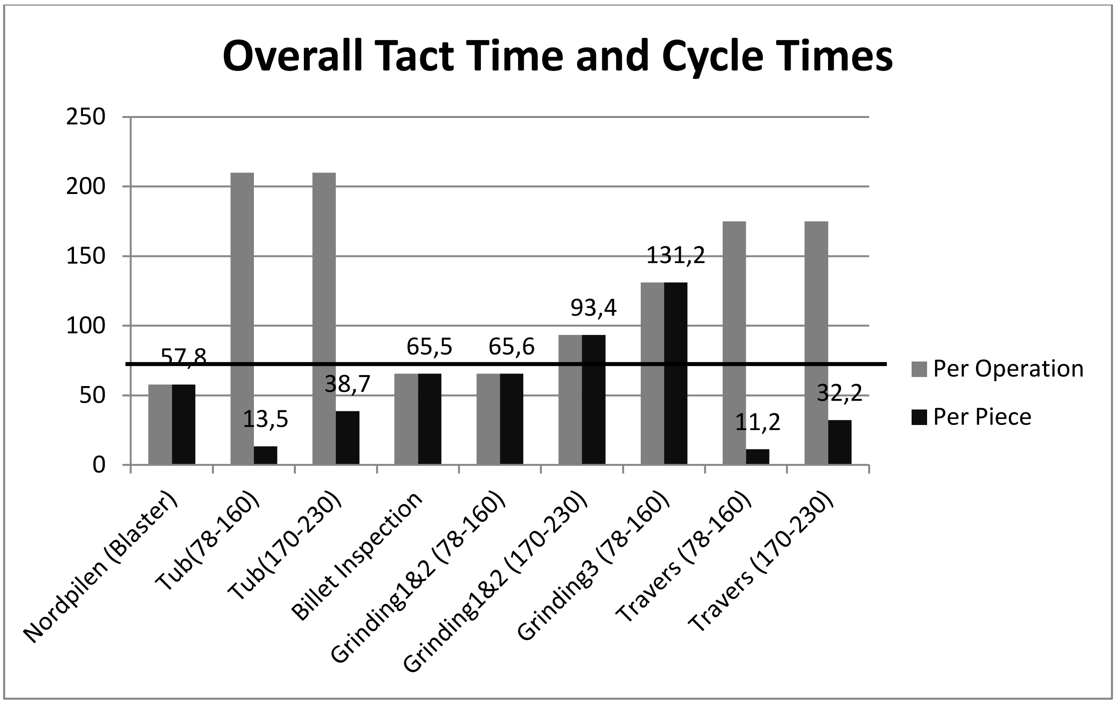


Figure 24. Overall tact and cycle times for the current state

The overall tact time (the red line) is 63.2 seconds. This includes flow A1 and A2 which have significantly shorter tact than the other flows. This results in that the B and C- flows in have a longer tact.

4.1.2 Lifts with traverses

A significant part of the movement of the bars in the process is done by lifts with traverses. To analyze these properly the lifts must be visualized in the actual layout.

14 individual lifts has been identified, which will be shown using arrows on the layout, divided in three different intensities of the flow.

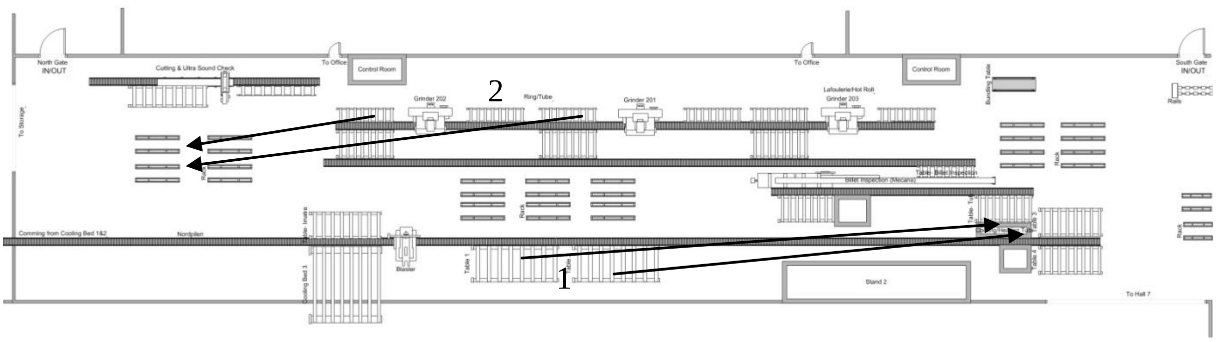


Figure 25. Especially Intensive Flow (20 000pc's<)

The category, especially intensive flow, regards flows with more than 20 000 pieces. The lifts are here illustrated with arrows.

These lifts are done in connections:

- Table 1&2 – Cooling tub (1)
- Grinder tables 201&202 - Finished stock racks (2)

These are the two main in and out lifts from the process.

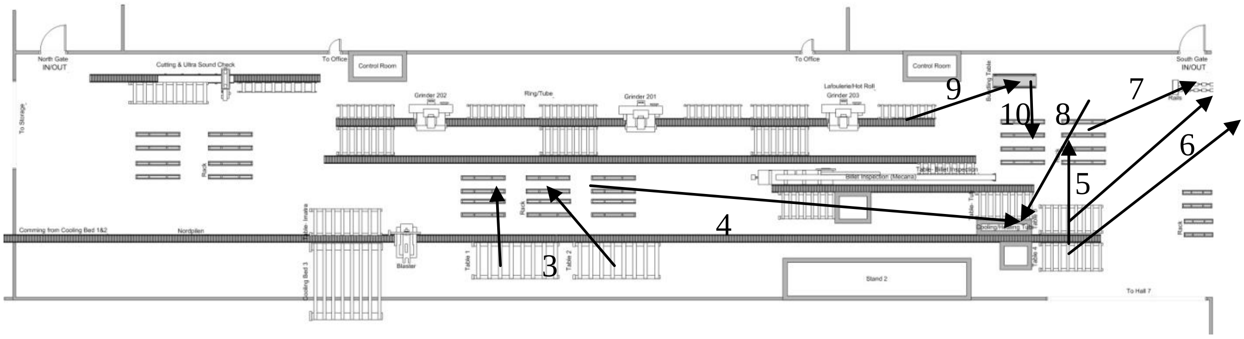


Figure 26. Intensive Flow (1 000<20 000pc's)

The category intensive flow, contains lifts with a flow intensity of 1000 to 20 000 pieces. These lifts are done in connections:

- Table 1&2 – Cooling Racks (3)
- Cooling Racks – Tub (4)
- Table 3&4 – Finished stock Racks (5)
- Table 3&4 – Train Carriage (6)
- Finished stock Racks – Train Carriage (7)
- Racks (Incoming Gods)– Tub (8)
- Grinder 203 – Bundling (9)
- Bundling - Finished stock Racks (10)

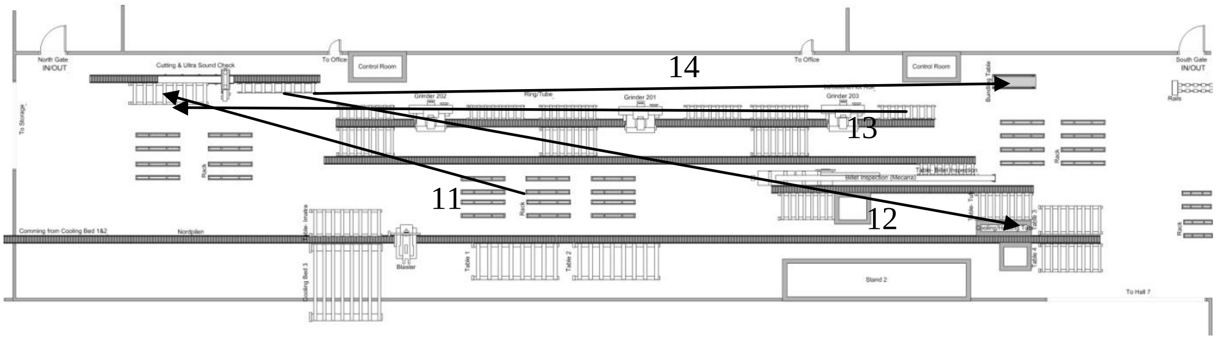


Figure 27. Ordinary Flow(25<1 000pc's)

The last category considers lifts in flows with an intensity from 25 to 1 000 pieces. These lifts are done in connections:

- Cooling Racks – Ultrasonic inspection (11)
- Ultrasonic inspection – Tub (12)
- Grinder 203 – Cutting (13)
- Cutting – Bundling (14)

Lifts will be illustrated in the same manner through all the report.

Another important aspect of the traverse lifts is the limitation of the customers' traverses and cranes. Since the customers in their inflows must lift the entire bundle, the weight of the bundle must be adapted for their limitations.

For flow A1&A2 as well as C1&C2 and C5 to C7, the limit is set by Ovako's own traverse which can handle maximum 16 ton, but 12 ton is used as a standard for maximum weight.

But for flow B1 as well as C3&C4, the limitation is 5 ton per lift. This means that more than twice as many lifts will be needed. This does only apply for the last lift out from the process. Regarding lifts within the process, 12 tons can always be lifted.

4.1.3 Activity Relationships

These relationships include not only operations in the process but also support-processes or other factors that are important to consider. It describes the specific connection between different activities and factors, which in the end should decide the closeness of the studied activities in the finished layout.

As discussed before, the focus on the activities is decided based on the type of production. In an extreme HVLV- production like this, the actual operation activities must be prioritized over other factors (see chapter 3.2.1).

According to this study the most prioritized relationships proved to be:

- Cooling Bed 1&2 – Blaster
- Blaster – Table 1&2
- Table 1&2 – Tub
- Tub - Table Tub
- Table Tub – Billet Inspection
- Billet Inspection – Table Billet Inspection
- Table Billet Inspection – Grinding 1&2
- Grinding 1&2 – Table Grinding 1&2
- Table Grinding 1&2 – Finished Stock Rack

This is the main flow in which almost all sub-flows passes, creating a much greater intensity here than any other place in the finishing activities. These relations given above must be the very core of the layout planning. If one of these activities will be poorly planned, it will result in huge losses for the entire production.

The second most prioritized relationships where:

- Cooling Bed 3 – Blaster
- Table Imatra – Blaster
- Cooling Bed 1&2 – Table 3&4
- Table 1&2 – Cooling Rack
- Cooling Rack – Tub
- Cooling Rack – Table Tub
- Table Billet Inspection – Grinding 3
- Grinding 3 – Table Grinding 3
- Table Grinding 3 – Bundling
- Bundling – Finished Stock Rack
- Table 3&4 – Finished Stock Rack

- Finished Stock Rack – Railway
- Table 3&4 – Railway
- North Gate – Finished Stock Rack
- Table Imatra – North Gate
- Finished Stock Rack – South Gate

These relationships are between activities and other factors that is not part of the absolute main flow but still are very important due to the intensity between the activities.

For the two remaining activity relation categorizations, see, appendix 10.5

4.1.4 Relationship Diagram

The last part of what could be considered to be the current state mapping is the relationship diagram *(see full-size diagram in appendix 10.6).* Here the entire flow between certain activities are mapped, and not as in the process flow diagram, divided by product groups.

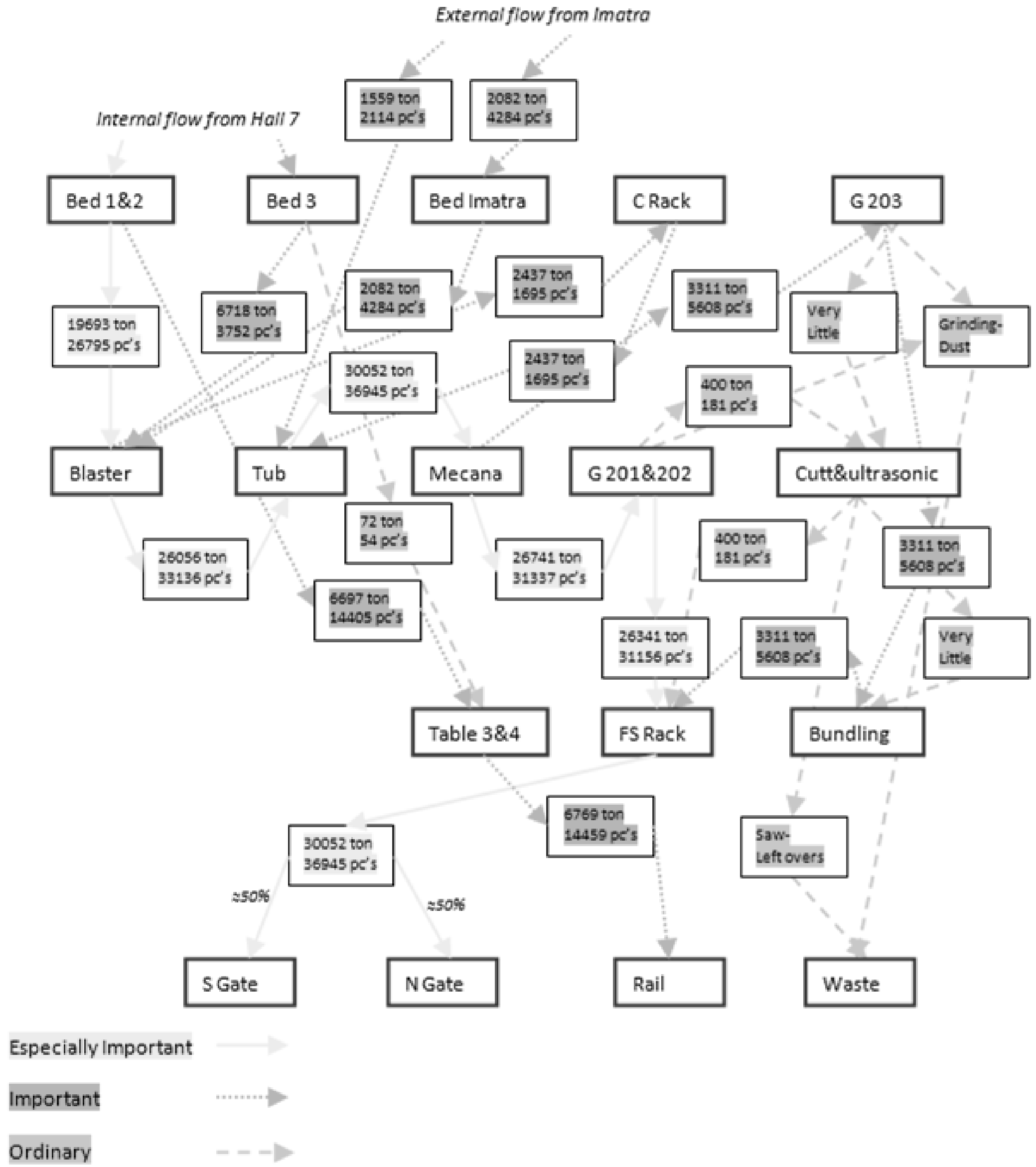


Figure 28. Current state relationship diagram

Due to the state of the production (HVLV) the identified high intensity flows here should correlate pretty well with the activity relationship chart, when both in this case are focused towards production activities with high flow intensity.

No new important relations were discovered in this phase, which means the prioritized relationships are still the ones mentioned in the activity relations section. The intensity of each flow for the highest prioritized relations proved to be: (Given in pieces)

- Cooling Bed 1&2 – Blaster 26 795
- Blaster – Table 1&2 34 831
- Table 1&2 – Tub 33 136
- Tub - Table Tub 36 945
- Table Tub – Billet Inspection 36 945
- Billet Inspection – Table Billet Inspection 36 945
- Table Billet Inspection – Grinding 1&2 31 337
- Grinding 1&2 – Table Grinding 1&2 31 337
- Table Grinding 1&2 – Finished Stock Rack 31 156

The intensity for the second most prioritized relations were: (Given in pieces)

- Cooling Bed 3 – Blaster 3 752
- Table Imatra – Blaster 4 284
- Cooling Bed 1&2 – Table 3&4 14 405
- Table 1&2 – Cooling Rack 1 695
- Cooling Rack – Tub 1 695
- Cooling Rack – Table Tub 1 695
- Table Billet Inspection – Grinding 3 5 608
- Grinding 3 – Table Grinding 3 5 608
- Table Grinding 3 – Bundling 5 608
- Bundling – Finished Stock Rack 5 608
- Table 3&4 – Railway 14 459
- Table 3&4 – Finished Stock Rack *(14 459 when out of wagons)*
- Finished Stock Rack – Railway *(14 459 when out of wagons)*
- North Gate – Finished Stock Rack 18 473 *(50% of 36 945)*
- Table Imatra – North Gate 6 398
- Finished Stock Rack – South Gate 18 473 *(50% of 36 945)*

The intensity of relations between the two gates and finished stock rack are approximated to 50 percent of the flow each coming from the finished stock racks. This is not perfectly true. The distribution may be argued to be more like 60-40 or even more towards the north gate. This is however not in any way critical and an approximation of 50-50 will be sufficient.

A measure of subjectivity is incorporated into this type of creation of relations. It could be argued that the flow towards Hällefors going from cooling bed 1&2 towards table 3&4 actually should be considered as number one priority. However, these subjective relations are mostly a pedagogical help, where the actual intensity should be considered as the “hard” data.

4.1.5 Space requirements and availability

What has been presented so far is essentially the intensity and characteristic of each flow in a detailed level. Remaining of the current state mapping is to decide which space is required for different activities and which space is currently available. This information gathered so far in the project will together result in a first, crude, layout.

These factors have all been taken into consideration while developing the current state layout.

4.1.6 Present state up times

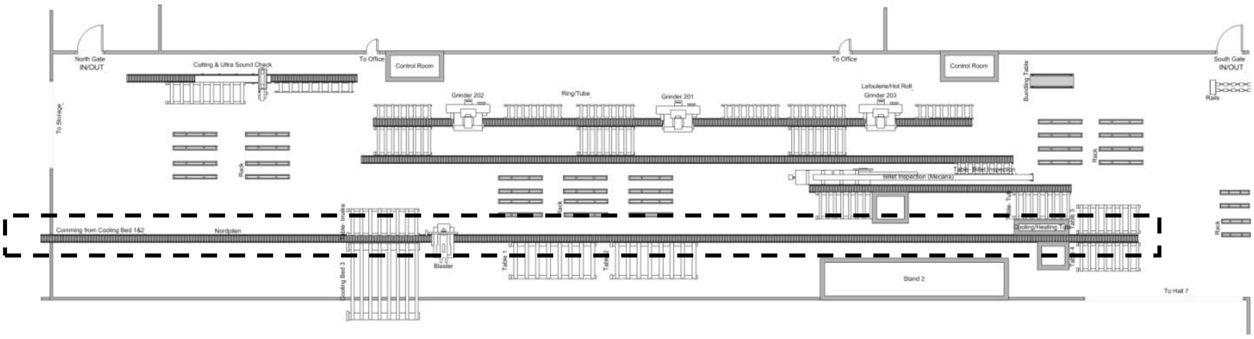
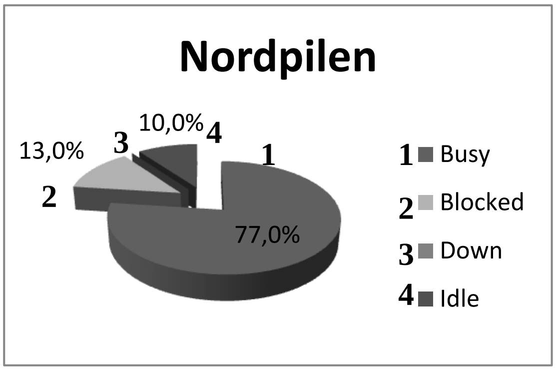


Figure 29. Layout Nordpilen, present state



The entire line reaching from cooling bed 1&2 at the north side (to the left in the layout) to table 3&4.

Figure 30. Uptime Nordpilen, present state

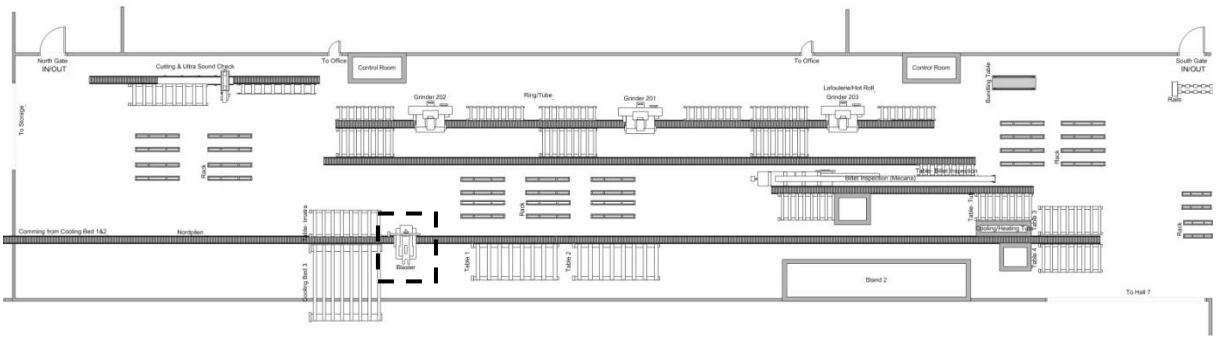
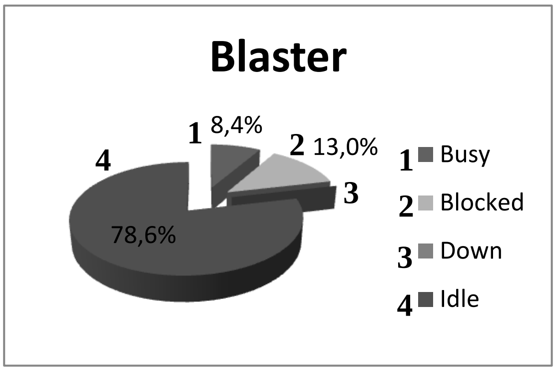


Figure 31. Layout blaster, present state



The blaster is mounted on the "Nordpilen" between cooling bed 3 to the north and table 1&2 to the south. Table 1&2 is the designated unloading tables for the blaster and material for the main flow.

Figure 32. Uptime blaster, present state

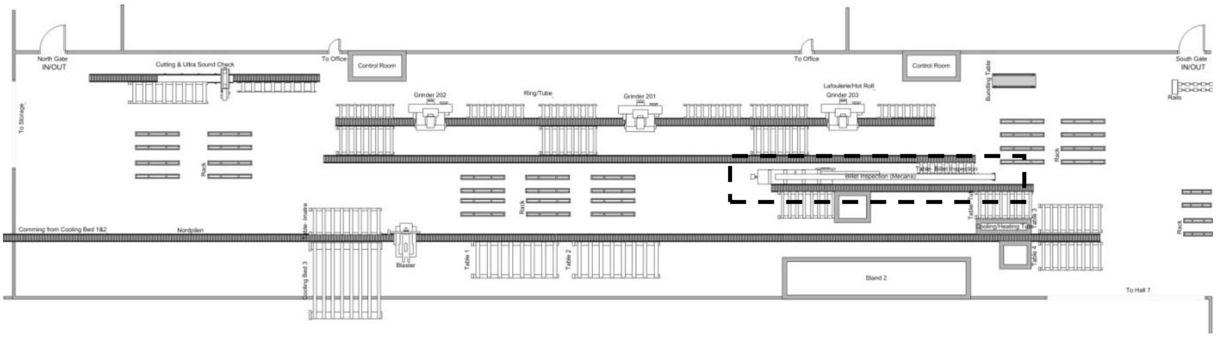
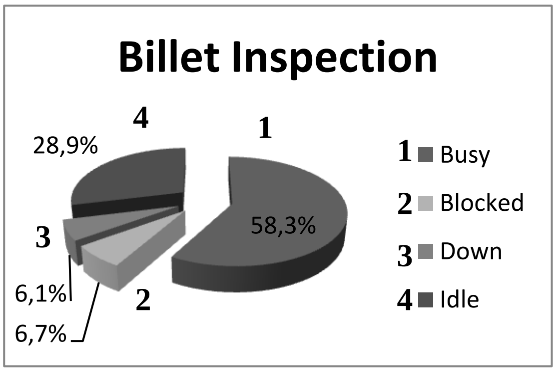


Figure 33. Layout billet inspection, present state



The magnetic particle inspection

Figure 34. Uptime billet inspection, present state

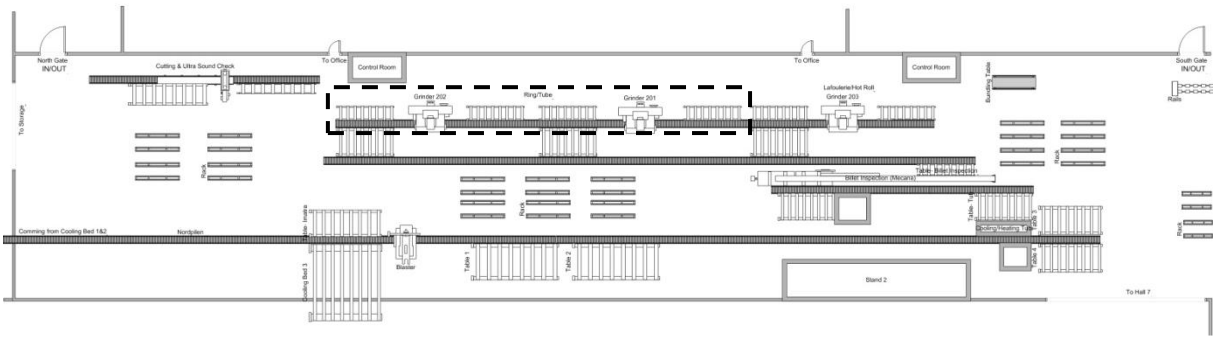
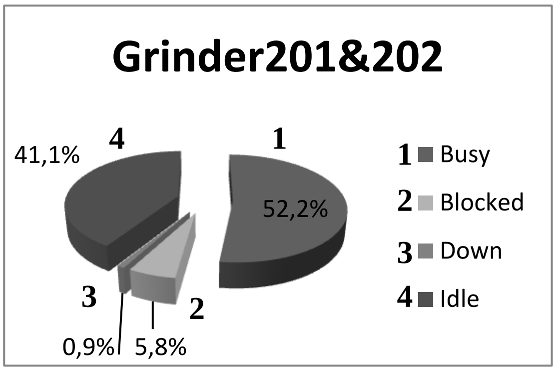


Figure 35. Layout Grinder 201&202, present state



Grinder 201 to the south and grinder 202 to the north. Each grinder has two designated unloading tables, one for the main flow (the northern tables) and one for scrap material (the southern tables)

Figure 36. Uptime grinder 201&202, present state

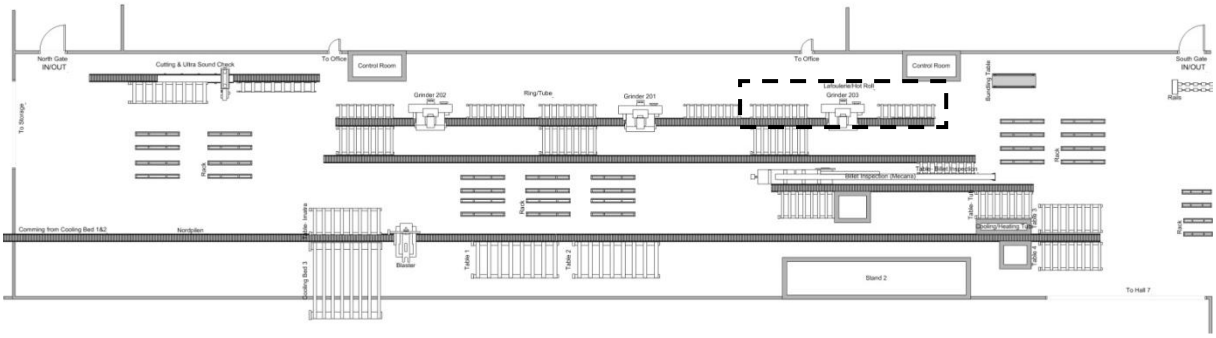
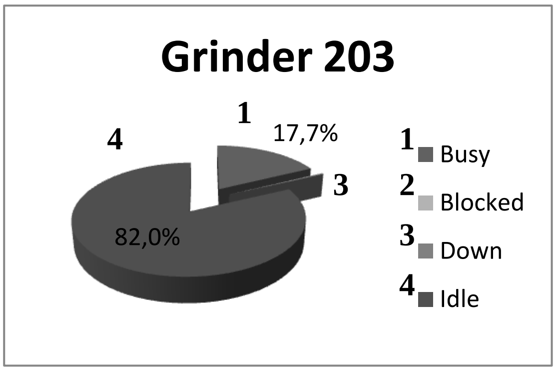


Figure 37. Layout grinder 203, present state



The grinder farthest to the south including two unloading tables, one for the main flow (to the south) and one for scrap material (to the north)

Figure 38. Uptime grinder 203, present state

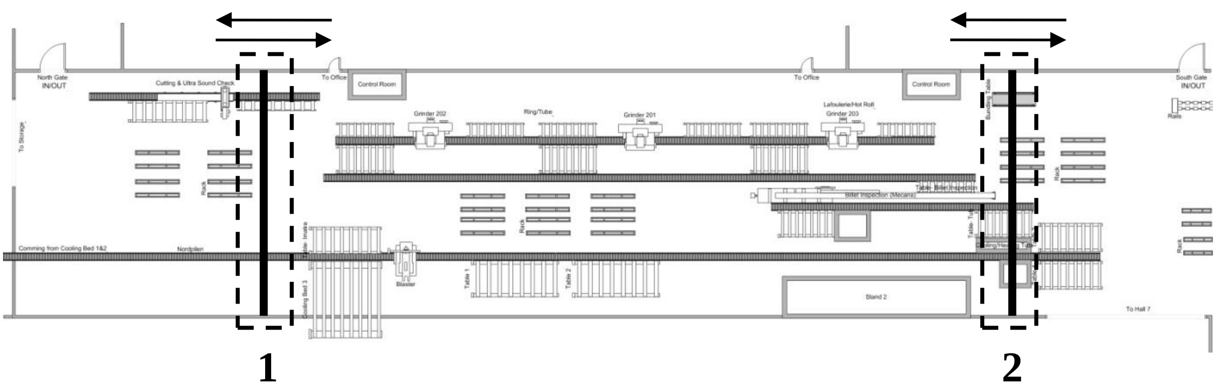


Figure 39. Layout traverses, present state

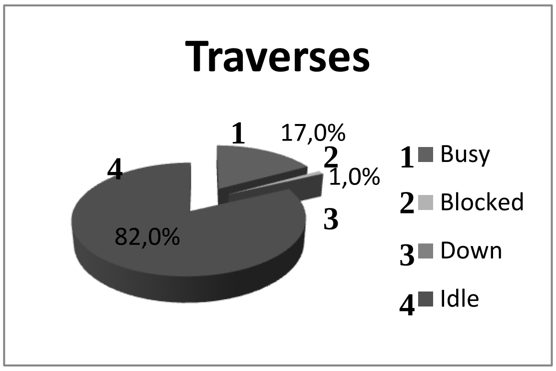


Figure 40. Uptime traverses, present state

The traverses are cranes that can travel through the entire hall 2. These can never pass each other, which constitute the very problem in handling these traverses.

4.2 The Future State

According to the pre-study, the flow to cooling bed 3 should be closed down and instead redirected towards bed 1&2 and 4, where 170mm should go to 1&2 (nr 2) while 190-230 will end up at bed 4 (nr 1). In the same time the demand from the internal customer “Tube” will be changed to coarser dimensions, resulting in that the same volume now will equal slightly less produced bars.

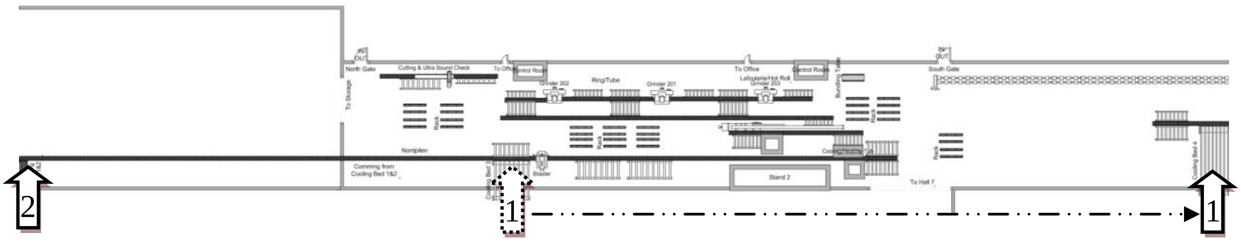


Figure 41. Entire layout hall 2 and loading area. Changed inflow from bed 3 to bed 4

This change in production will yield an increase in production capacity of 9%. The increase is based on weight, which means due to the coarser dimensions the increase in number of produced bars will be less, approximately 7.7%.

Including the reduction of pieces due to coarser produced dimensions to Tube and the external incoming material (C5, C6 and C7) that will remain the same, the final increase in production capacity given in pieces, will be 6.6%.

Furthermore the overall tact including all 10 flows will drop from 63.2 to 59.3 seconds.

Flow	Coming From(Bed)	Going To(Customer)	Sizes
A1	1&2	Hällefors	78-170
A2	4	Hällefors	190-230
B1	1&2	La Foulerie & Hot Roll	78-160
C1	1&2	Tube	78-170
C2	4	Tube	190-230
C3	1&2	Ring	78-170
C4	4	Ring	190-230
C5	Imatra 280T&285K	Tube	78-160
C6	Imatra 280T&285K	Tube	170-230
C7	Imatra 803F	Tube	78-160

As given above, the flows will be slightly changed. The flows coming from cooling bed 1&2 will from now on include 78mm-170mm. The flows that former was arriving at "Nordpilen" trough cooling bed 3 will now instead arrive at cooling bed 4, and then only 190mm-230mm.

There will be slight changes in the intensity of the flows, which is given by the Process-Flow diagram (see Figure 42).

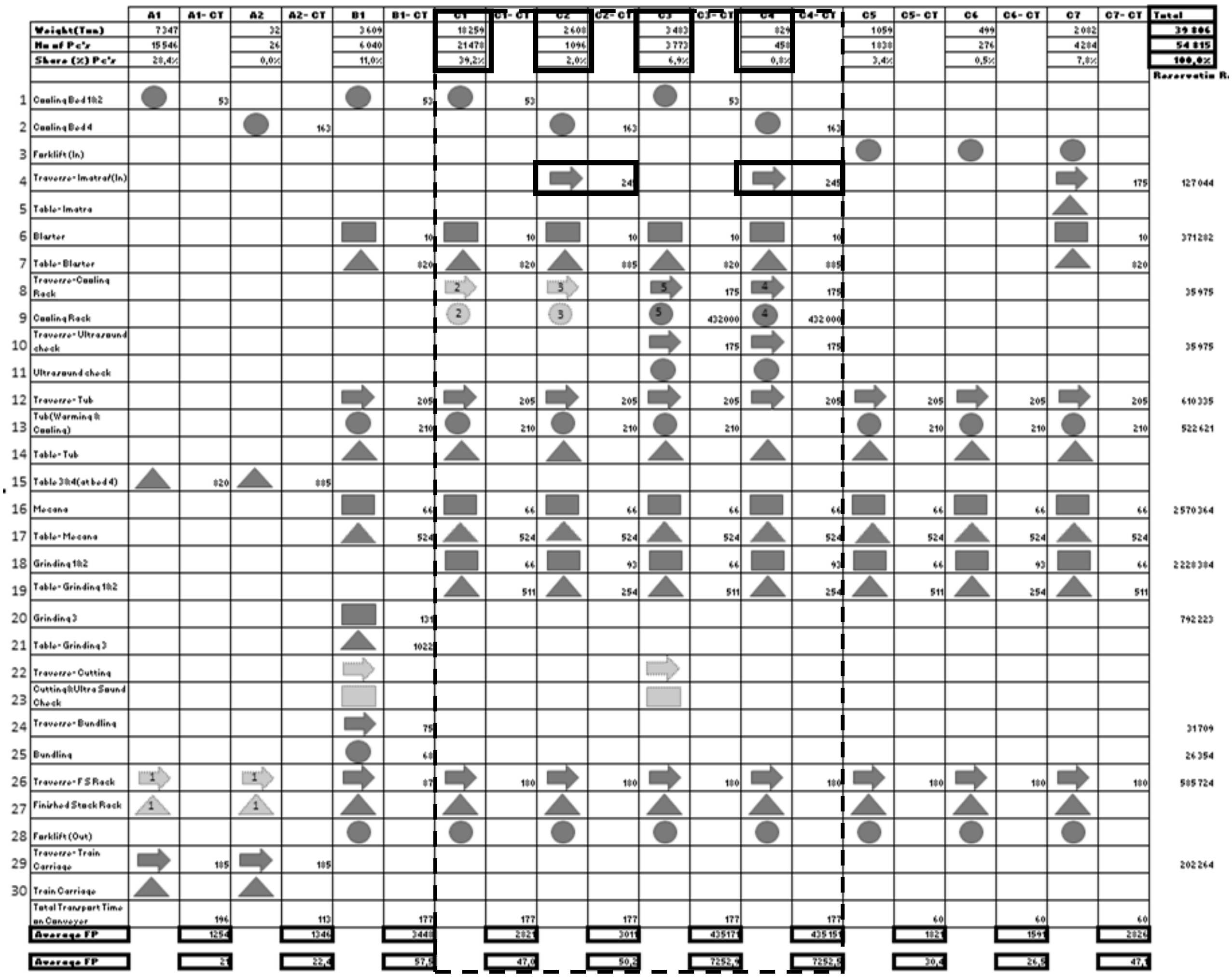


Figure 42. Process-Flow Diagram (Future State)

Flows A1, A2 and B1 will not be affected considerably. C5, C6 and C7 will not be affected at all since these are external flows, and are never entering the rolling operation.

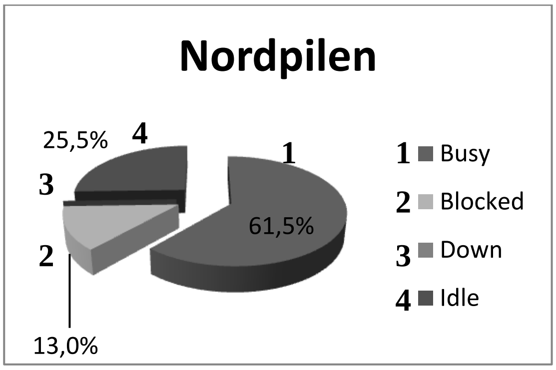
Instead, the significant changes will be seen in flow C1, C2, C3 and C4 (within the dashed line).

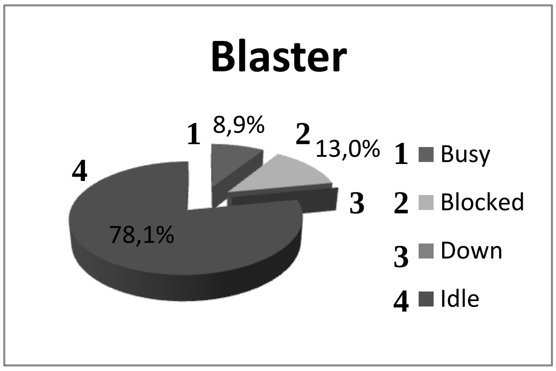
C1 and C2 are the flows going to Tube, and since this is the customer that has the forecasted change, these flows will be most affected. C1 is going from 18 276 pieces to 21 737 meanwhile C2 loses from 2735 to 1110. This is due to the fact that 170mm bars are forecasted to be around 85%, counted in weight, of the total production for tube.

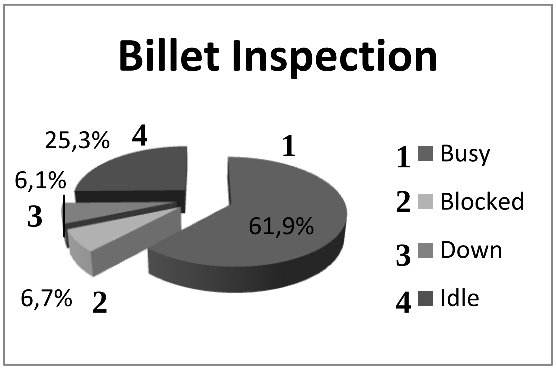
C3 and C4 will also be affected relatively much. This is due to the considerable amount of 170mm bars produced to this customer, a diameter that will be redirected towards cooling bed 1&2.

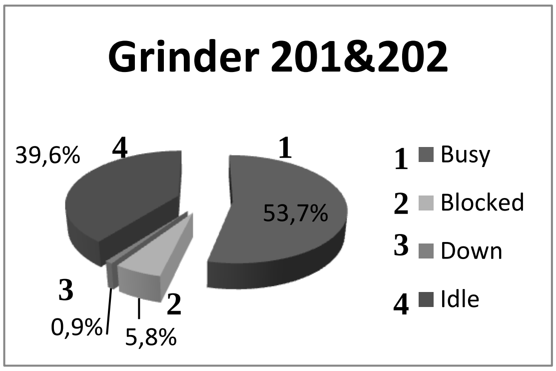
C2 and C4 will have one added lift (bold marking) since these now must be lifted from Bed 4 to the Tub.

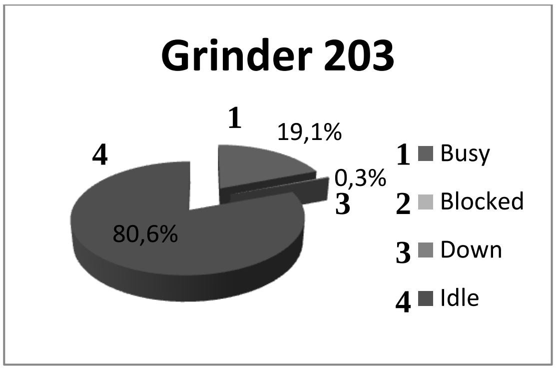
4.2.1 Future State Up Times











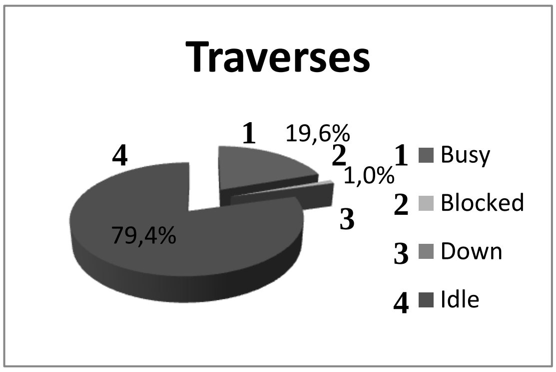


Figure 43. Uptimes all activities, future state

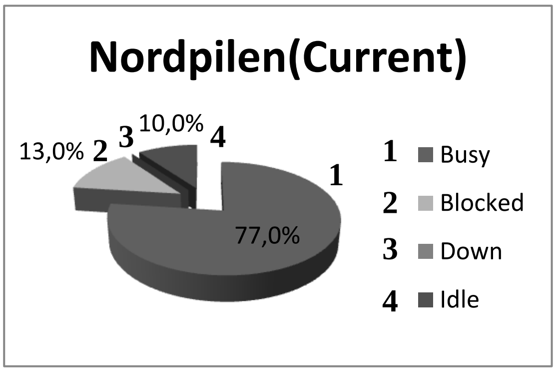
5 Analysis

This chapter will at first in detail go through each critical factor in the flow and which intricate problems the factors will lead to in each situation. Secondly, each possible layout suggestion will be created based on these analyses, so that the factors are taken into consideration for the suggested layouts. Finally the layouts will be evaluated due to different criteria and one optimal solution will be presented.

5.1 Analysis of Activities and connections

The first pie chart (left) shows the current state. The other chart (right) is based on calculations made for how the production would look like after changes are implemented in the rolling operation according to the pre-study.

5.1.1 Nordpilen



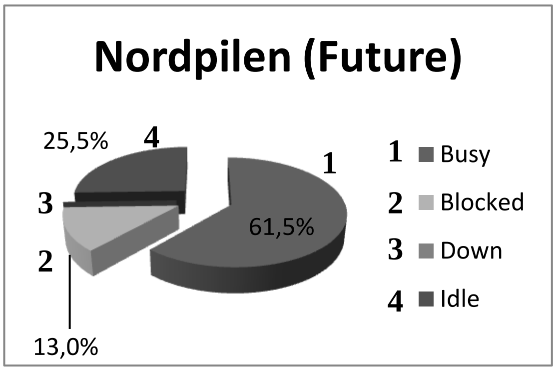


Figure 44. Uptime Nordpilen, present and future state

In the current state,"Nordpilen" appears to be the critical part of the production in the finishing section. However it is not this actual line, but instead the flow coming out from rolling operation that is the really critical part. While blocked 13%, this does not mean it is not operative since the flow here are divided in two directions. While the blockages appear, often caused by problems or reparation at the billet inspection, the flow A1 and A2 (towards Hällefors) is still operative. That means a blockage here is not automatically a stop in the whole production.

The 10% of idle time and a large part of the 13% blocked time, the "Nordpilen" is suffering from starvation due to production stop from rolling operation.

The cycle time is set by the rolling operation, this means depending on production of choice the cycles can differ greatly. The extreme would be when solely 78-80mm bars are produced in the rolling operation, which would yield a cycle time of approximately 20 sec coming out from cooling bed 1&2. This is however extremely rare.

When one of cooling bed 1&2 or 3 are operative, it will automatically close the connection for the other one, blocking this entirely until the other flow is cut off.

Maybe one of the most critical parts in the production flow is the lift between "Nordpilen" and the cooling/warming tub. This is a lift over a long distance passing high objects and narrow spaces. It also disturbs the one-piece-flow, aggregating the bars in everything from a few up to around 15 pieces per bundle.

To get rid of this lift entirely however may prove difficult. The customers of Ovako all have different demands for sorting of the steel. This may be for example that end pieces, that could show slightly different characteristic compared to the other rolled pieces from the same ingot, should be sorted separately. Since these steel bars, weighing several tons each is hard to separate when finally put together, this sorting must take place before put in finished stock racks. The sorting currently is made during this lift. So this sorting procedure when trying to implement a one-piece-flow here must be made later in the process, preferably after the grinding operations. While indeed possible, this may prove tough to realize and even harder to prove economically viable. This means in actual terms that more tables after grinding operation has to be installed, as well as a system that divides pieces before grinding to each grinder depending on the customer demand on that specific batch. To motivate these investments, a considerable advantage in the production flow must exist. Also even if the investments are made, there is a lack of space at this section, and more tables here would risk resulting in a very crowded layout. Another investment that has to be made is a cooling tub that permits a one-piece-flow.

There is however also possibilities to greatly shorten this lift, which not would render in a single flow but at least reducing the time consumed when doing the lift to an absolute minimum.

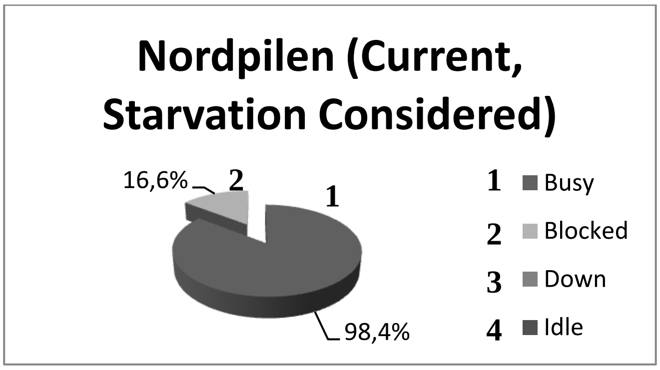


Figure 45. Uptime Nordpilen, present state with starvation from rolling considered

The graph above shows the workload for “Nordpilen” when the starvation from rolling operation is excluded. This means that in the current state, this line is always used to around 100% when the production is going in rolling operation. When the line is always used, and mostly fed from bed 1&2, bed 3 cannot operate so even if there is extra capacity everywhere else and the pieces are already rolled, they cannot enter the second hall, creating poorly used capacity.

5.1.2 Blasting Operation

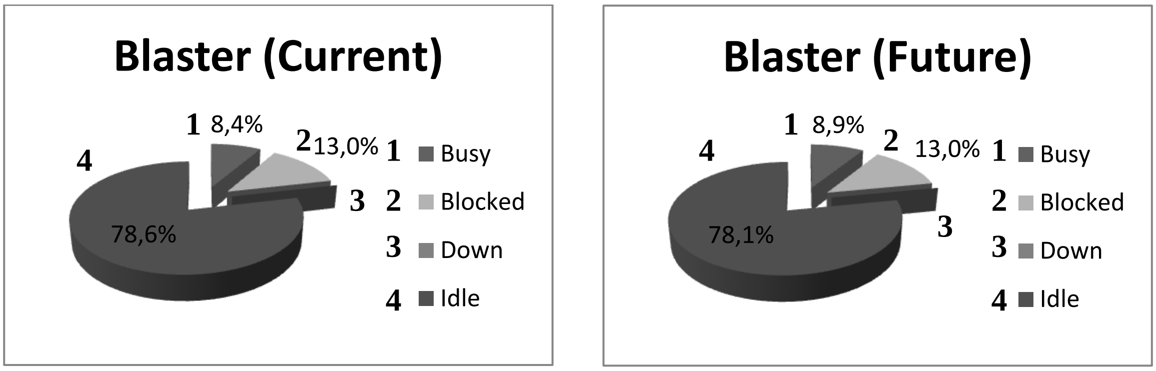


Figure 46. Uptime blaster, present and future state

The blaster will have a slightly higher workload after the changes are implemented due to the somewhat increased production rate.

The blaster position may possess the largest potential of gains to be made in the entire layout. While all material from the rolling needs to pass through the blaster, some is actually not blasted but just run through the blaster in off mode (A1 and A2). This occupies the blaster without adding further value. In the same time, material arrives from Imatra that needs to be blasted. If the blaster is removed from the line towards Hällefors ("Nordpilen"), this material could be produced parallel with the steel to Hällefors. This would mean that around 8.3% of the entire production could be produced in the same time as the 28.1% going to Hällefors. This would render these 8.3% as extra capacity for the finishing operations in hall 2.

This is not the bottleneck of the operations which means that the extra production capacity will be shown in more effective utilized time, but not more bars produced. However, if more external material where to be used, this layout change would contribute hugely to a potential significantly increased production.

The position of the blaster holds a huge potential but it will also create one of the largest problems in identifying the optimal layout. When the flow coming from rolling is altered and material will enter the second hall from both the north and the south side, this flow has to be connected somewhere before the blaster. This means the blaster must receive material from two different directions, which will present a problem.

This could be solved in three different ways.

1. The material could be lined so that the bars coming from different sides, is connected together before the blaster so that the blaster only needs to receive material from one direction
2. The material could be lined from two different directions. Then the line into the blaster must be able to feed in two directions so that it is altered depending on what is produced for the moment.
3. The table for material from the north could also receive the material from the south. This however would mean a long and problematic lift with the traverse each time material 190-230 must enter the blaster.

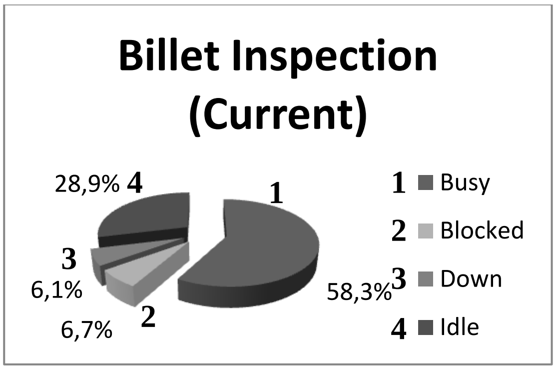
Also worth considering is that after the changes, material from the south that must be fed through the blaster counts only for 1573 pieces or 2,8% of total production. This means it will be hard to justify large expenses to optimize only this flow.

5.1.3 Tub

As seen in the tact time chart (see Figure 24), the cycle time for the tub is not critical. Even though rising far over tact time in the diagram, for each batch, when calculating each single piece's cycle time they are far beneath overall tact time. While the cycle time for large pieces, due to smaller batches, are almost 40 sec and closing to overall tact, the time for thinner pieces are considerably shorter (up to around 15 sec).

The pieces cooled down in the tub must never be warmer than 200 degrees, since this would mean risks both for splashing boiling water, crooked bars but also a risk to affect the steels properties.

5.1.4 Billet Inspection (Mecana)



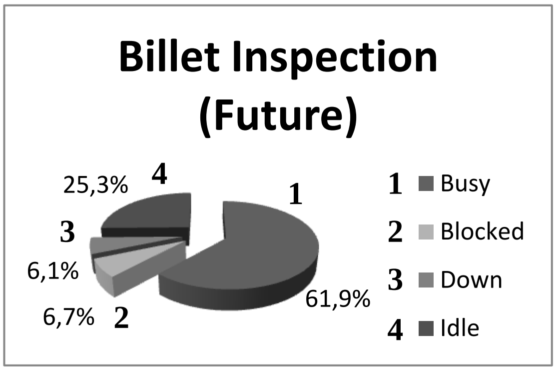


Figure 47. Uptime billet inspection, present and future state

The billet inspection is in certain cases the bottle neck of hall 2.

When pieces in average 78-160 are produced, the cycle time for the billet inspection and the grinders are similar. When producing thinner pieces the Billet inspection becomes the single bottleneck.

While being slightly over the overall tact time, this will in many cases be compensated by the production not passing through the Billet Inspection, which means the production towards Hällefors, at least speaking in average terms. This could lead to small temporarily stockings before the billet inspection.

This risk also increases after the changes are implemented. The overall tact from rolling will drop from 63 to 59 sec. This is however calculated with flow A1 and A2 taken into consideration. When these parts, that have a shorter production time is extracted, more than calculated tact time will remain for the rest of the parts to be produced.

This machine cannot inspect material warmer than 70 degrees or colder than 20 degrees, which is a problem since coarser pieces not will have time enough to cool down to 70 degrees while just following the ordinary material flow. Included in the term "ordinary flow" is here the flow through the tub. So this means while thinner pieces are cool enough to be cooled in the tub after the cooling bed operation (less than 200 degrees), the coarser pieces are not.

The Billet inspection can only inspect dry pieces, since a wet piece would mean that too much ferro- magnetic particles would get stuck elsewhere on the piece.

5.1.5 Grinder 201&202

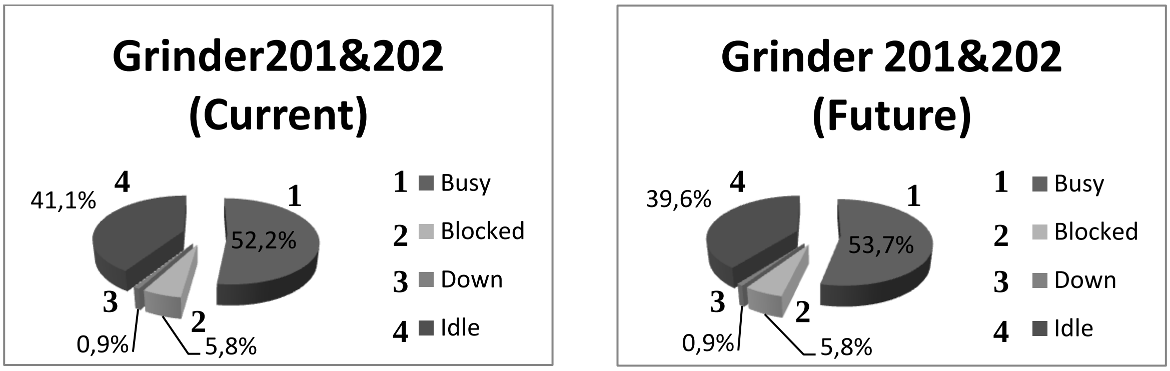


Figure 48. Uptime grinder 201&202, present and future state

This is in certain cases a bottle neck. The average grinding time for products 170-230 lies clearly over overall tact time and takes longer time than the rest of the activities in the process. This could be seen through large amount of products stocking the grinders and causes the total process all the way back to the tub to stock. This leaves however the flow to Hällefors open, which explains why the total workload for "Nordpilen" could be over 100%, while it could be blocked in one direction but operative in another. These grinders are currently used for only little more than 50%. So even though they cannot manage to keep up with the other activities in the process while producing coarser pieces, when the flow is diverted towards Hällefors or changed to thinner pieces, they have usually time to finish their parts before needed again. Also it is noticeable that for dimension 78-160, the grinders are approximately as fast as the billet inspection, and since these products make up for around 90% of production, the stocked grinders are not that very common and therefore not an as huge problem as it first seems.

The fact that these machines, together with the billet inspection cannot be moved is a problem, so is the lack of space in front of the grinders. Ideally, the area for finished gods would be just in front of the grinder tables. This would take away the poor lift from especially grinder 201. However, there exists no such area in front of the machines, which leaves the only opportunity to improve this lift to move the tables. To do this, the flow must either be redirected so that the line that feeds material between the billet inspection and grinders are moved to the other side of the grinders, or the lines will have to cross each other.

Since different customers have different demands on the weight of the bundles sent to them, the grinder with worst position should be assigned for the flow with least lifts/ton, which means the C1&C2. This means that flow B1, C3 and C4 that represents approximately 20% of the entire production should if possible be diverted mainly to grinder 202 (if outflow is assigned to the north side). The flow C1, C2, C5, C6 and C7 to Tube then must equal out so that the approximately the same amount of bars are directed to the two grinders.

5.1.6 Grinder 203

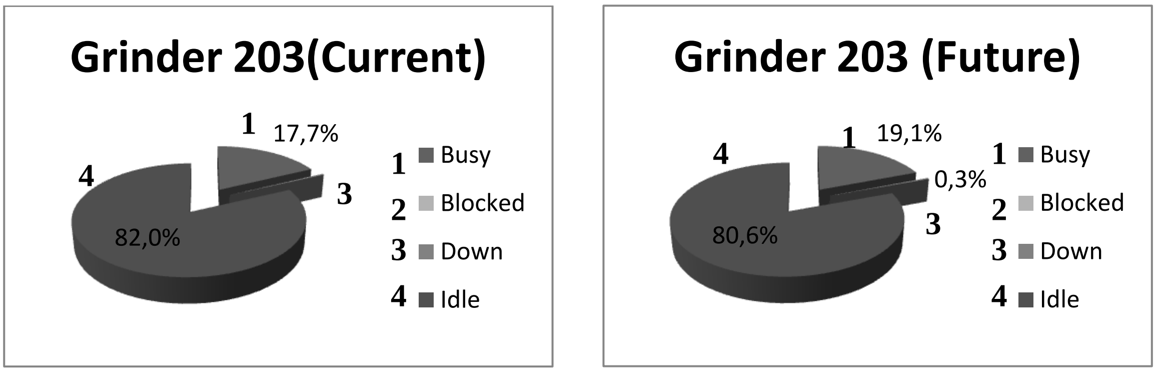


Figure 49. Uptime grinder 203, present and future state

This grinder is used for production towards external customers only (La Foulerie and Hot Roll). When used, this grinder are rapidly overcrowded (see Figure 24), since it is then doing the work two grinders normally are splitting. When this grinder is used G201&202 are usually inactive. This flow is however only 10% of the total flow which means that it will be able to finish the grinding procedure until next time the external goods is being produced. The problem would be in that case when too much external material is produced at the same time. If the table before the grinder is full then it would cause a blockage all the way back to the tub. As seen in the graphs above, this grinder is not even being used to 20% of its total capacity.

5.1.7 Grinding of Forged Steel

Due to customer demand, the company will start to grind their forged pieces. This means that this flow must be incorporated into the flow in the second hall. One potential solution for doing this would be to assign two grinders for rolled material and one for forged.

The number of forged bars amounts to 415 which equals around 7.5/day. This means that the total operating time required on the traverses would be 44 min/day.

The uptime on the grinder used for the operation would, with an operation time of 7 minutes per piece, equal 52 minutes per day. (The operation has never been done before which means the processing time of 7 minutes/piece is an assumption of the average grinding time)

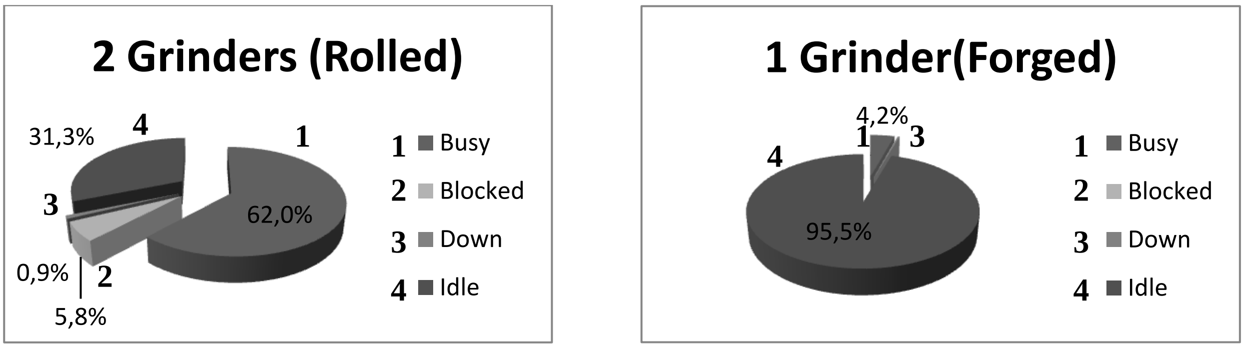
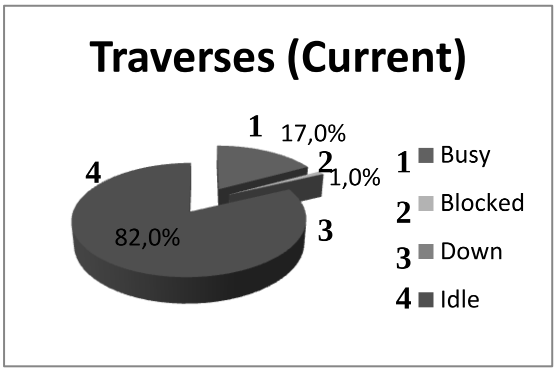


Figure 50. Uptime grinders after tasks assigned, future state

The two grinders will have an increased up- time. However for the average production it should not be any problem. Situations will occur, as before, when focused production towards thinner bars are produced, that the grinders will not keep up. In those, not very common situations where a faster production is needed, grinder three with 95,5% of idle time could be used if needed.

5.1.8 Traverses



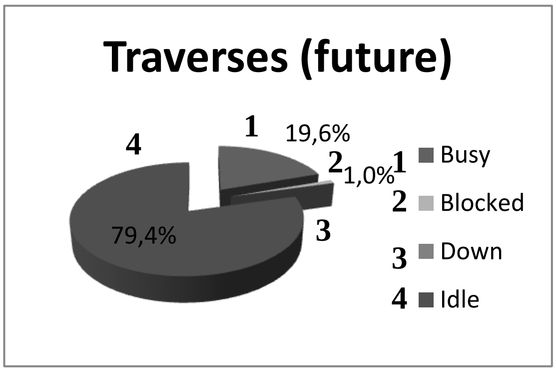


Figure 51. Uptime traverses, present and future state

Although not bottlenecks, these traverses are a problematic part of the production. Even when a lift works perfect it is still time consuming. Especially long lifts over other machines, forcing the operator to raise the bundle all the way towards the ceiling consumes a lot of time. Therefore a lift should always be short, no necessity to lift especially high (not over other machines) and preferably only in one other direction.

Maybe the most significant problem with these traverses is that the two lifts made in and out from the main flow (from tables 1&2 towards the tub and from grinder 201&202 towards finished stock racks) are in line with each others. This makes it impossible to do the lifts at the same time. While these lifts are done very often during the production (ca 70% of production), this will be a repetitive waste of time since there is a risk that one traverse must wait for the other to leave before it can start to load its cargo. It would be desirable that the two traverses could work independently of each other, and then especially concerning the main flow.

It is not only important to consider the actual start of the lift, but the whole working area for the traverse in that operation. E.g. the traverse should be able to work between table 1&2 and the tub independently while the second traverse does the same between grinding 201&202 and finished stock racks.

Lifts that has to be done all the way from one end of the production area to the other almost always results in time wasted when the other traverse first must be moved out of the way. Desirable would be a situation where the second hall could be divided into separate areas with a definite line they would never have to cross (during one type of production) and where both traverses got the same up time and nothing had to be made simultaneously in that very area. This solution is not fully achievable within these delimitations, but should be an ideal to strive for.

As already been mentioned, the weight of the bundle leaving the process must be adapted for the customers limitations regarding lifting capacity.

Regarding flow A1&A2 as well as C1&C2 and C5 to C7, the limit is set by Ovako's own traverse. This will handle maximum 12 ton.

For flow B1 as well as C3&C4, the limitation is 5 ton per lift. This means that more than twice as many lifts will be needed.

This means that the grinder that has the worst placement could be assigned 50% of the flow going through here, but less than 50% of the lifts will be needed. Material in the flows where 12 tons bundles was accepted, should preferably be grinded on grinder 201(the middle grinder). Material that needs to be lifted more times should then be grinded on any of the corner grinders so that these lifts will be shorter and faster.

Flow B1 and C3&C4 should preferably be grinded on the best placed grinder. Since these make up for around 18,7%, these should be complemented with 17,1% of the material from any of the other flows to be grinded. This would render in that 35,8% of the total production is sent to each grinder, and they receive the same amount of work.

However, only 1374 lifts need to be done from the middle grinder while it from the corner grinder has to be done 2378 lifts. Around 5 minutes would be saved per day due to this operation in comparison to if the production is randomly sent to the grinders.

But this would require an adaption of the production planning. This means too much of material from flow B1 or C3&C4 cannot be produced consecutive after each other, since this would mean that also the worst placed grinder has to grind these pieces.

5.1.9 Cooling Racks

The cooling racks are needed for several reasons. Some alloys must receive a special treatment, which makes it impossible to keep these billets on the production line. Steel type 277 and 477 (678 pc's) must never be cooled down faster than what it means letting them cool in room temperature, otherwise they will bend.

Furthermore all steel 170mm<230mm going to Ring, must be ultrasonic tested due to risk for hydrogen embrittlement. This may occur a long time after the actual production. A balance between probability that the embrittlement have had time to occur and convenience out of a logistic as well tied up capital perspective is at Ovako considered to be 5 days. Therefore this steel (1017 pc's) must be kept in cooling racks for 5 days before continuing through the ultrasonic inspection, billet inspection and grinding.

Apart from these pieces always passing the racks, all steel warmer than 200 degrees or when the line is blocked must also be laid here. It's very hard to estimate how many these actually are, since it is depending very much on the single case, but at least it is an amount big enough so that it can be called a prioritized flow and there is large savings potentials to be found.

As earlier mentioned, the rolling operation is the actual bottleneck, therefore blockage in the rolling operation due to stocking in the finishing operation must be avoided.

5.1.10 Ultrasonic Inspection

The inspection with ultra sound is made manually on a wet surface. This means there is some problems to link the ultra sound with the billet inspection, since the material must be dry before entering.

There is however problematic to switch the order of those to operations. Ultra sonic inspection must preferably be done before billet inspection since the ferro- magnetical particles that gets stuck on the pieces disturbs the reading from the ultra sound inspection.

If these should be linked, the steel bars must be dried quickly. It is also important to consider the intensity of this flow. One lift could be saved by integrating the ultrasonic inspection to the line. This would mean 1017 pieces which would correspond to a time saved of something between 4 and 10 minutes (or 3.45 lifts) on the traverses per day, depending on layout.

This flow could however differ greatly, since the flow going through ultrasonic inspection mostly is decided by the customer, resulting in that the flow could due to customer demands change quite rapidly.

According to future expectations this procedure will be much more common in the future. The case may even be that all material passing through the finishing operations also shall go through ultrasonic inspection. In this case the operation would be insufficient. If this will be the case an automatic line mounted inspection device should be installed and then the material needs to pass through a section that can dry the material quickly. This may not be economically viable for now, but would definitely be if these changes take place. Around 54 lifts would be saved per day with an integrated ultrasonic inspection if the entire main flow were to be inspected.

Another concern that appears after the changes is that the 170mm flow from bed 1&2 towards Ring must be laid in rack for 5 days and then ultrasonic inspected. Either a possibility to check the material at the north side must be added or the material itself must be transported to the south side and then inspected together with the other, coarser flow. To avoid a long lift over the machines, 170mm to “Ring” could be transported to table3&4 via “Nordpilen” and then join the other flow at the cooling racks.

5.1.11 Table for bars 190-230 from Cooling Bed 4 (Input towards blaster)

This is important due to the convenience of the lift from bed 4. The lift will be relatively long, which is hard to do anything about if not installing a new line which hardly would be possible to motivate due to the small intensity of the flow. But if the lift never has to be done up towards the ceiling, lot of time is saved when keeping the bundle close to ground level. This means the input into the main flow should be from the south side of the blaster and billet inspection, so that it never has to be lifted over any machines.

It would also be preferable if this input is placed south from the tables of grinder 201. In this way, the traverses would have a decreased risk to block each others.

5.1.12 Table 3&4 towards Hällefors

The flow towards Hällefors is a high intensity flow. These connections should not be put so that they risk blocking the traverse working with the main flow. This means it would preferable be placed further to the south than any other connection in the main flow.

5.1.13 Table 1&2

These tables have part in one of the two most important lifts in the process. This means that the tables must not be in line with the tables to the grinders utilized for the main flow.

It is also important these tables are placed in a big open area with close to racks so that a minimal lift is required. Occasionally the flow to the cooling racks will be large, forcing longer lifts, this however should not be necessary unless extreme situations.

These tables could also be replaced by some form of tray. This would be more space consuming along the line (due to that 4 is needed) but less space consuming out from the line. The reason why a large table where the bars are transported across is needed is that a small gap must be made between different types of steel, and by this separate the bars. With four trays, two could be used and while these are emptied the other two may be utilized.

5.1.14 Warming procedure of Steel

A steam operation is built into the tub. This is used for cold and wet, external steel, before entering the billet inspection operation. So with the current layout the main flow is blocked while heating these pieces. This is not a significant problem if cycle time of the steam operation is shorter per piece than the grinding and billet inspection cycle time.

This operation would preferably be built in earlier in the operations so that when the material reaches the line, the properties of the steel are already correct. This would cut this non-value adding heating time from the operation and free more capacity. However, this would only concern the steaming of the first bundle if, as stated above, the cycle time is short enough.

5.1.15 Flow in and out of the Gates in Hall 2

The flow through the gates in hall 2 is not very regulated. In and out flows are passing both gates rendering in mix of different materials in racks all over the factory floor. It would be preferable if this could be unidirectional flows, creating one in and one out flow. This would give an easier sorting and keeping of the material while not operated on.

Preferably would this flow enter the south side and exit the north side. Due to the lesser flow in incoming and the congestions that already exist at the south side, it would be a disproportional amount of activity if done otherwise.

5.1.16 Buffer after lift: Nordpilen – Tub

This is not a buffer in that sense that it is needed for maintaining constant production but rather to decrease the need for laying material at the side of the line.

The ideal naturally would be if no material had to be laid at the floor in racks, since this would save two lifts per billet. However, the extremes could never be covered since this would mean disproportionately large tables that could not be justified. Therefore a balance between minimal extra, unnecessary lifts, enough material on the table so it never runs out and stops the process as well as not to large tables must be found.

A simplified calculation gives that with a certainty of 99% (2.33 standard deviations) it will be sufficient with a table size of 1.63m. This means that nothing will have to be laid at the floor if no exceptions exist.

The standard deviation of the lifts is 272 sec which gives a buffer demand for 633 sec. This means that for cover up the differences between lifts and by that in general have the same amount of steel bars on the table there is a need for maximum a 633sec worth of buffer. What also has been stated is that in average the products coming in to the lift and the products operated after the lift has the same cycle time, which means the standard deviation should give an approximate picture of the reality.

However, this calculation implies that the production would go through the entire range of different diameters one after one covering them all before starting on a new round. This is not true since several small diameters could be produced after each other. This is though, highly irregular and a scheme or rule does not exist here. Also this does of course not consider the temperature or the alloy as factors.

Dim	Pc's/Lift	Sec Between Lifts	Cycle Time	Bottleneck (after)	BN(s)	Lift<BN (s)
78	15,58	472	30	Mecana	66,0	Yes
80	15,58	602	39	Mecana	66,0	Yes
85	15,58	716	46	Mecana	66,0	Yes
90	15,58	846	54	Mecana	66,0	Yes
95	15,58	830	53	Mecana	66,0	Yes
100	15,58	895	57	Mecana	66,0	Yes
105	15,58	960	62	Mecana	66,0	Yes
110	15,58	1286	83	Mecana	66,0	no
115	15,58	1237	79	Mecana	66,0	no
120	14,46	1253	87	Mecana	66,0	no
125	15,58	1237	79	Mecana	66,0	no
130	11,65	1253	108	Mecana	66,0	no
135	11,11	1253	113	Mecana	66,0	no
140	10,71	1253	117	Mecana	66,0	no
150	9,68	1253	130	Grinder1&2	80,5	no
160	9,23	1253	136	Grinder1&2	80,5	no
170	5,77	1253	217	Grinder1&2	80,5	no

Table 3. Relation between bottleneck and rolling operation cycle time

Table 3 describes the cycle time of outgoing bars from rolling operation in comparison to the cycle time of the bottle neck in the finishing operation. The time it will take for a batch (lift) of bars to arrive at the tub is compared with the time it will take for the same billets to continue through the billet inspection and grinding operation.

Given from the last column is that concerning steel from 78mm to 105mm, there are an imminent risk that the steel bars will push much faster than the finishing operation can handle. This creates the situation where the billets after a while must be put at the floor. From 110mm to 170mm on the other hand, the finishing operation has more capacity than the rolling operation, creating no problem for the lift or the buffer size.

The intensity of this flow 78mm to 105mm is by no means negligible, when it amounts to 11920 pieces, around 39% of total internal flow between Nordpilen and Tub.

78 mm bars will be lifted each 472 sec meanwhile each lift will have cleared the billet inspection after 1043 sec. This means that less than half the billets has yet left the buffer (55cm of table space), rendering 68cm of the table still crowded when next batch is to arrive. According to this, a table of almost 2m is needed only to coop with the current lift plus what is left not yet inspected from the previous lift. A third lift without laying anything aside would mean a table of 260 and so on.

5.1.17 Rack area close to the lift Nordpilen-Tub

Of the steel 78-105 mm (where the rolling cycle time is less than the finishing bottle neck cycle time), 90mm is the by far most common type. In the most extreme case during the given period, 108 ingots resulting in 756pc's of 90 mm bars where produced continuously after each other. The theoretically shortest cycle time for 90 mm in rolling operation is 41s giving that an amount of 461 bars would pile up in front of the billet inspection, equaling over 40 m.

In this extreme case it will take around 30 lifts to get rid of the bars that start to pile up in front of the billet inspection before the production schedule is switched and the finishing section once again is faster than the rolling operation. Approximated that these occurrences happens once every week, 17 minutes could be saved per day (2h/w), through placing cooling racks close to this lift.

A comparable "ordinary" every day situation with temporarily heights would equal around 4m of needed space in front of the billet inspection (6 lifts to clear). This occurs in average twice per day and would result in a time saving of approximate 24min/day with racks close to the lift.

To empty the line in the most extreme case mentioned above it will take little more than 5 racks, which may be an amount hard to fit extremely close to the connection. In the ordinary day scenario on the other hand it will be sufficient with 2-3 racks. One rack will be needed for the temporarily maximums, one for storing the sensitive alloys that may not be cooled down to fast and one extra as buffer.

5.1.18 Changes in the process for the internal customer Ring

Due to customer demands, the allowed size of bundles differs greatly. Since different customers have different regulations in their inflow and cannot in many cases lift as much as the traverses of Ovako rolling mill, this last lift must be adapted after the customers' traverses.

If these allowed weights could be increased it would mean less lifts and saved time. Ring has currently a restriction of 5 tons. If this could be increased to 12 tons as for Tube, it would mean 495 lifts saved equaling approximately 30 min/day.

This customer cannot receive full length bars. Therefore the bars are split in more pieces resulting in an increased uptime for the finishing operation. If they could receive full length bars this would decrease the billet inspections uptime from 61.9% to 60.8% and the grinders from 53.7% to 52.5%. Since these machines acts as the bottlenecks of the finishing operation, the entire production capacity could through this be increased by little more than 1%.

Ring are a geographically closely situated internal customer. These are changes that are possible in the future and would present an advantage if realized.

5.1.19 Sporadic Lifts

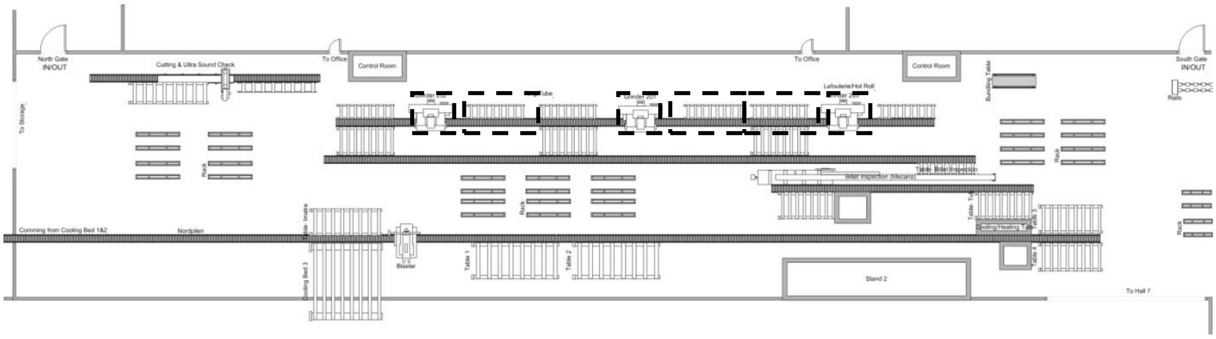


Figure 52. Layout traverses, sources generating sporadic lifts

This group of lifts incorporates extremely low intensity lifts such as removal of grains from grinding, flawed bars that is not reaching the quality requirements and the waste from the cutting operation. These are crucial lifts as well as important to bear in mind when creating a new layout, but are not frequent enough to be considered as main factors in the analyses.

Within the dashed markings are the sources of waste out of hall 2. One flow of waste also starts from the cutting operation, which is removed by fork lift.

Apart from these lifts, there are other even more sporadic occurring lifts. Examples of these are machine repairs, service and maintenance etc.

Although the weight of these lifts cannot be emphasized enough, they have an extremely low intensity, and should simply either be planned for in the production uptime or done in situations where the operation is temporarily closed down (removal of waste, maintenance and reparations etc)

5.2 Layout Analyses

This part contains the layout suggestions that are based on the previous analyses. The calculations for saved time in this section are based on the difference compared to the future state scenario. This means the savings potential is compared to if the changes are made in the rolling operation according to the discussed pre-study but nothing is done in the finishing section (apart from lifting the bars 190-230 from bed 4 to the tub since otherwise the flow won't work). In most layouts, the traverse lifts are divided into clusters. This is to show how one traverse can work independently of the other. Each cluster describes the entire range of one or some lifts that should be done by one single traverse. The layouts are presented according to scale, that means all measurements are very close to the reality. This includes both the existing layout as well as the new additions contained in each layout. However, these are not to be seen as blueprints. The designs are meant to give an idea about how different layouts could be developed.

5.2.1 Analysis- Layout 1 (Blaster moved away from nordpilen)

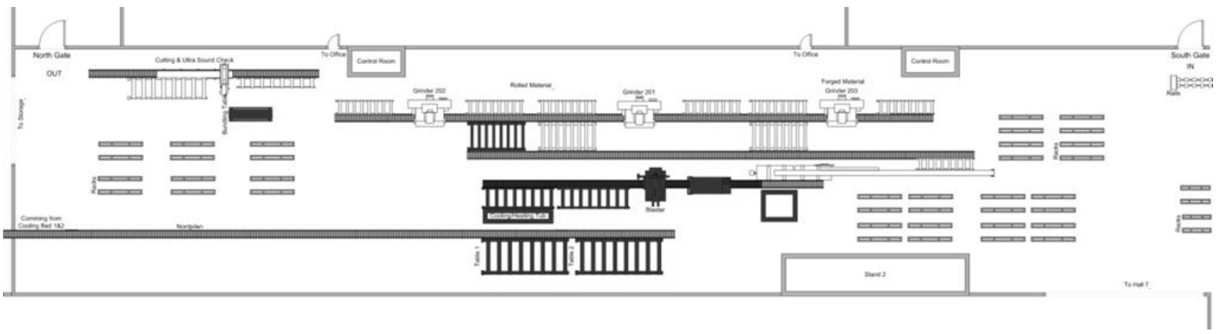


Figure 53. Layout 1

- The blaster is moved to the line leading into the billet inspection.
- The tub is moved slightly north, to before the blaster.
- An in-flow table with steam operation is installed close to the tub. This would also permit external steal to be steamed during the operation of the main flow
- An automatic ultrasonic inspection is installed after the blaster
- The south gate is assigned as in-flow and the north as out-flow (except for forged material where all is handled at the south side).
- Because of this the bundling table must be moved to the north side.
- Grinder 201 and 202 will be used for the main flow, with a possibility to be assisted by grinder 203 in critical situations. 203 will then mainly be used for grinding of forged steel.
- The connection from the billet inspection to grinder 202 is moved slightly south to make room for more racks.

Traverse Lifts

- Lift from Table-1&2 to Tub much shorter, but still in line with table for grinder 201 which risks to cause interruptions in lifting operation.
- One lift for flow C7 is removed entirely.

- One lift from flow C4 (and 170mm from C3) is removed entirely.
- Most long lifts through entire hall 2 is removed, but improper lifts still exist

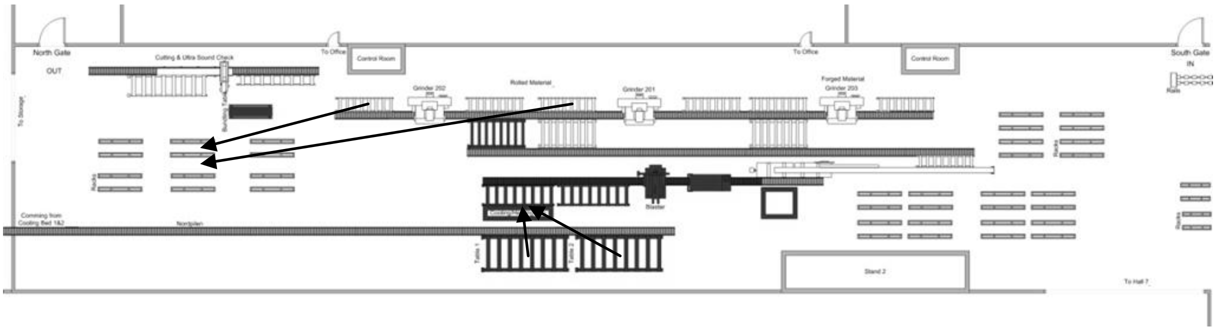


Figure 54.Layout 1, especially intensive flow (20 000pc's<)

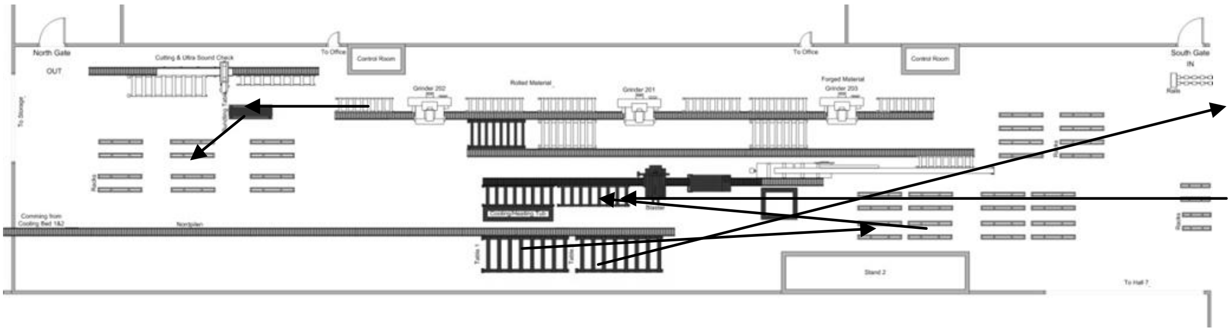


Figure 55. Layout 1, intensive flow (1 000<20 000pc's)

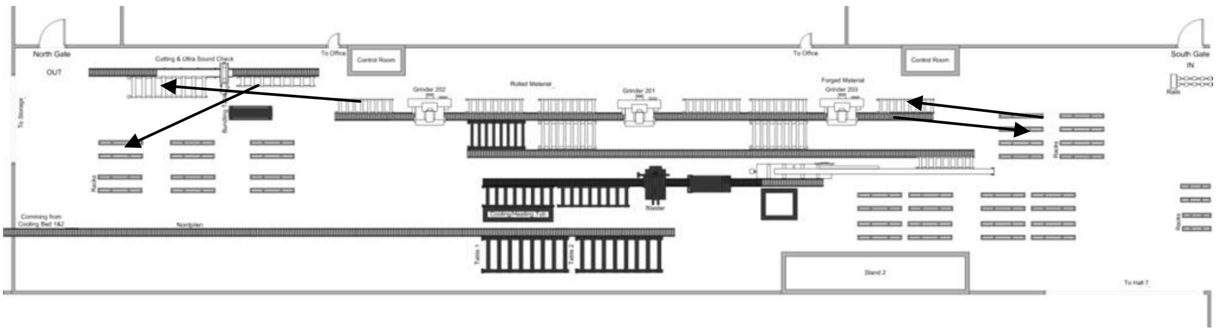


Figure 56. Layout 1, ordinary flow (25<1 000pc's)

Table 1&2 - Tub	65 min/day
External inflow (C5,C6,C7) - Tub	28 min/day
Table 1&2 – Cooling rack – Tub (minimum)	8 min/day
Rack – Grinder 202 - Rack	44 min/day
Grinder 201&202 - Rack	139 min/day
Grinder 201&202 – Bundling - Rack	30 min/day

Bed4 – Rack – Tub 2	8 min/day
Bed 4 – Tub 2	12 min/day
Table 3&4 - Rail	67 min/day
Bed 4 - Rail	0 min/day
Table 3&4 – Rack – Ultrasonic insp. – Tub 2	5 min/day
Total	**406 min/day**

→ **Saved operator time: Minimum 78 min/day**

Production Capacity

- Flow C7 that previously had to go through Nordpilen now can be processed while producing flow A1. C7, after the production increase will stand for 7,7% of the entire production which gives that this time is freed for other production. The entire incoming external flow amounts to 10,5%. This percentage can then be produced parallel to A1 which makes up for 28,4% of the entire production.

→ **Capacity increase: 7,7% (8,3% compared to current situation)**

Space for Cooling and Finished Stock Racks

- Due to the placing of table 1&2 and the tub, there is relatively close to the racks. A lot of space has been freed permitting extra racks to be used.

→ **Closer connection between tub and racks**
→ **More space for cooling racks close to table 1&2**

Summary

Removing the blaster from Nordpilen permits operation of flow C7 parallel with A1, giving cause to a capacity increase of 7,7%.

The short lift drastically reduces operation time of the traverses, saving 1,3 hours per day of operator time.

Overall this is an easy solution but with some drawbacks. The placing of the tub and blaster forces all material not coming from bed 1&2 to be lifted a long way and over several machines. These lifts are not very good and should optimally be removed, even though the intensity of the flows is rather low.

Advantage:

- Demands few investments/few relocations

Disadvantage:

- A few poor lifts over machines and risk for traverses to block each other

5.2.2 Analysis- Layout 2 (Extended blaster line, shifted input/output)

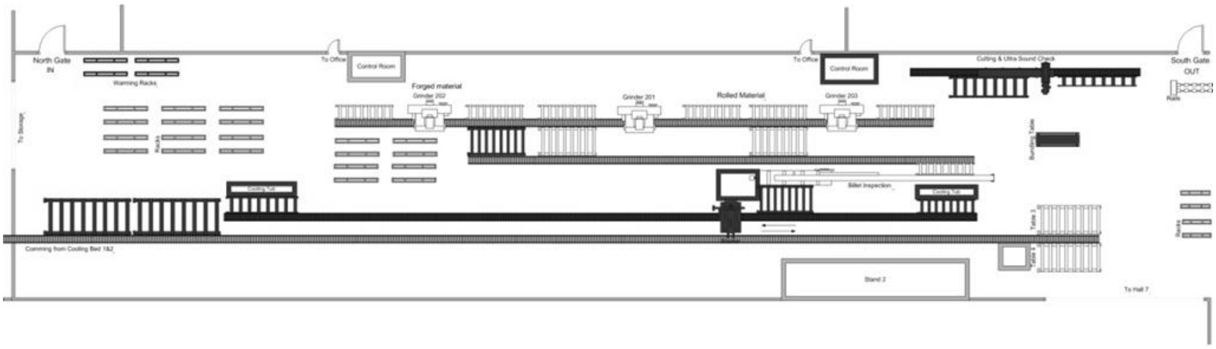


Figure 57. Layout 2

- Table 1&2 are moved to the other side of nordpilen and slightly to the north.
- Blaster is moved to the line leading into the billet inspection.
- The tub is placed close to and in line with table 1&2 on the same line as the blaster.
- The control room is moved slightly to make room for the blaster.
- Another tub is placed on the south side of the new line, close to where the old tub was situated.
- The part of the line at the blaster and connection with the billet inspection permits feeding in both directions. In this way the blaster can be used for material 190-230
- Connection from billet inspection to grinder 202 is moved to the south in order to create more space for racks.
- The in-flow is assigned to the north side and out-flow to the south (Except for forged material that is all handled at the north side.
- Cutting&Ultrasonic inspection is moved to the south side of the process, this demands a slight movement of this control room.
- Bundling table is moved slightly.
- A new steaming procedure is installed at the north side of the process that is not connected to the rest of the line.

Traverse Lifts

- The lift from table 1&2 to the tub is very short and in line. This means that only a very small lift and then movement in only one direction is necessary.
- The long lifts across the entire hall is eliminated reducing the risk for wasted time when moving the other traverse
- One lift for flow C7 is removed entirely.

- The lift from bed 4 is shortened and no lifts to the ceiling is necessary. The connection (tub 2) is placed at the southern end of the process, minimizing the risks for collisions between traverses.

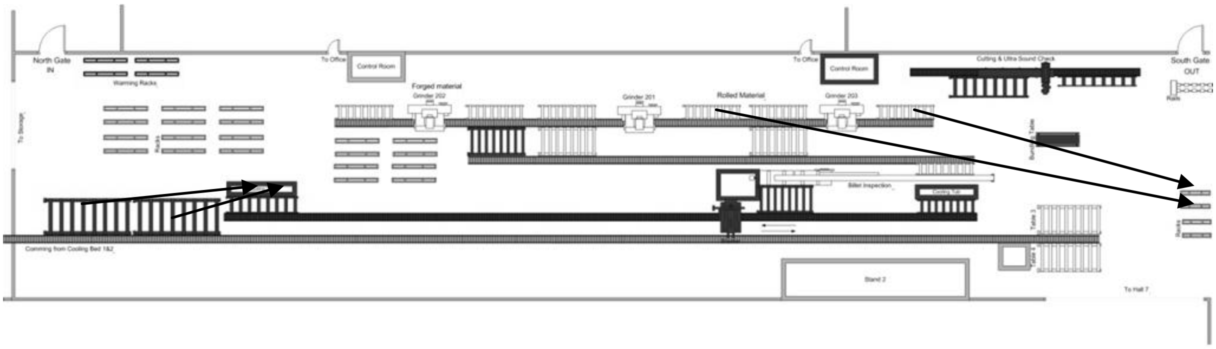


Figure 58. Layout 2, especially intensive flow (20 000pc's<)

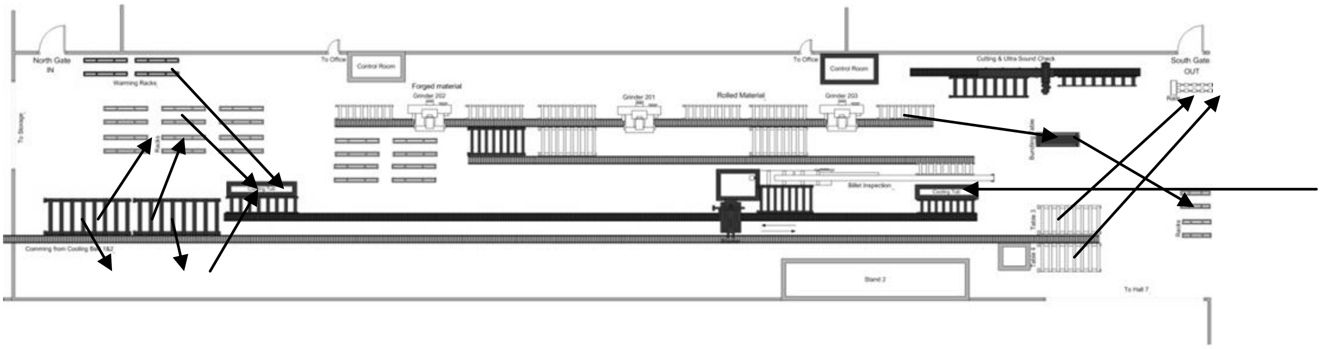


Figure 59. Layout 2, intensive flow (1 000<20 000pc's)

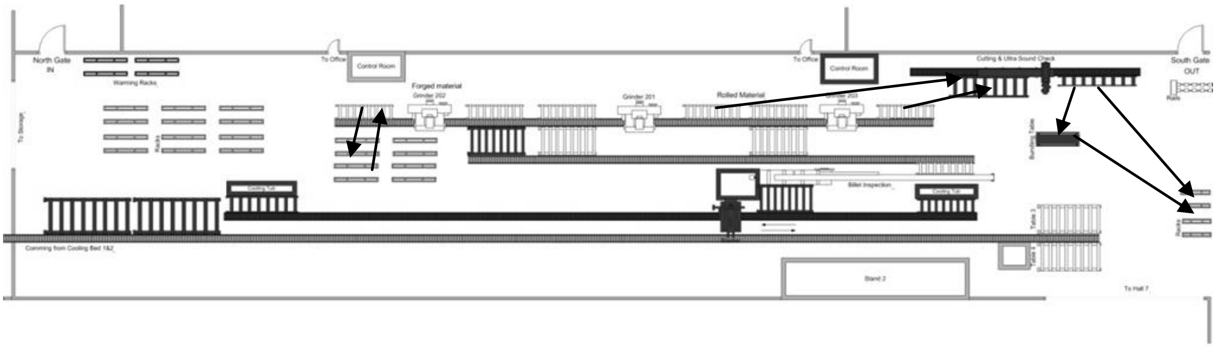


Figure 60. Layout 2, ordinary flow(25<1 000pc's)

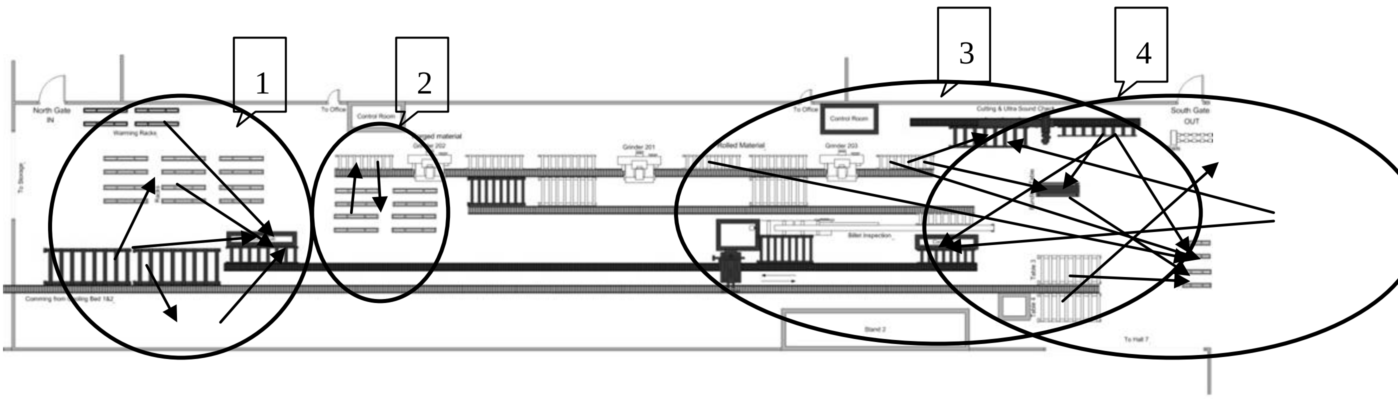


Figure 61. Layout 2, lifts divided into Clusters

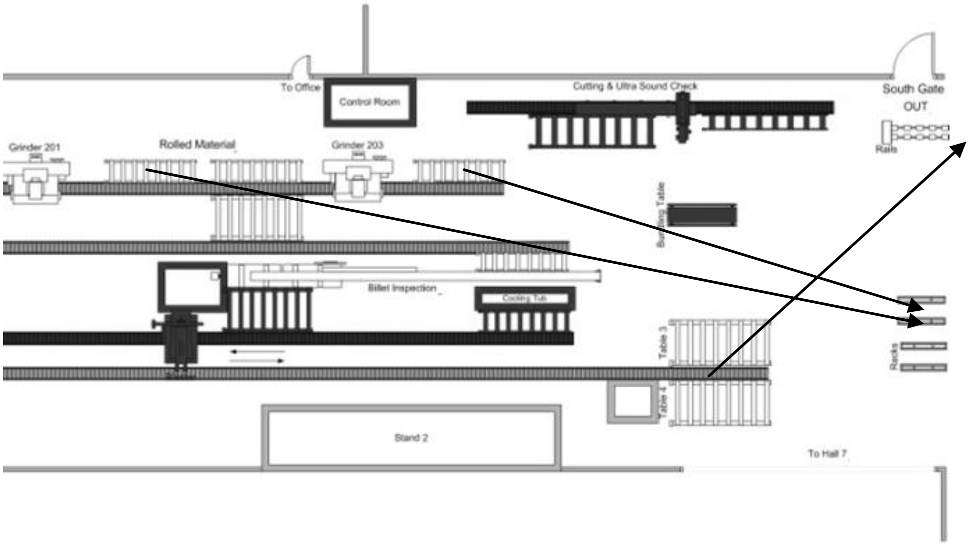


Figure 62. Layout 2, clarification of lift in the southern part of hall 2

Cluster three and four may look a little crowded at first. But it must be considered that most of these lifts are lower prioritized lifts with less intensity. Given above is the southern part of the process illustrating the very high priority lift from the grinders to the racks and the high priority lift from table 3&4 to the rails. Since the external in-flows (C5, C6 and C7) are relatively small compared to flow A1, most of the time only one of these to lifts will be active, rendering in a relatively small risk for collisions between traverses or temporarily deficient capacity.

Cluster 1:

Table 1&2 - Tub	51 min/day
External inflow (C5,C6,C7) - Tub	23 min/day
Table 1&2 – Cooling rack – Tub (minimum)	3 min/day
Total	**77 min/day**

Cluster 2:

Rack – Grinder 202 - Rack	44 min/day
Total	**44 min/day**

Cluster 3:

Grinder 201&203 - Rack	133 min/day
Grinder 201&203 – Bundling - Rack	27 min/day

Total	**160 min/day**

Cluster 4:

Bed4 – Racks – Ultrasonic inspection – Tub 2	10 min/day
Bed 4 – Tub 2	10 min/day
Table 3&4 - Rail	67 min/day
Bed 4 - Rail	0 min/day
Table 3&4 – Rack – Ultrasonic insp. – Tub 2	5 min/day
Total	**93 min/day**

Cluster 1will be operated by traverse 1, and Cluster 4 will be operated by traverse 2.

Cluster 2 can probably be operated by traverse 1 almost entirely without being deficient.

Cluster 3 has to be divided among the two traverses depending on production for the moment. While the main flow is operative, traverse 2 must take most responsibility for cluster 3. When flow A1 to Hällefors is operating, there will be more up time for traverse 2 in cluster 4. However, much of the time when this flow is running, the main flow is not, totally removing cluster 1 and 3.

→ **Saved operator time: Minimum 110 minutes/day**

Space for Cooling and Finished Stock Racks

The placing of table 1&2 results in a very short distance to the racks. The re-location of cutting&ultrasonic inspection also creates a lot of free space to use, easily accessible.

→ **Greatly improved access to a large area with racks**

Production Capacity

See argument for layout 1

→ **Capacity increase: 7,7% (8,3%)**

Summary

The capacity increase seen in layout 1 can also be found here. This layout is even more focused towards a good traverse flow. The layout has a large free area at the northern end for incoming goods, cooling racks as well as racks for forged material.

This layout will save more operator time than what is presented here. These 110 minutes per day could be seen as a minimum of time saved. Lots of problematic situations however cannot be calculated due to its irregularity. If one traverse is blocking the path for the other one, it takes a lot of time to move it out of the way, and if it is working the other traverse may have to wait.

Another thing is that the amount of steel laid in racks differs greatly. The steel bars calculated with here are only the ones always laid in rack. However, if the line is full, the steel is to warm etc it will be put in racks. This is an ordinary everyday scenario and happens continuously several times a day. Due to the greatly improved lift to racks in this layout, the savings potential gets bigger the more steel that has to be put in rack.

As discussed before, when solely small diameters are produced, the finishing section will be the bottleneck. Therefore not to risk that the finishing blocks the entire rolling operation, the bars must be removed from the line. Due to this, the lift to cooling racks from table 1&2 and the available space close to it is crucial.

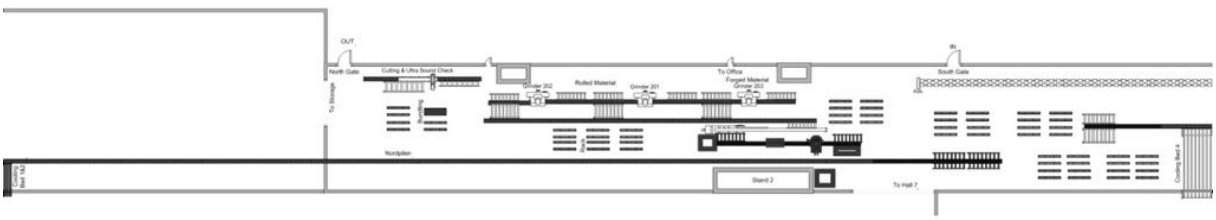
Advantage:

- No collisions with traverses and very good space utilization (close to racks)

Disadvantage:

- Demands some expensive relocations and new technology (two-way feeding line)

5.2.3 Analysis- Layout 3 (Function of Table 1&2 and 3&4 merged together)



- The function of Table 1&2 are joined with table 3&4 at the extended end of Nordpilen.
- A new line leading into the Billet inspection, coming from the south, containing the tub, blaster and automatic ultrasonic inspection is installed. This enables a possibility to receive the entire flow from one direction into the blaster. Due to the fact that the doorway leading into hall 7 may not be blocked, table 3&4 that is replaced by 4 more narrow tables is placed further to the south.
- The part of Nordpilen that covers the entrance to hall 7 will be possible to open. This kind of openable line is already used for one section on the north side of the process
- The south flow is assigned as in-flow and the north as out-flow. Due to this the bundling table must be moved to the north side of the process.

- Grinder 201&202 is used for the main flow and grinder 203 for forged steel and as backup for the main operation.
- A steam operation is included in the table for external material

Traverse Lifts

- The lift from Nordpilen to the tub is quite short and fairly in line. This means that only a small lift and movement in more or less only one direction is necessary.
- The long lifts across the entire hall is eliminated reducing the risk for wasted time moving the other traverse drastically.
- One lift for flow C7 is removed entirely.
- One lift from C4 (and 170 from C3) is removed entirely.
- The lift from bed 4 is shortened and no lifts to the ceiling is demanded. The connection (tub) is placed at the southern end of the process, minimizing the risks for collisions between traverses.

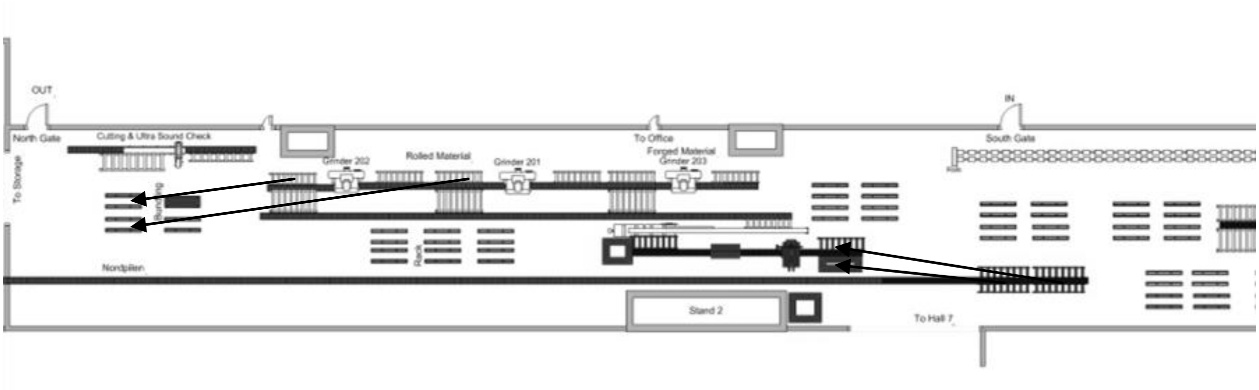


Figure 63. Layout 3, especially intensive flow (20 000pc's<)

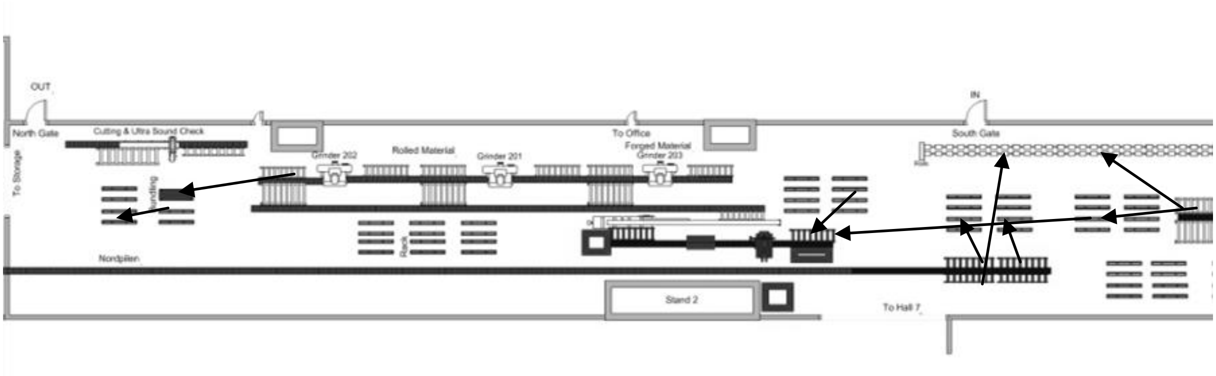


Figure 64. Layout 3, intensive flow (1 000<20 000pc's)

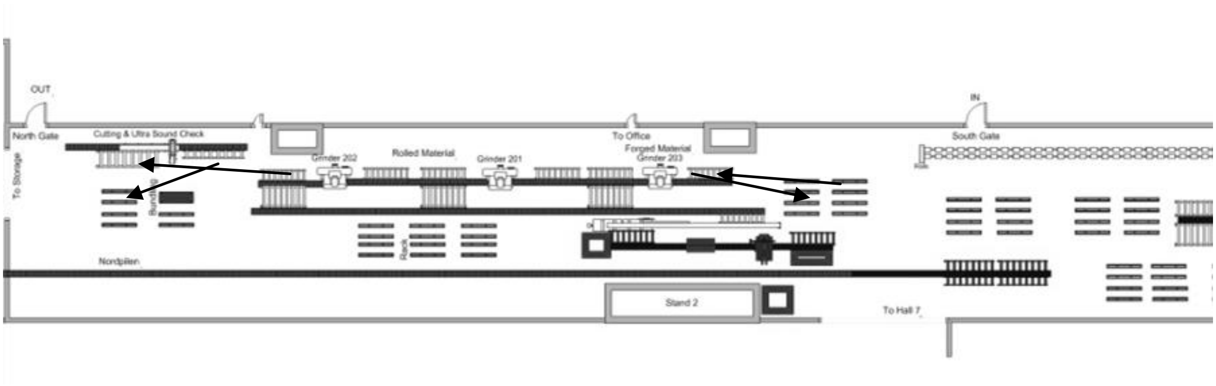


Figure 65. Layout 3, ordinary flow(25<1 000pc's)

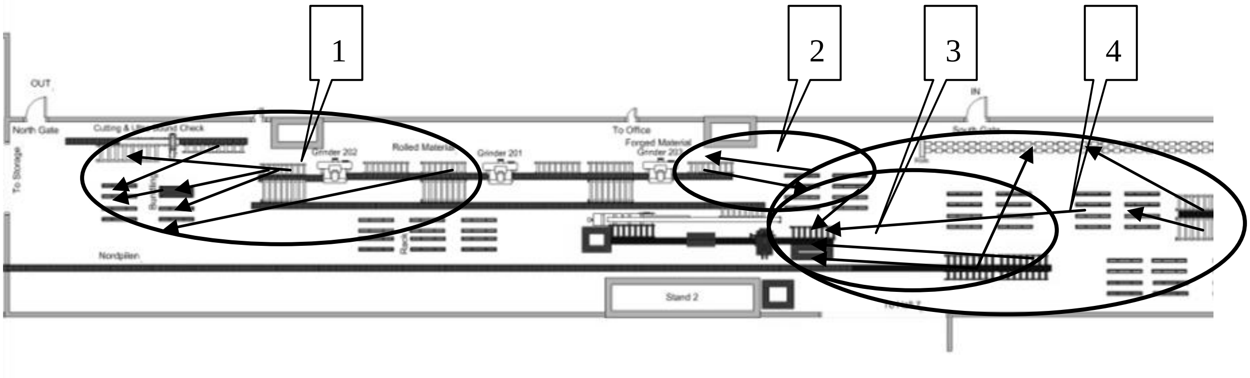


Figure 66. Layout 3, lifts divided into clusters

Cluster 1:

Grinder 201&202 - Rack	133 min/day
Grinder 201&202 – Bundling - Rack	27 min/day
Total	**160 min/day**

Cluster 2:

Rack – Grinder 203 - Rack	44 min/day
Total	**44 min/day**

Cluster 3:

Table 1&2 – Cooling rack – Tub (minimum)	5 min/day
Table 1&2 - Tub	53 min/day

External inflow (C5,C6,C7) - Tub	23 min/day
Total	**81 min/day**

Cluster 4:

Bed4 – Racks – Ultrasonic inspection – Tub 2	10 min/day
Bed 4 – Tub 2	11 min/day
Table 3&4 - Rail	69 min/day
Bed 4 - Rail	0 min/day
Table 3&4 – Rack – Ultrasonic insp. – Tub 2	5 min/day
Total	**95 min/day**

Cluster 1 will be operated by traverse 1 and cluster 3 by traverse 2. These lifts are done simultaneously. Cluster 4 that also will be handled by traverse 2 may occasionally be blocked while several flows running at the same time goes through here. However, as stated in layout 2, most of the time the main flow and flow A1/A2 is not operational at the same time.

→ **Saved operator time: Minimum 104 minutes/day**

Space for Cooling and Finished Stock Racks

The placing of table 1&2 results in a fairly short distance to the racks. The problematic situation is that that there may not be enough space for cooling racks at the south side. A lift to and from the north is both long, passing obstacles and also crossing other clusters. Cluster 2 is containing lifts of this nature, which in worst case could interrupt the other three clusters.

→ **Fairly improved access to a large area with racks**

Production Capacity

See argument for layout 1

→ **Capacity increase: 7,7% (8,3%)**

Summary

The placing of the blaster further to the south creates a smother flow in that sense that it permits all material coming in from the same side. Compared to layout 1, the traverse lift in and out from the main flow is separated, permitting the lifts to be done simultaneously.

Even though the saved operator time only differs 6 minute compared to layout 2, this is probably in the reality a bit more. This layout does not permit an as good placing and closeness to cooling racks as layout 2 did, meaning that the difference to layout 2 will grow with the number of bars laid in racks.

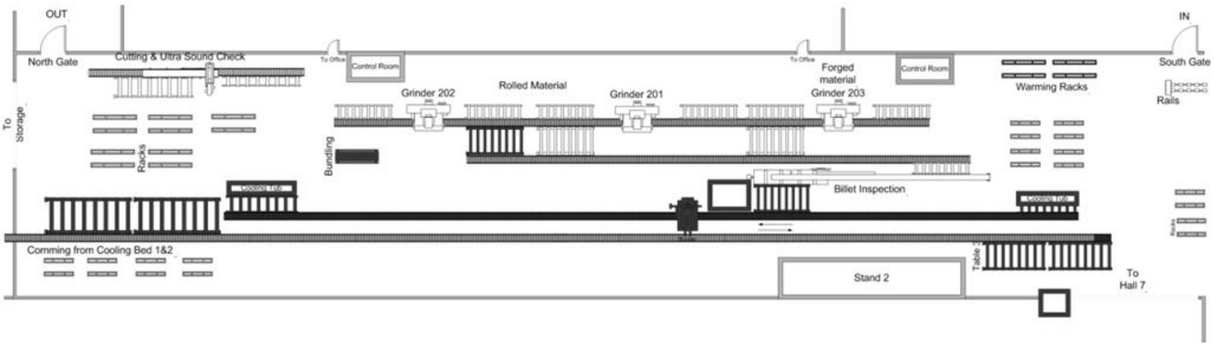
Advantage:

- Demands relatively few investments but still nice structured lifts with traverses

Disadvantage:

- Risk that it will be crowded in racks at the south side

5.2.4 Analysis- Layout 4 (Variation of layout 2 with changed In/Out flow)



- In and out flow from the respective gate is changed compare to in layout 2. (In-South/Out- North)
- Warming procedure for external incoming steel moved to the south side
- Bundling operation moved to the north side
- The new part of the line is extended so that tub 2 is placed where table 3 former were in order to receive a clear lift without being interrupted by the billet inspection.
- A possibility for ultrasonic inspection must be built into the southern loading area

Traverse Lifts

- The lift from Nordpilen to the tub is very short and in line. This means that only a very small lift and then movement in only one direction is necessary.
- The long lifts across the entire hall is eliminated reducing the risk for wasted time moving the other traverse drastically.
- One lift for flow C7 is removed entirely.
- The lift from bed 4 is shortened and no lifts to the ceiling is necessary. The connection (tub 2) is placed at the southern end of the process, minimizing the risks for collisions between traverses

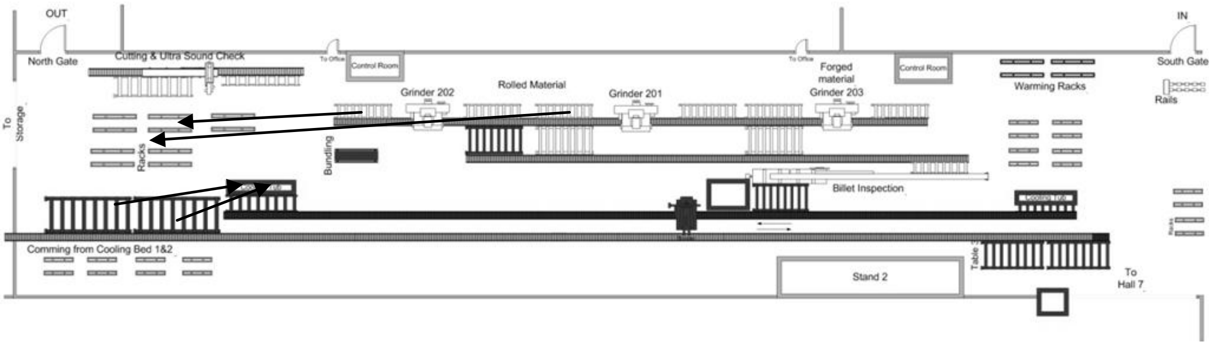


Figure 67. Layout 4, especially intensive flow (20 000pc's<)

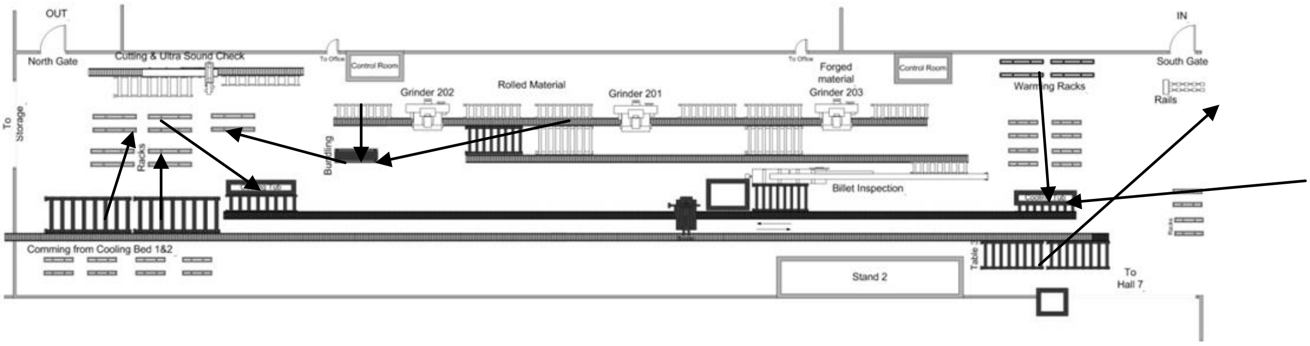


Figure 68. Layout 4, intensive flow (1 000<20 000pc's)

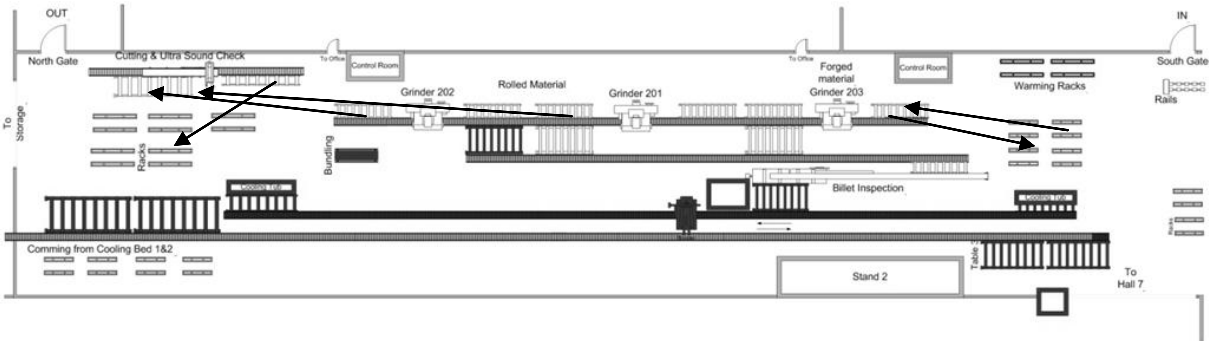


Figure 69. Layout 4, ordinary flow(25<1 000pc's)

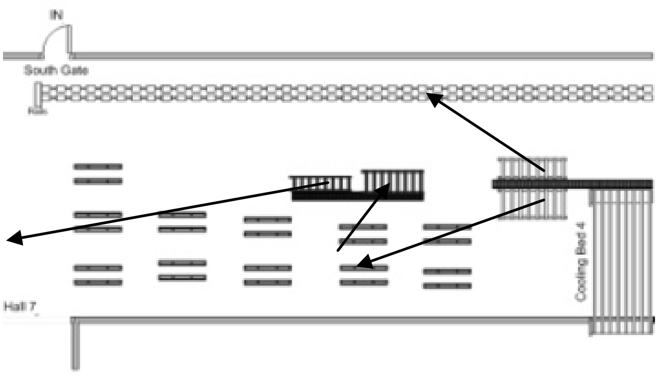


Figure 70. Layout 4, clarification of lifts at the southern part of hall 2

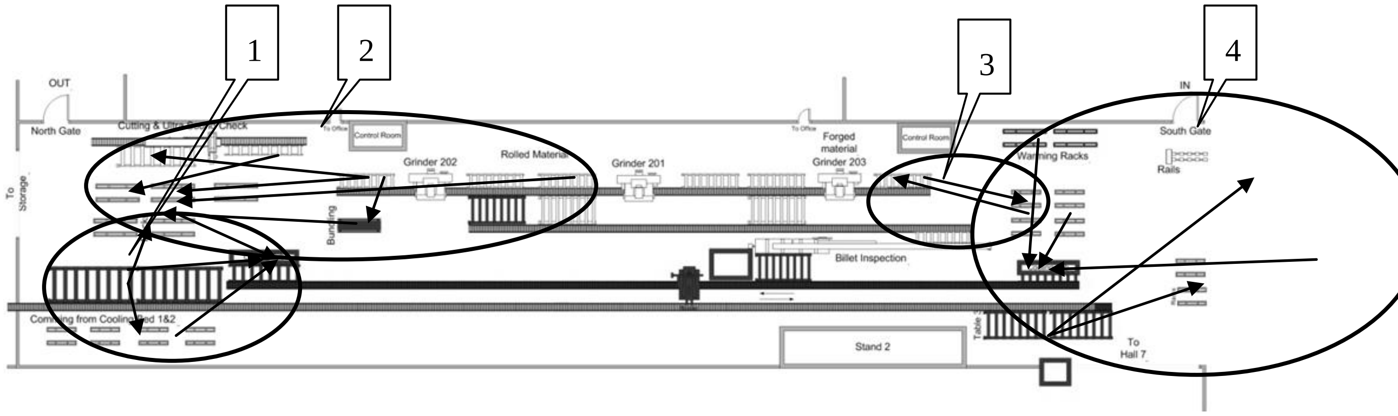


Figure 71. Layout 4, lifts divided into clusters

Cluster 1:

Table 1&2 - Tub	51 min/day
Table 1&2 – Cooling rack – Tub (minimum)	5 min/day
Total	**56 min/day**

Cluster 2:

Grinder 201&202 - Rack	134 min/day
Grinder 201&202 – Bundling - Rack	28 min/day
Total	**162 min/day**

Cluster 3:

Rack – Grinder 203 - Rack	44 min/day
Total	**44 min/day**

Cluster 4:

Bed4 – Racks – Ultrasonic inspection – Tub 2	10 min/day
Bed 4 – Tub 2	10 min/day
Table 3&4 - Rail	67 min/day
Bed 4 - Rail	0 min/day
Table 3&4 – Rack – Ultrasonic insp. – Tub 2	5 min/day
External inflow (C5,C6,C7) - Tub	23 min/day

Total	**115 min/day**

Cluster 1 and partly cluster 2 needs to be operated by traverse 1. These are the two flows with highest intensity. Since the traverse lift will be needed every period of 472 sec when 78mm bars are produced, and the same traverse in this case have to handle both lifts (gives each period of 236 sec), and these lifts will average to 145 sec, there will only be 91 sec left. This is far too little to be sure that the lift will be made in time. In many lifts, things will not go according to plan, which quickly consummates time. The traverse also has to be moved between the different lifts which also take time. If traverse 2 is used for one of the lift, it will be a big risk for collision between the traverses

Cluster 4 is then used mainly when cluster 1 and 2 is inactive.

Cluster 3 is only used sporadically over the day and will not be any obstacle.

- → **Saved operator time: Minimum 107 minutes/day**

Space for Cooling and Finished Stock Racks

Very close to a large area of racks. However, both cooling as well as outgoing goods has to share this area, which may risk that the space is not enough. This renders in a situation where most goods will be put at the north side and relatively little at the south side.

- → **Improved access to an area with racks**

Production Capacity

See argument for layout 1 and 2

- → **Capacity increase: 7,7% (8,3%)**

Summary

The distribution of work for the traverses may be a problem. Only counted in seconds per day, the division is fairly good. However, since the main flow enters and exits at the same side, forcing one traverse to do the lifts, this may in extreme situations render in that the traverse cannot coop with the pace and this will stop the entire finishing section from operating.

There is also a risk that too much material has to be stored at the north side of the process

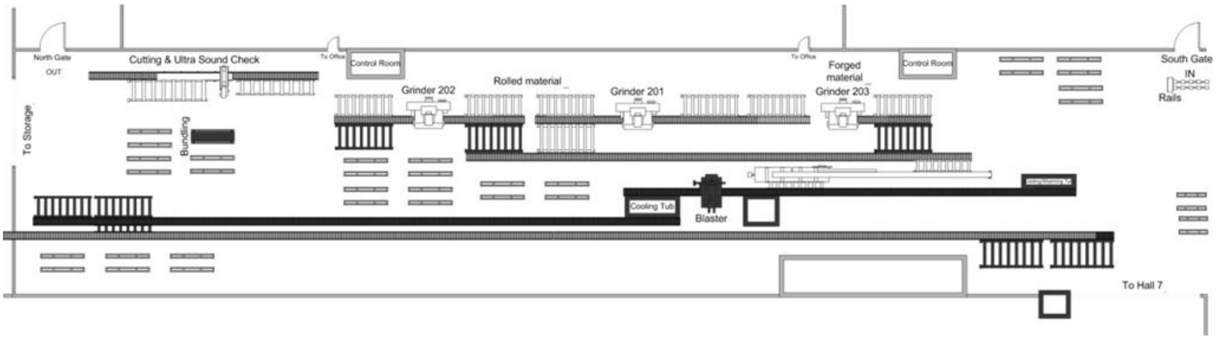
Advantage:

- Relatively few collisions with traverses and demand relatively few investments

Disadvantage:

- Risk that one traverse is overloaded when in and out- flow at the same side and slight risk for lack of floor space at the north side

5.2.5 Analysis- Layout 5 (Continues one-piece-flow from Nordpilen)



- Two tables are installed for sorting material to be put aside from the line
- A new tub that permits a one piece flow with adjustable speed depending on diameter.
- A two way feeding system at the line so that pieces can be blasted from both directions
- Tub 2 installed close to racks, with a sensible distance to the Mecana
- Table 3&4 moved to the other side of nordpilen in order to make room for Tub 2
- Each of the grinders assigned for rolled material has three tables each, due to sorting requirements
- Bundling table moved to the side of the outgoing flow

Traverse Lifts

- The lift from Nordpilen to the tub is eliminated
- The long lifts across the entire hall is eliminated reducing the risk for wasted time moving the other traverse drastically.
- One lift for flow C7 is removed entirely.
- The lift from bed 4 is shortened and no lifts to the ceiling is demanded. The connection (tub) is placed at the southern end of the process, minimizing the risks for collisions between traverses.

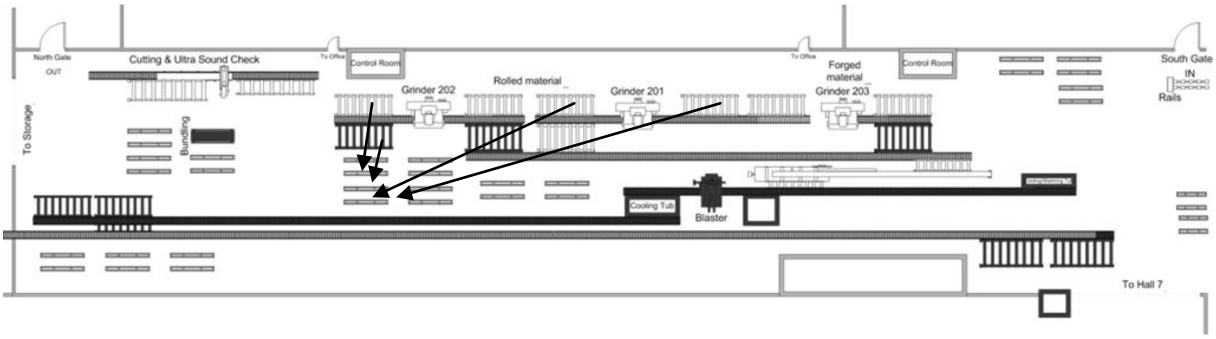


Figure 72. Layout 5, especially intensive flow (20 000pc's<)

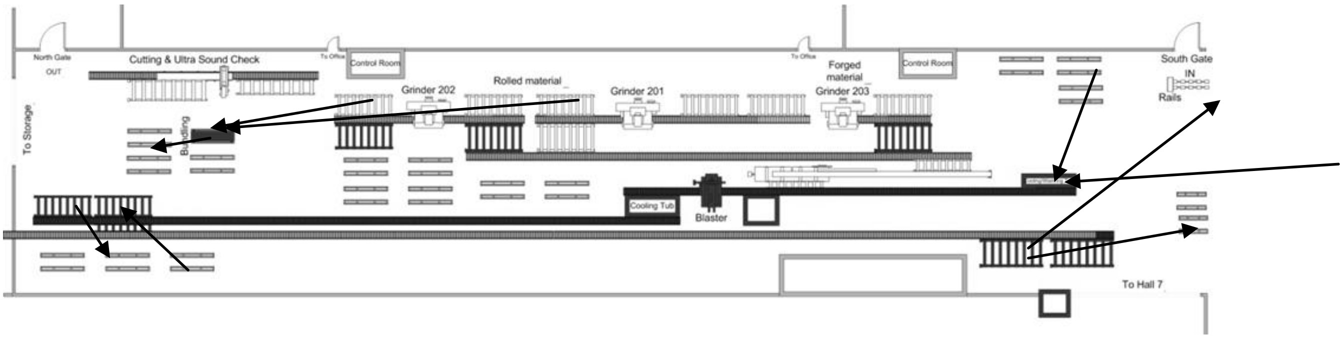


Figure 73. Layout 5, intensive flow (1 000<20 000pc's)

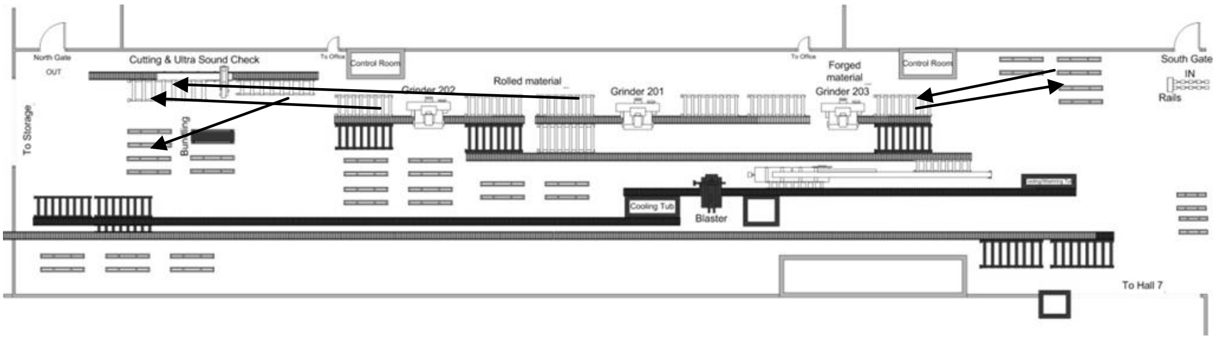


Figure 74. Layout 5, ordinary flow(25<1 000pc's)

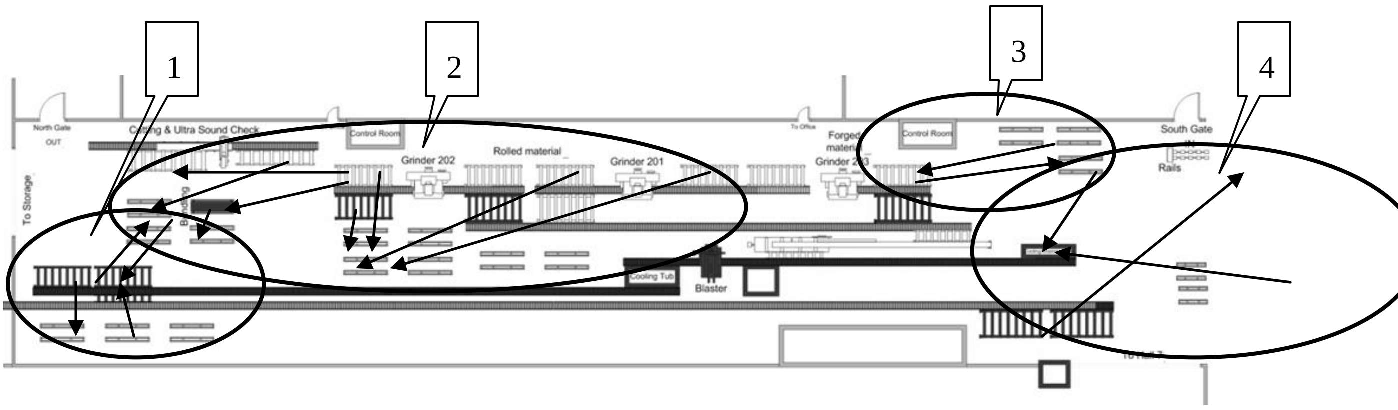


Figure 75. Layout 5, lifts divided into clusters

Cluster 1:

Table 1&2 – Cooling rack – Tub (minimum)	3 min/day
Total	**3 min/day**

Cluster 2:

Grinder 201&202 - Rack	133 min/day
Grinder 201&202 – Bundling - Rack	27 min/day
Total	**160 min/day**

Cluster 3:

Rack – Grinder 203 - Rack	44 min/day
Total	**44 min/day**

Cluster 4:

Bed4 – Racks – Ultrasonic inspection – Tub 2	10 min/day
Bed 4 – Tub 2	10 min/day
Table 3&4 - Rail	67 min/day
Bed 4 - Rail	0 min/day
Table 3&4 – Rack – Ultrasonic insp. – Tub 2	5 min/day
External inflow (C5,C6,C7) - Tub	23 min/day
Total	**115 min/day**

Cluster 1 will be close to nothing in a minimum scenario. However, when the amount of bars laid aside due to stocking before the billet inspection or due to temperature over 200 degrees, this cluster will increase significantly.

The other three clusters will be identical with layout 4.

There will be a risk that if too much needs to be laid aside from table 1&2, the traverses will start to block each other and this layout will be less advantageous

→ **Saved operator time: Minimum 162 minutes/day**

Space for Cooling and Finished Stock Racks

Very close to a large area of racks. However, both cooling as well as outgoing goods has to share this area, which may risk that the space is not enough. This renders in a situation where most goods will be put at the north side and relatively little at the south side.

→ **Greatly improved access to an area with racks**

Production Capacity

See argument Layout 1

→ **Capacity increase: 7,7% (8,3%)**

Summary

This layout would cut first piece lead-time for the main flow with about 24 minutes, decreasing it with not far from 50%.

When the billet inspection can coop with the production from rolling operation and no bars has to be put aside due to high temperature, not that much would have to be put aside. But as soon as one batch must be put aside in racks, much of the advantage from this layout would vanish. To put aside would also mean to consolidate the billets in batches which makes the continuous flow useless when they are once more connected to the line.

The drastically shortened first piece lead time would save a lot of time if many stops are made in the finishing section, since this results in that the finishing activities are drained from material. Each time it would have to start up again, 24 minutes would be saved. However this is not that very common, since material put aside the line often can be used to fill shorter gaps from rolling operation. In this case the decreased first piece lead time would not save especially much time but rather advance the entire production 24 minutes.

The reduced first piece lead time would make the finishing section slightly more responsive, but due to the constraints in operations before and after it will not result in any significant improvement.

The quality control would theoretically gain slightly. Problems could be identified earlier, making the useless workload on the flawed material minimal. This is not very significant though, since the difference of processed material would not differ that much and the bars still would have to be pushed through the different activities until reaching a table where they can be lifted with the traverses.

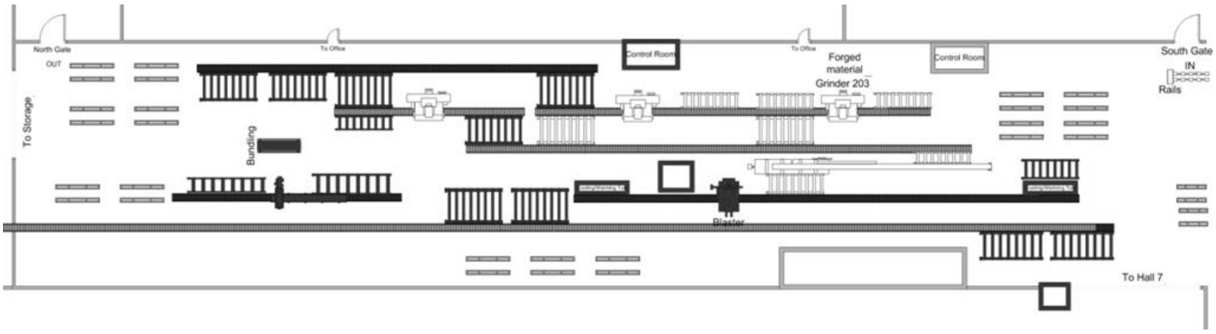
Advantage:

- Shorter FP LT, potential in the future for increased production capacity and less traverse lifts

Disadvantage:

- Very expensive and not that advantages in the near future

5.2.6 Analysis- Layout 6 (Shortened lift after grinding)



- Table 1&2 moved to the other side of nordpilen
- A new line installed containing the blaster and the two tubs
- Tub 2 will be integrated with a steam operation for external material
- Table 3&4 moved slightly to make room for tub 2
- A new line is installed after the grinders in order to create a simple lift after the grinding operations.
- The connection to grinder 202 is moved slightly to the south in order to make room for the new table for discarded materials
- The control room must be moved slightly
- Bundling table and cutting operation is moved to be more incorporated into the flow

Traverse Lifts

- Very short lift from Table 1&2 to Tub
- Very short lift from grinder tables to rack
- The long lifts across the entire hall is eliminated reducing the risk for wasted time moving the other traverse drastically.
- One lift for flow C7 is removed entirely.
- The lift from bed 4 is shortened and no lifts to the ceiling is demanded. The connection (tub 2) is placed at the southern end of the process, minimizing the risks for collisions between traverses.

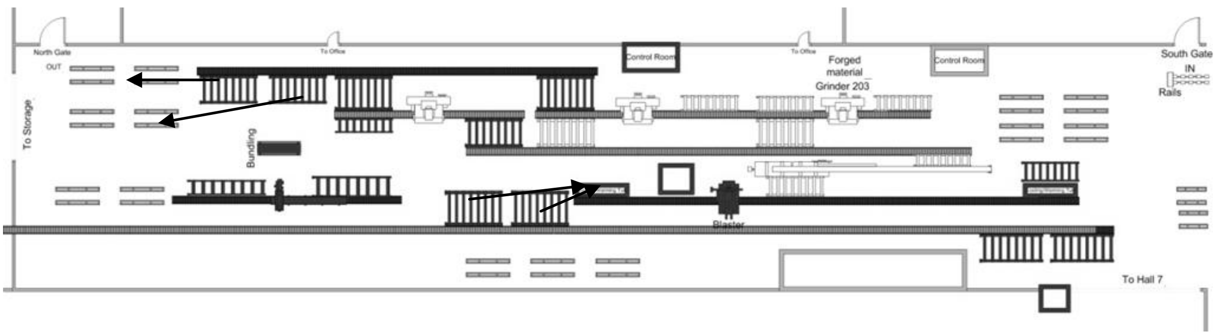


Figure 76. Layout 6, especially intensive flow (20 000pc's<)

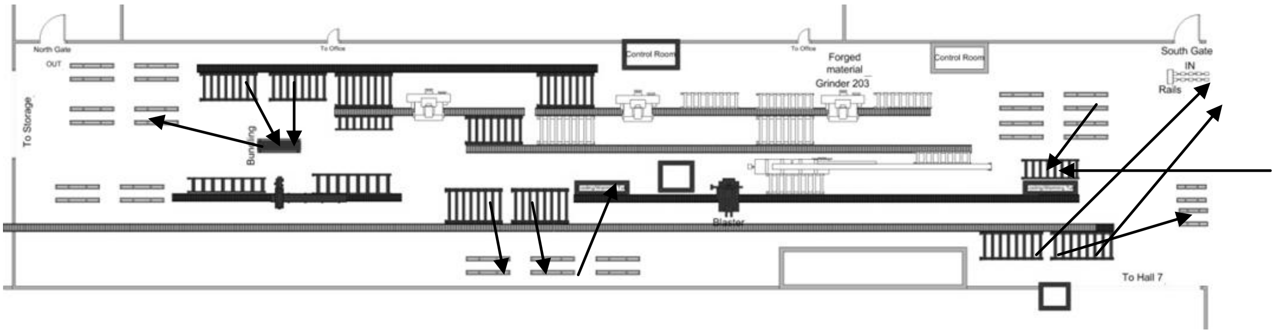


Figure 77. Layout 6, intensive flow (1 000<20 000pc's)

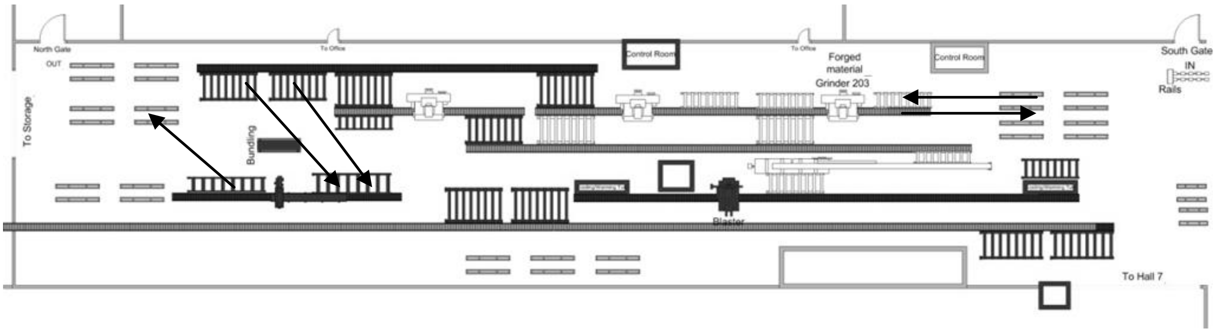


Figure 78. Layout 6, ordinary flow(25<1000pc's)

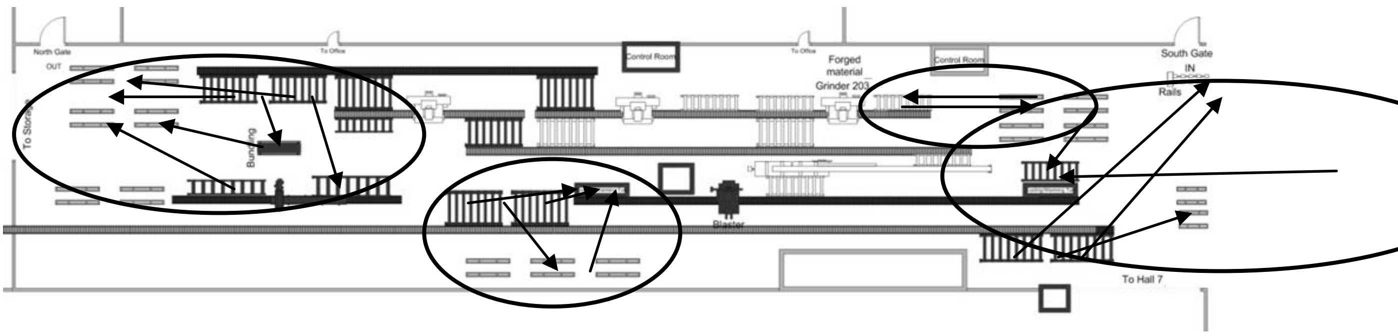


Figure 79. Layout 6, Lifts divided into clusters

Cluster 1:

Grinder 201&202 - Rack	83 min/day
Grinder 201&202 – Bundling - Rack	20 min/day
Total	**103 min/day**

Cluster 2:

Table 1&2 - Tub	51 min/day
Table 1&2 – Cooling rack – Tub (minimum)	3 min/day

Total	**54 min/day**

Cluster 3:

Rack – Grinder 203 - Rack	44 min/day
Total	**44 min/day**

Cluster 4:

Bed4 – Racks – Ultrasonic inspection – Tub 2	10 min/day
Bed 4 – Tub 2	10 min/day
Table 3&4 - Rail	67 min/day
Bed 4 - Rail	0 min/day
Table 3&4 – Rack – Ultrasonic insp. – Tub 2	5 min/day
External inflow (C5,C6,C7) - Tub	23 min/day
Total	**115 min/day**

All clusters are very well divided into separate areas without any immediate risk of collisions. Cluster 1 and 2 will be operated by two independent traverses. When production is aimed towards table 3&4, traverse 2 will deal with cluster 4.

→ **Saved operator time: Minimum 168 minutes/day**

Space for Cooling and Finished Stock Racks

Close to a fairly large area of racks. It will be a little more crowded however due to the new line after the grinders

→ **Fairly improved access to an area with racks**

Production Capacity

See argument Layout 1

→ **Capacity increase: 7,7% (8,3%)**

Summary

The lift after grinding operation in this layout is improved. But this extra line also takes much space reducing the possible amount of racks. One short lift into the finishing operation and one short lift out. This layout will render in almost three hours of minimum time savings per day.

However, to squeeze in the new line between the wall and the grinders may prove difficult, and when done the walking path for the operators would be blocked forcing them either to go another route or having stairs installed leading over this line.

Advantage:

- Extremely shortened traverse up time with lots of operator time saved

Disadvantage:

- Expensive and space consuming

5.3 Evaluation

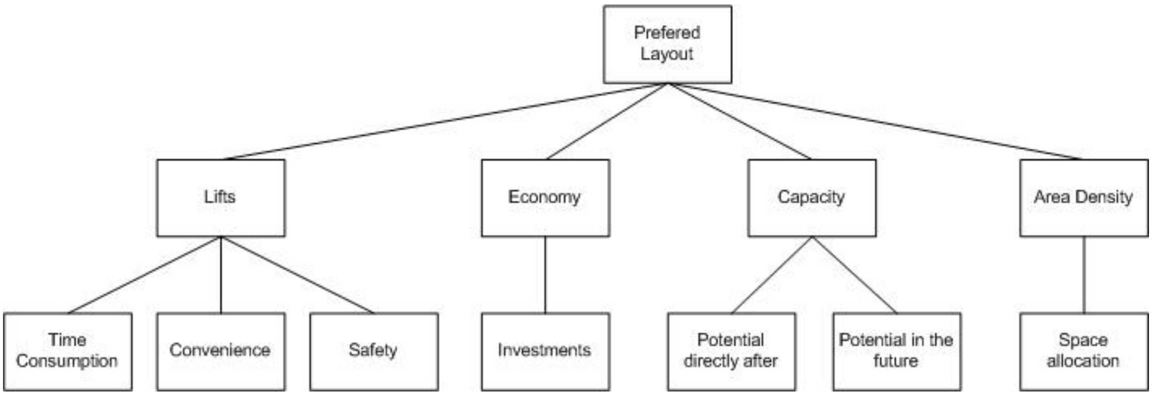


Figure 80. Model for evaluation based on AHP

5.3.1 Factor Definitions

The factors and sub-factors are explained in detail.

Lifts

- Time Consumption

Describes the actual time saving (If the layout has an automated ultrasonic inspection or not, does not affect the rating)

- Convenience

This factor is favored with short and easy lifts, less walking for the operator and no machines or obstacles to pass during the lift

- Safety

The lower lift and the less lift, the higher safety

Economy

- Investment

The more rearranging needed the higher investments cost. (Rearranging of old equipment is relatively cheap compared to sourcing for new equipment.)

Capacity

- Potential directly after Implementation

This factor considers the immediate production capacity after implementation

- Potential in the Future

Compared to the factor above, this factor focuses on potential saving in the future. A layout that will not have a high capacity increase immediately but potential due to possible future production improvements will score high here.

Area Density

- Space Allocation

Considers where existing areas for laying material in rack are compared to the connection the lift will be made from as well as the size of this area.

5.3.2 Define the weighted relationships

The weighted relationship "economy" was defined in congruence with the priorities of the management. The other three factors were defined based on findings during the process analysis. The economy factor were the major factor in the equation closely followed by lifts, whereas area Density and finally capacity were lower prioritized.

Major Relations	Lifts	Economy	Capacity	Area Density	Priority
Lifts	1	2/3	4	2	0,3255
Economy	1 1/2	1	2	2	0,3498
Capacity	1/4	1/2	1	1/4	0,1007
Area Density	1/2	1/2	4	1	0,2238

Table 4. Weighted Major Relations

The relations time consumption, Convenience and safety together forming the factor lifts were all considered as equally important.

Weighted Relations “Lift”	Time Consumption	Convenience	Safety	Priority
Time Consumption	1	1	1	0,3333
Convenience	1	1	1	0,3333
Safety	1	1	1	0,3333

Table 5. Weighted Relations for Lift

The relations “potential directly after” and “potential in the future” together forming the factor “capacity” was considered to be in the ratio 2:1 favoring capacity in the short run.

Weighted Relations “Capacity”	Potential directly after	Potential in the near future	Priority
Potential directly after	1	2	0,6667
Potential in the near future	1/2	1	0,3333

Table 6. Weighted Relations for Capacity

5.3.3 Layout Result

According to the AHP model, layout 3 proved to be the most suitable layout when all factors were weighted against each other. The difference between layout 3 and layout 1 with $1.3*10^{-3}$ is however relatively small. To the other layout suggestions the distance is longer, due to the more investment burdened nature of these layouts.

Score for each Layout	
Layout 1	0,1837
Layout 2	0,1669
Layout 3	0,1850
Layout 4	0,1603
Layout 5	0,1453
Layout 6	0,1587

Table 7. Total Score for each Layout according to AHP

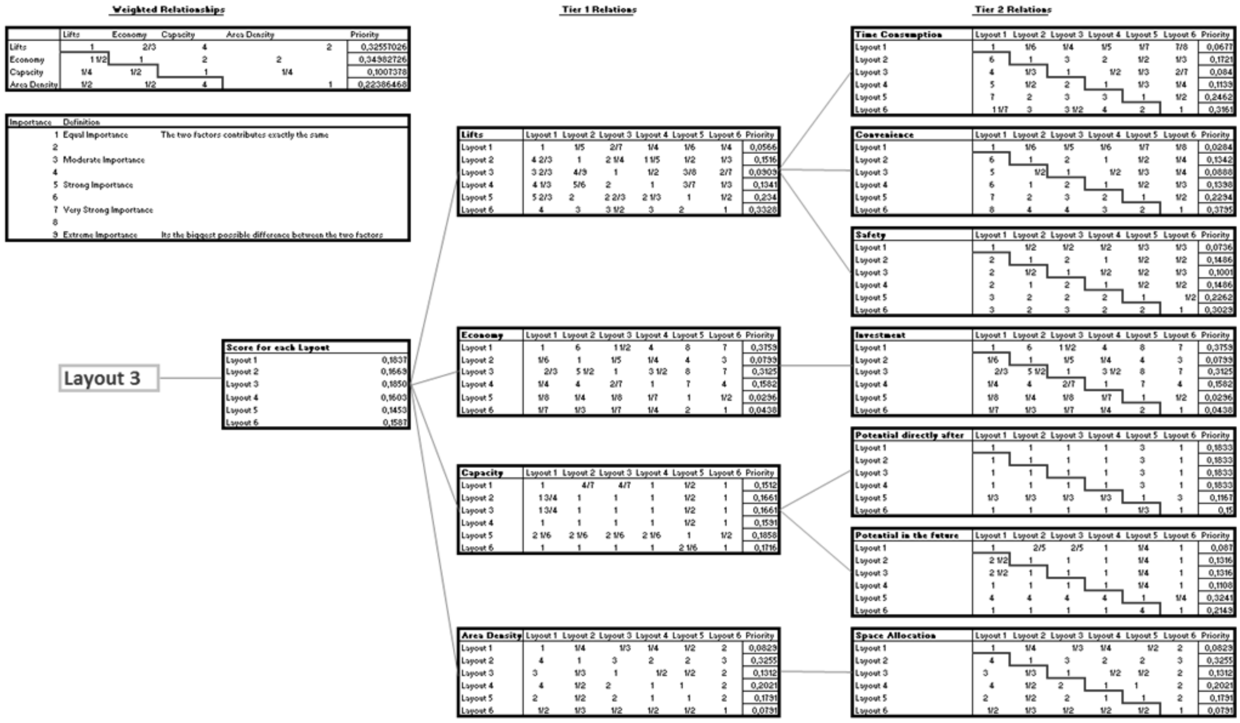


Figure 81. Evaluation model constructed in excel

5.3.4 Other potential results

One of the strengths with the AHP evaluation method is that the evaluating factors could be altered. This makes it possible to see how much the different factors must increase or decrease before the optimal solution is changed.

Increased importance of "Lifts"

This factor favor layout 6, due to the extremely short lifts in and out of the process. This is followed by layout 5 and then layout 2.

If "economy" and "area density" is considered unimportant and "lifts" extremely important, then layout 6 would be optimal. In the other end layout 1 and then layout 3 would be least preferred.

Increased importance of "Economy"

The more this factor would be increased, the more it would favor layout 1. This layout demands least investments (high score in "economy"), score fairly high on "area density" but otherwise low.

Next layout 3 would be favored. In the other end layout 5 would be least favored followed by layout 6.

Increased importance of Area Density

This factor favors several layouts rather similar with a slightly advantage for layout 2. This would be followed by layout 3, 1 and 4. Least favored would be layout 6 followed by 5.

Increased importance of capacity

The different layouts score very similar on the "capacity"- factor. Layout 5 has a slight advantage in the long run due to potential advantage in decreased first piece lead time. On the other hand there is a slight disadvantage in the short run when the connection to the third grinder from the main flow has been cut off.

Summary

Layouts 1, 2, 3 and 6 are all potential optimal layouts depending on the ranking of the evaluation factors.

Layout 4 and 5 will not be favored in any situation. This is due to that they do not have any really strong side compared to the other nor do they have a good average.

While layout 2 and 3 are potential layouts due to their good average scores, layout 1 and 6 are potential solutions due to a few very strong factor scores.

5.3.5 Summary Layout 3

This part describes the final layout that was chosen and some concluding remarks about the layout in particular. In the calculation for layout 3, the internal customer "Ring" is assumed to have made the changes discussed earlier in the report. (Capable to handle full length steel and 12 ton bundles) The full process flow diagram for the situation when layout 3 has been implemented can be seen in appendix 10.4

	Current Situation	**Future Situation**	**Layout 3**
Blaster	8,4%	8,9%	8,8%
Billet Inspection	58,3%	61,9%	60,8%
Grinder 201&202	52,2%	53,7%	62,0%
Grinder 203	17,7%	19,1%	4,5%
Traverse	17,0%	19,6%	15,6%
Nordpilen	77,0%	61,5%	58,8%

Table 8. The final up times

Layout 3 proved to be the best combination of investment expenses and good production flow.

The cost aspect is not differentiating very much between layout 1 and 3. The cost for the extra line that is needed may reach heights of some 500 000 sek or a little more but not nearly in the regions of what some of the other layout suggestions would have meant.

In the same time the flow will be improved compared to layout 1, especially when considering the inflow of external material and use of traverses.

The one drawback that could be identified with this suggestion would be the risk for too much activity and need for storage area in the southern parts of the hall. Therefore all material and activities that are not crucial to have in this area should be moved to the northern area, since here there will be access to free space. One example of this is the storage of containers for grinding remains, which could be moved to the other side of the process etc.

This layout assumes an installation of an automatic ultrasonic inspection (as stated this has not been considered in the evaluation scores). If this is not done, then another possibility to inspect material at the southern side must be created. Otherwise this would mean a lift through the entire hall, which has been one of the main focuses to eliminate in this research.

This layout will save a lot of time for operators due to shorter traverse lifts. However, compared to for example layout two, the potential of further time savings is a little less. It has been discussed that the more that has to be put in rack, the more the time savings will be in comparison. But when the area around table 1&2 (and 3&4) is full, this layout will show no such further improvements.

6 Discussion

In this part the author's discussion will follow. Here, all the relevant discussion themes that needs to be handled to make the thesis complete will be presented. Possible methods and solutions that are not a part of the actual result is discussed and demonstrated why in fact these parts were left out.

6.1 One Piece Flow

Achieving a one piece flow is indeed possible, but whether it is advantageous or not is a far more complex question. The main problems against the implementation would be sorting, cooling and financial issues. If the sorting of bars could not be done at table 1&2 it has to be done later in the process. This could be done after the grinding operation like in layout 5, however the space is scarce here and no matter how this solution would look like the process would suffer from this. It would also demand four new tables, a new control system to redirect the bars as well as a control system to split the bars in an advantageous manner. This is so that the bundles could be created from each grinder table and the two grinders receive approximately the same amount of bars. These issues are not only problematic, they are also expensive to solve.

It would also take a tub that can feed in a one piece flow and is adaptable depending on needed cooling time. This is maybe less problematic but still rather expensive.

A large amount of the material could not be fed into the line straight through but has to be laid aside for cooling. As long as this is the fact, a continuous one piece flow between Nordpilen and the tub would be too costly. But there are some technical progresses that could make this solution interesting for the future. As an example, a new ferro- magnetic powder is tested, in order to increase the maximum temperature to feed billets into the inspection. If a powder that can handle so high temperatures that nothing has to be put aside due to this, then this solution would be much more interesting.

The advantages are however not that considerable so that very large investments could be motivated. The production would be somewhat more responsive and the first piece lead time would almost be cut in half, but to make any real changes these advantageous must be utilized after the process. The production is also very dependent on the rolling operation. As long as this remains the same few of the potential advantages could be utilized.

The quality control would theoretically gain. But since all the billets has to be put through the process anyway before removed and the batches still are relatively small, it is questionable if this would give any reel effect.

The production capacity would be slightly higher, especially in situations where the line is switched on and off much and the line is emptied all the time. Then each start could be done slightly faster and machines are used more effectively. This difference is however more of an academic nature than a really potential to make big difference.

But there would be large savings in time consumed for traverse operators, and also it would totally remove one problematic lift making the production environment safer and simpler.

6.2 Constraints and how they came to affect the result

The constraints in this research came to affect the result significantly. Not being able to move either the three grinders or the billet inspection made it very difficult to achieve any serious improvements to the process. Furthermore the slightly claustrophobic production area did not allow any seriously redirected flows. Significant improvements would have been realistic if those two constraints were to be removed.

6.3 The Third Grinder

Grinder 203 will mainly be assigned to forged material. But to take away the possibility entirely to use it as a spare for the main flow may prove unwise. Partly due to the obvious reason that something may happen with one of the other two, leaving only one grinder able to process. But also because when thick bars are produced, the two grinders are the bottleneck of the finishing activities. However, when these pieces are produced, the overall bottleneck is not the finishing but rather the rolling operation.

6.4 Ultrasonic inspection and cutting connected to the main flow

It seems likely that the future will favor a more automatic approach of ultrasonic inspection. This will not only save a lot of operator time doing the actual inspection but also save one lift for the entire main flow of the production.

It means an investment but also an effort to solve the problem regarding the impossibility to inspect wet billets in the billet inspection. However, as earlier mentioned this is done due to demands from the customers. If the demands will increase, which seems likely, and all billets need to be inspected, there will be no other possibility than doing this investment, since the alternative would mean a huge disadvantage.

The same reasoning as have been done for the ultrasonic inspection above could be done for the cutting procedure. If in the future all products would have to go through the cutting procedure, it would have to be integrated into the line. But in difference to the inspection, the trend is going in the other direction. Less material are being cut and the future seems more probable to exclude this operation than to favor integration into the line.

6.5 Handling of bars due to hydrogen embrittlement

Currently the entire flow C4 is laid aside the line due to the risk for hydrogen embrittlement. Probably only a few of the alloys are actually in need for such a treatment, but the operation is made on the entire flow just in case.

If these alloys could be identified, the rest could then join the main flow without laying five days in racks. This would also be one further step towards making it possible to implement a one piece flow. There are of course other obvious advantages with this such as decreased capital tied up etc.

6.6 Focus when deciding evaluation parameters ranking

It may seem wrong to focus the most on the “economy”- factor, which means to hold down direct investments cost. In the same time it was stated earlier that Meyer (1993) considered the layout as one of the most important things for the entire company since small differences will have large impact due to high production rate.

But in the same time the company is in a period of large investments. Much money is invested elsewhere in the production and the finishing section as it appears is not in need of emergency investments (with the exception of the blaster). This altogether means that an investment must not only be economically viable but also very well motivated.

In the current situation, investments that are needed for layout 5 and 6 are not possible to motivate, especially since the advantages, as discussed, will not be immediate or very significant.

As an example, the largest contribution from layout 6 will be an extra hour saved per day due to less traverse operating (compared to layout 3). Saying that the company expenses for this operator is 50 000 sek per month, the company could save little over 100 000 sek per year. It would be fair to assume that the extra expenses due to purchasing of longer production line, new tables, new connections between lines, relocation of the cutting procedure etc, would reach heights of at least 5 million sek. This would mean a payback time for this extra investment of minimum 50 years, which probably is very low calculated.

This is not enough to motivate these larger expenses. It is also critical what happens with the extra operator time that has been freed. In worst case, this would only lead to less productive time for the operators. In the best case the operator would be utilized more effectively decreasing the payback time.

The payback time for layout 5 would be even longer. Since many of the potential advantages with a continuous flow not could be utilized due to technical limitations, this layout would be even harder investment to motivate. However as discussed before, it is an investment that may be justifiable in the future.

6.7 Layout analysis or process analysis

The difference between making a layout analysis and a process analysis is that after making a process analysis, the layout analysis continues further. A proper process analysis is a prerequisite before continuing to the layout. That means not all changes proposed actually considers the layout, but are more general process improvements.

7 Conclusion

This part contains the author's conclusion from the research. It will also include a recommendation for which direction the company should continue to work in as well as some comments about the current state of the academic research area.

The model proved to perform well in the environment where it was tested. The different tools that were used were all capable to gather and systematize a sufficient amount of data.

A layout project will always reach a "creative phase" where it is due to the experience possessed by the user of the model, how good the result will be. In this project the traverse lifts came to prove crucial, but also a potential for improvements. In another company this would have been different. This makes it obvious that a good model can be very helpful, especially in the early stages of the project, but it is not sufficient to reach an optimal solution.

On one hand technical limitations and space requirements and on the other hand a lack of willingness to do extensive investments stands in between the existing layout and serious potential future improvements. The finishing section proved to be fit to meet the future changes without any serious adaptations at all. This means that it will be hard to motivate expensive investments.

However, this research has shown that there are potential for significant improvements without huge investments. The production capacity could be increased by 7.7% through a change in the layout. More than 1% could be cut off from the uptime of the billet inspection and grinders due to changes at an internal customer (flow C3 and C4). These machines are the bottlenecks of the finishing operation. Significant time savings on traverse operations could also be achieved without affecting the operation negatively. 104 min would be saved due to layout improvements in hall 2 and another 30 min could be saved after the discussed changes at internal customer "Ring" has been implemented. This means that 134 min/day of traverse operator time would be saved.

Recommendations for future research

The area of layout planning is relatively frequently covered in recent academic research. Most of the articles written state that the input data is the really crucial part where the layout planning procedure often fail. This is especially the fact when inexperienced engineers are considered. When the awareness of this fact seems obvious, fewer seems to have concluded that new tools to optimize the gathering of data aimed towards less experienced engineers could be developed.

Many scientific papers present new models, and discuss the advantages these may contribute with. However, the adaption of the tools that are used to gather the in-data is often less emphasized. Since different tools in many cases will show different findings and then also result in different conclusions, this is a highly crucial part. The only really comprehensive discussion regarding how the tools used should be adapted to the type of production seems to be presented by Muther (1973) and Meyer (1993). These are not to be considered as academic research but rather practical industry guidelines for engineers.

There seems to have been few academic efforts to establish how different tools could prove advantageous in the different stages of a layout project, and then especially when considering inexperienced users. Further research in this area may therefore be fruit full, and lead to significant improvements in what could be called the weak link in the layout planning project.

Recommendations for the company

The layout in the company is tightly bound to technical innovations, and working on these areas would not only affect product quality and time consumption, but also open up for new layout improvements. But even though technical innovations can contribute to a better product flow, the limitations in the actual production site are significant. The area is small, barely large enough to carry the machines with its surrounding working area. Furthermore the restriction in machines that cannot be moved is significant.

There has been presented a number of constraints that prevents a better flow through the finishing section. To remove these would indeed create a possibility to further improve the production flow in the finishing operations.

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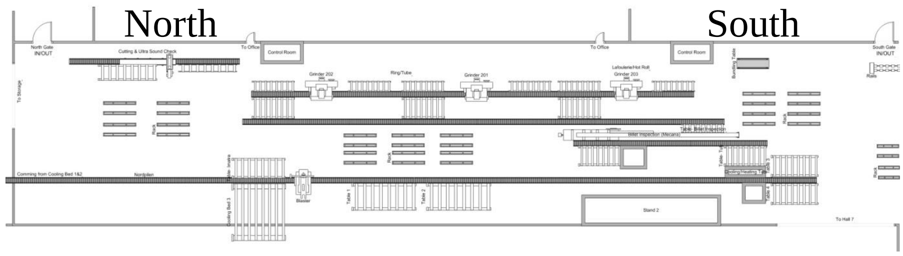
9 Glossary

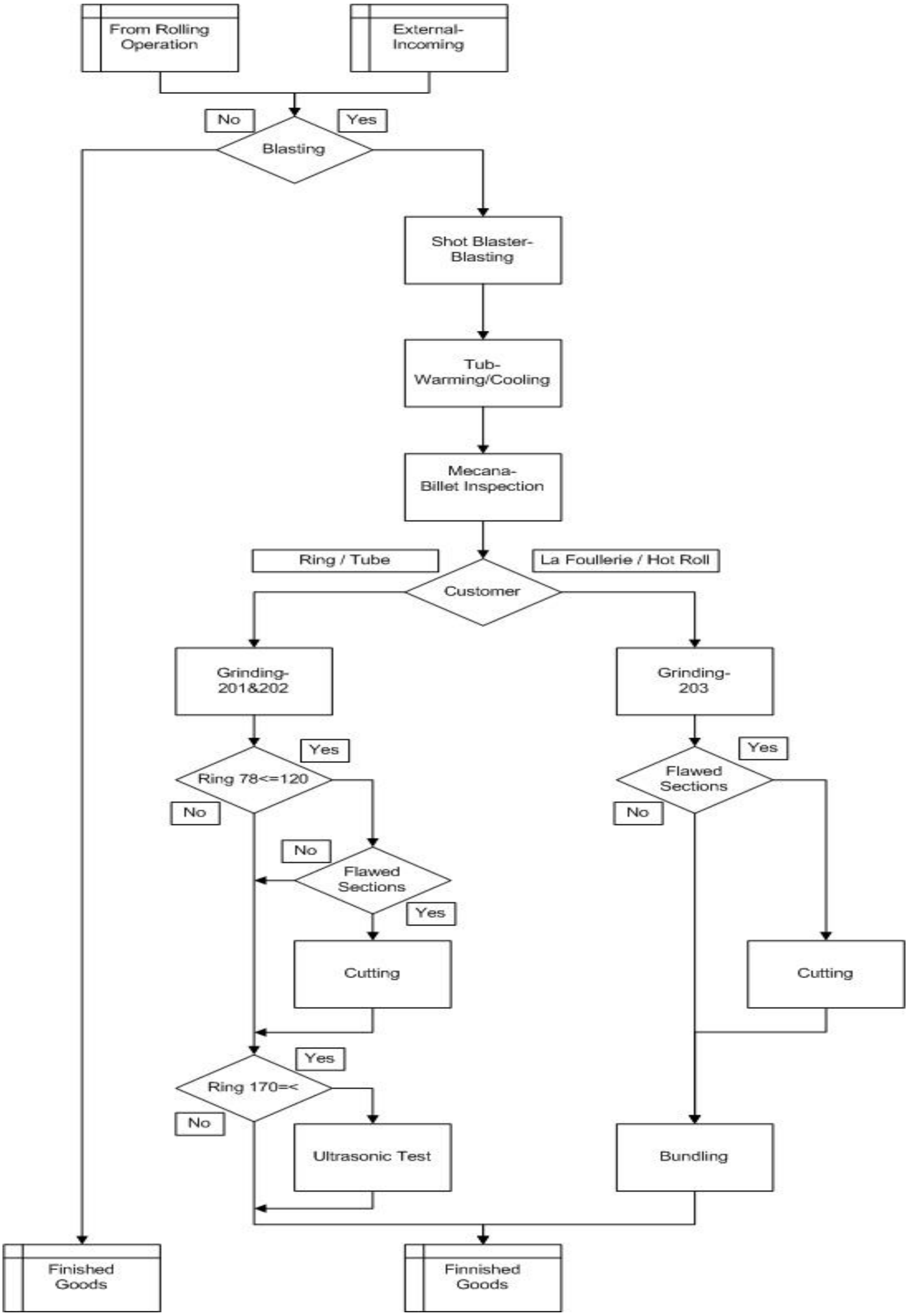
Billet inspection (Mecana)	Machine for automated magnetic particle inspection
Blockage	There is an activity later in the process that stops the flow
Cooling Bed	A long bed that continuously moves forward in a “wave-pattern” which turns the steel permitting the bars to cool down evenly
Finishing area	See Hall 2
Flow intensity	The number of pieces of steel that flows in a certain connection
Hall 2 (second hall)	The area where blasting, grinding, inspection, and cutting takes place
Hall 7	Where the rolling operation takes place
HVLV	High Volume/Low Variety production
LVHV	Low Volume production/High Variety
Main Flow	The flow through blaster, tub, mecana, grinders (Ca 30 000 pc’s) This includes flow B1 and C1-C7
Rolling Operation	The part of the production where the steel is rolled
South/North side	Compass directions will be used in the report to give a location



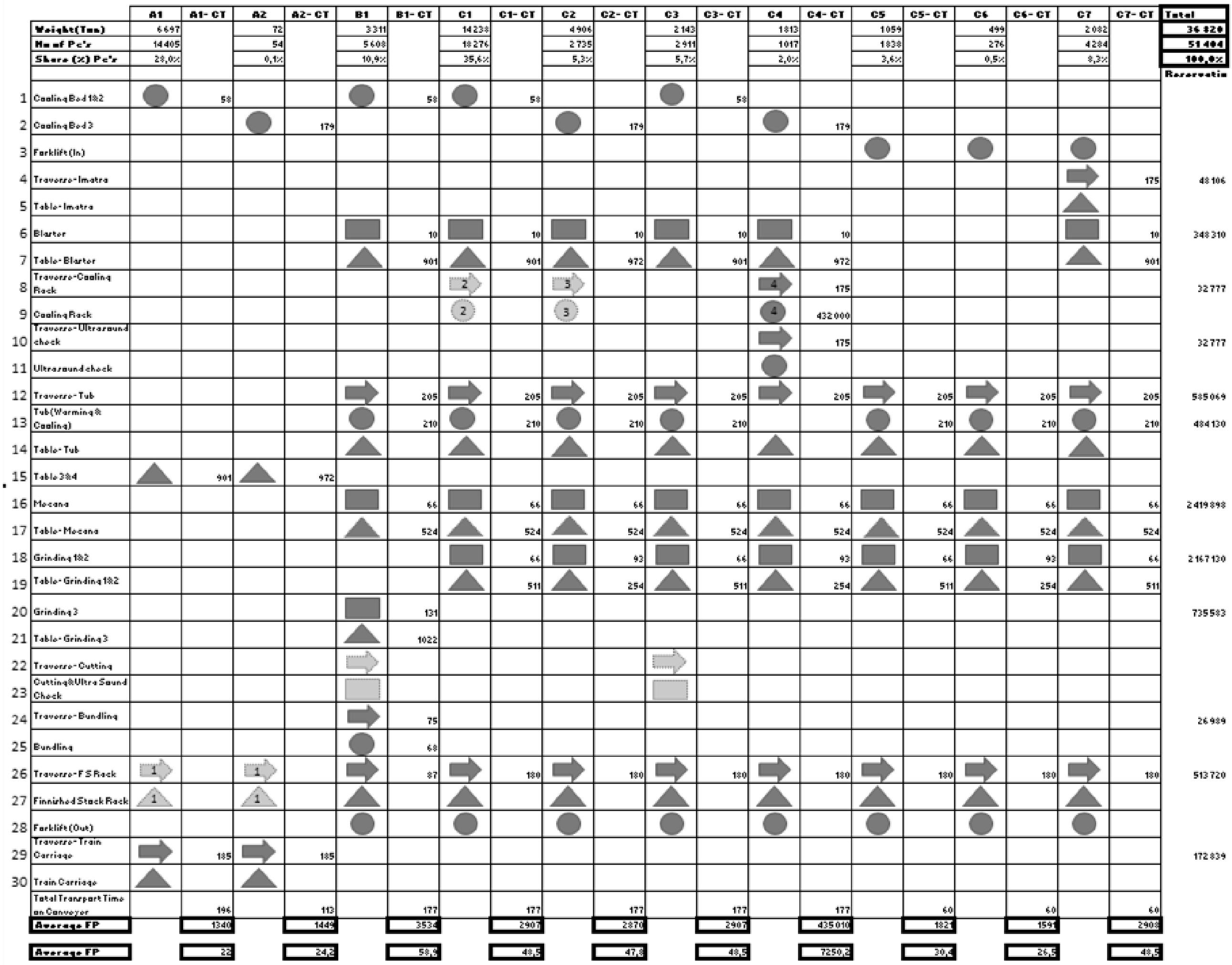
Starvation	There is an activity earlier in the process that stops the flow
Table	The connection on and off from a line at a lift is done from tables. Some tables are merely a place to put the bundle of billets, which is then scoped over to the line one by one, by a hydraulic arm (connection to the line). Some are containing for the billets dedicated carriers that transport the billets across the tables (connection from the line).
Travers 1&2	Crane mounted close the ceiling that can reach any part of the second hall from above. Traverse 1 = northern, Travers 2 = southern

10 Appendices

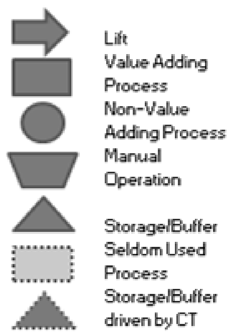
10.1 Flow Diagram, Hall 2 (Finishing)



10.2 **Process Flow Diagram- Current State**



	Coming From(Saw)		Going To(Custom	Sizes
A1		4	Hällefors	78-160
A2		3	Hällefors	170-230
B1		4	La Foulerie & Hot Roll	78-160
C1		4	Tube	78-160
C2		3	Tube	170-230
C3		4	Ring	78-160
C4		3	Ring	170-230
C5	Imatra 280T&285K		Tube	78-160
C6	Imatra 280T&285K		Tube	170-230
C7	Imatra 803F		Tube	78-160



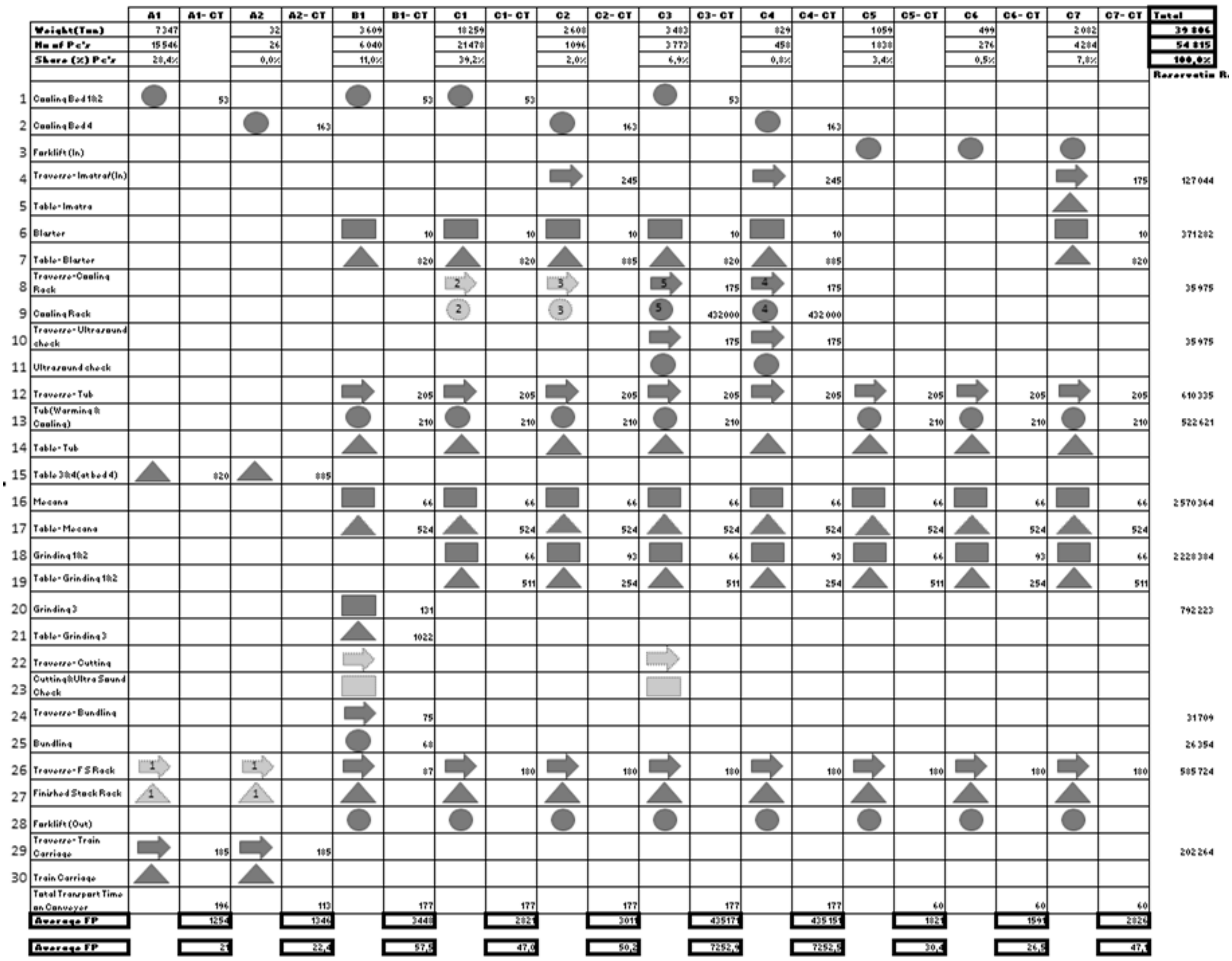
1: If no train carriages avaiable

2: If alloy 277 or 477

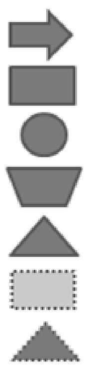
3: If alloy 277 , 477 or warmer than 200° C

4: 5 days maturing before ultra- sound- check

10.3 Process Flow Diagram- Future State



	Coming From(Saw)		Going To(Customer)	Sizes
A1		4	Hällefors	78-170
A2		3	Hällefors	190-230
B1		4	La Foulerie & Hot Roll	78-160
C1		4	Tube	78-170
C2		3	Tube	190-230
C3		4	Ring	78-170
C4		3	Ring	190-230
C5	Imatra 280T&285K		Tube	78-160
C6	Imatra 280T&285K		Tube	170-230
C7	Imatra 803F		Tube	78-160



1: If no train carriages avaiable

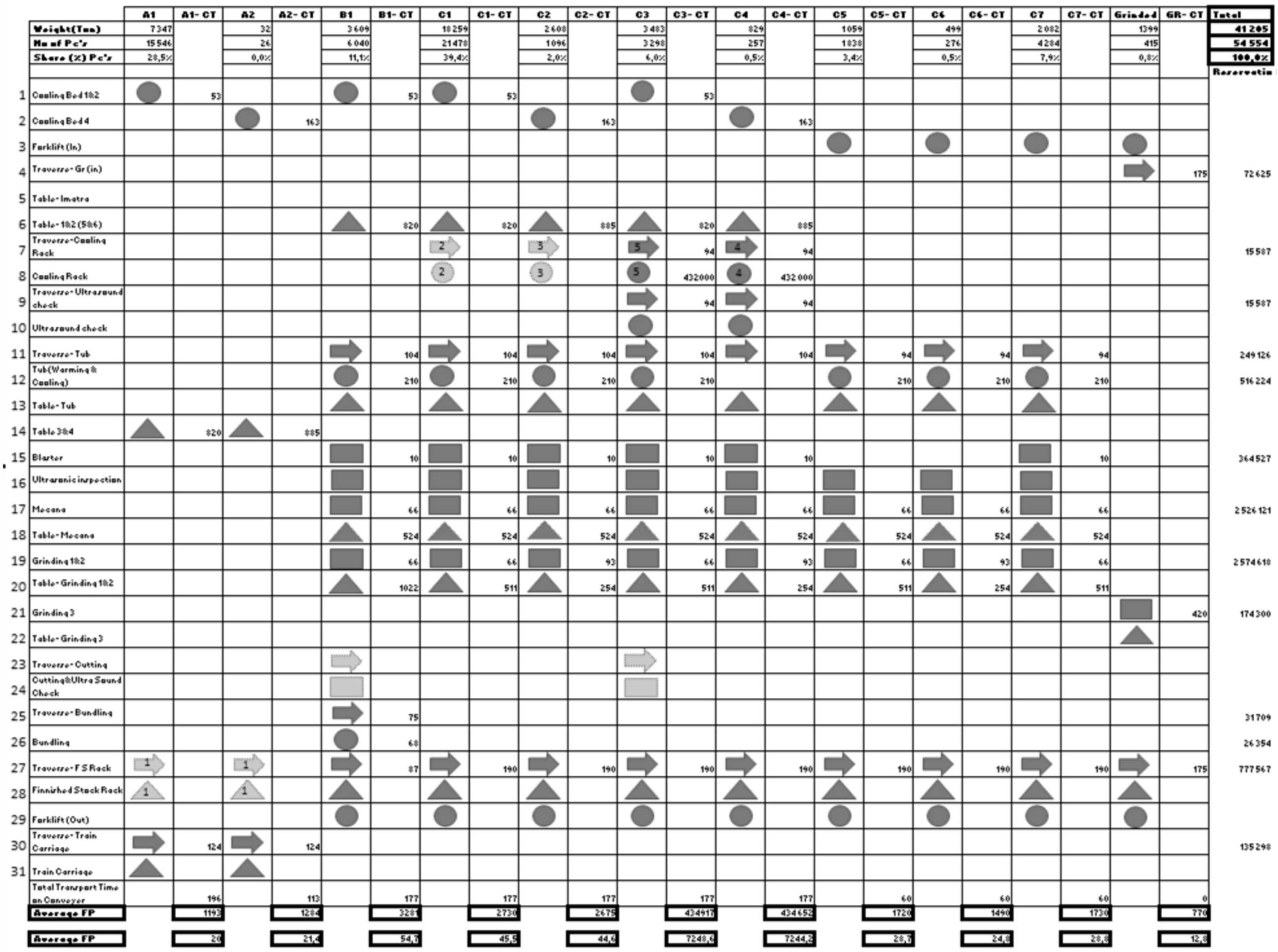
2: If alloy 277 or 477

3: If alloy 277 , 477 or warmer than 200° C

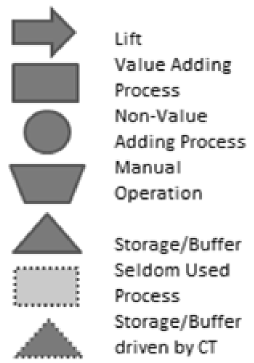
4: 5 days maturing before ultra- sound- check

5: 5 days maturing before ultra- sound- check (only 170)

10.4 **Process Flow Diagram- Layout 3**



	Coming From(Saw)	Going To(Customer)	Sizes
A1		4 Hällefors	78-170
A2		3 Hällefors	190-230
B1		4 La Foulerie & Hot Roll	78-160
C1		4 Tube	78-170
C2		3 Tube	190-230
C3		4 Ring	78-170
C4		3 Ring	190-230
C5	Imatra 280T&285K	Tube	78-160
C6	Imatra 280T&285K	Tube	170-230
C7	Imatra 803F	Tube	78-160



1: If no train carriages avaiable

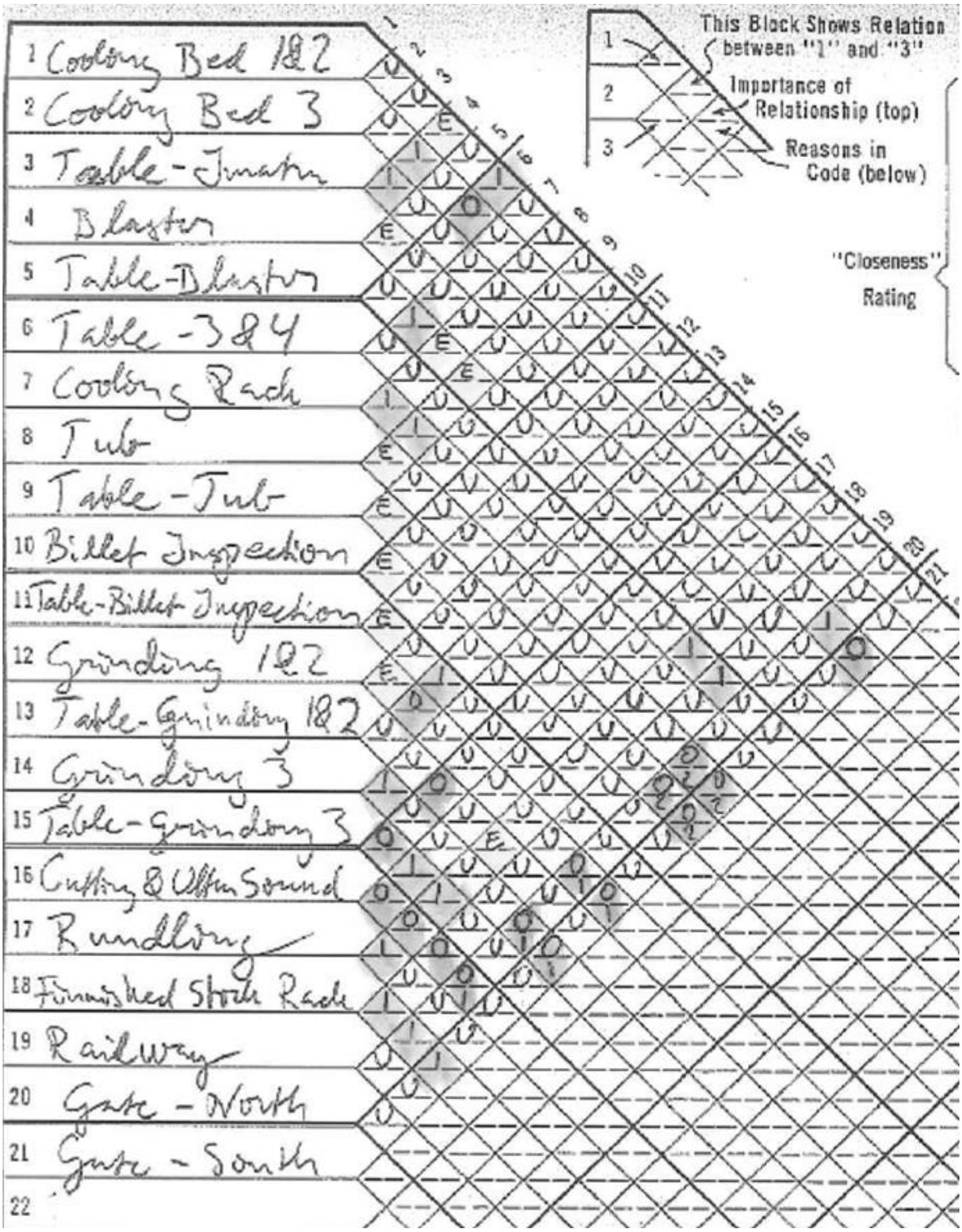
2: If alloy 277 or 477

3: If alloy 277 , 477 or warmer than 200° C

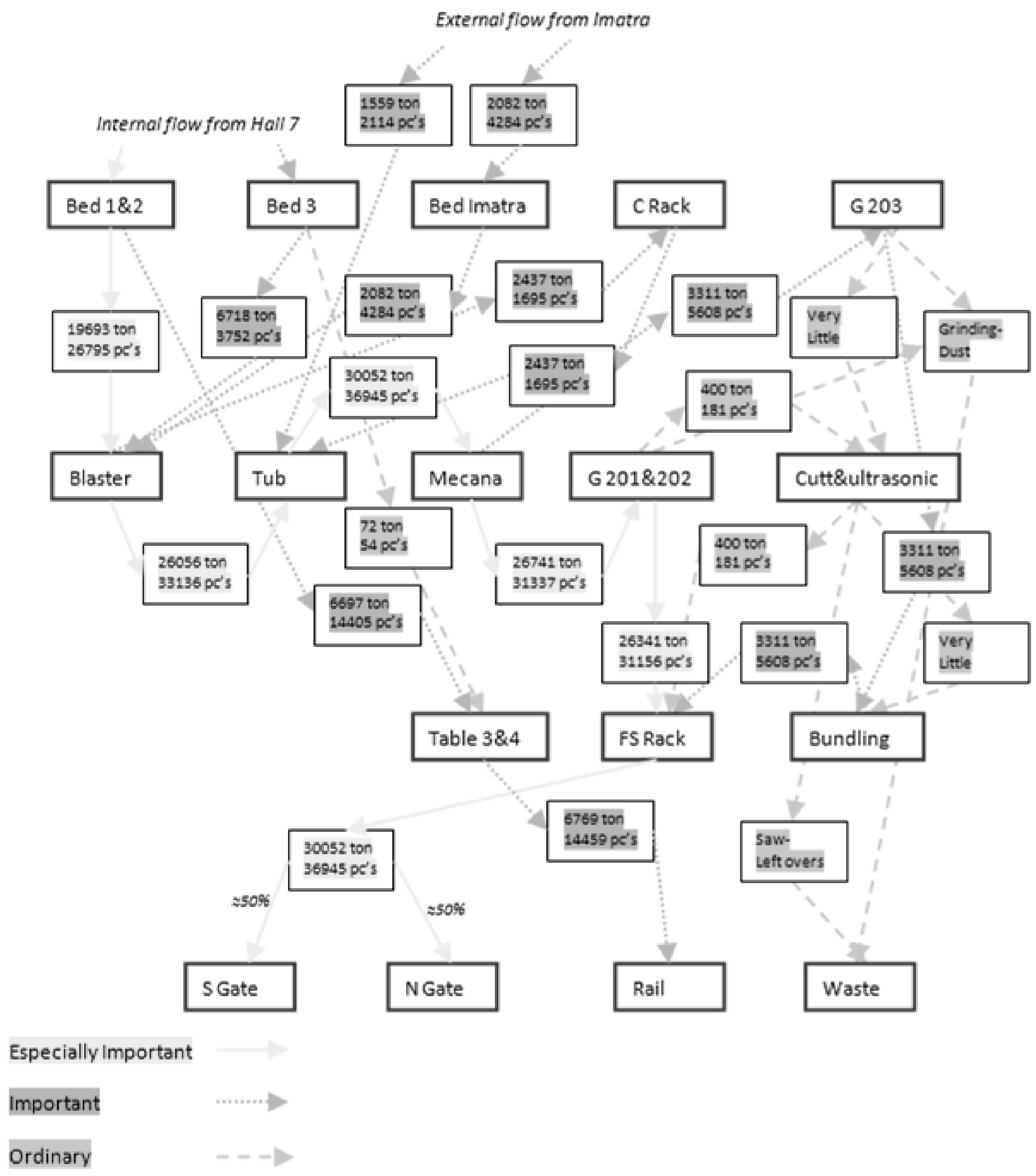
4: 5 days maturing before ultra- sound-check

5: 5 days maturing before ultra- sound-check (only 170)

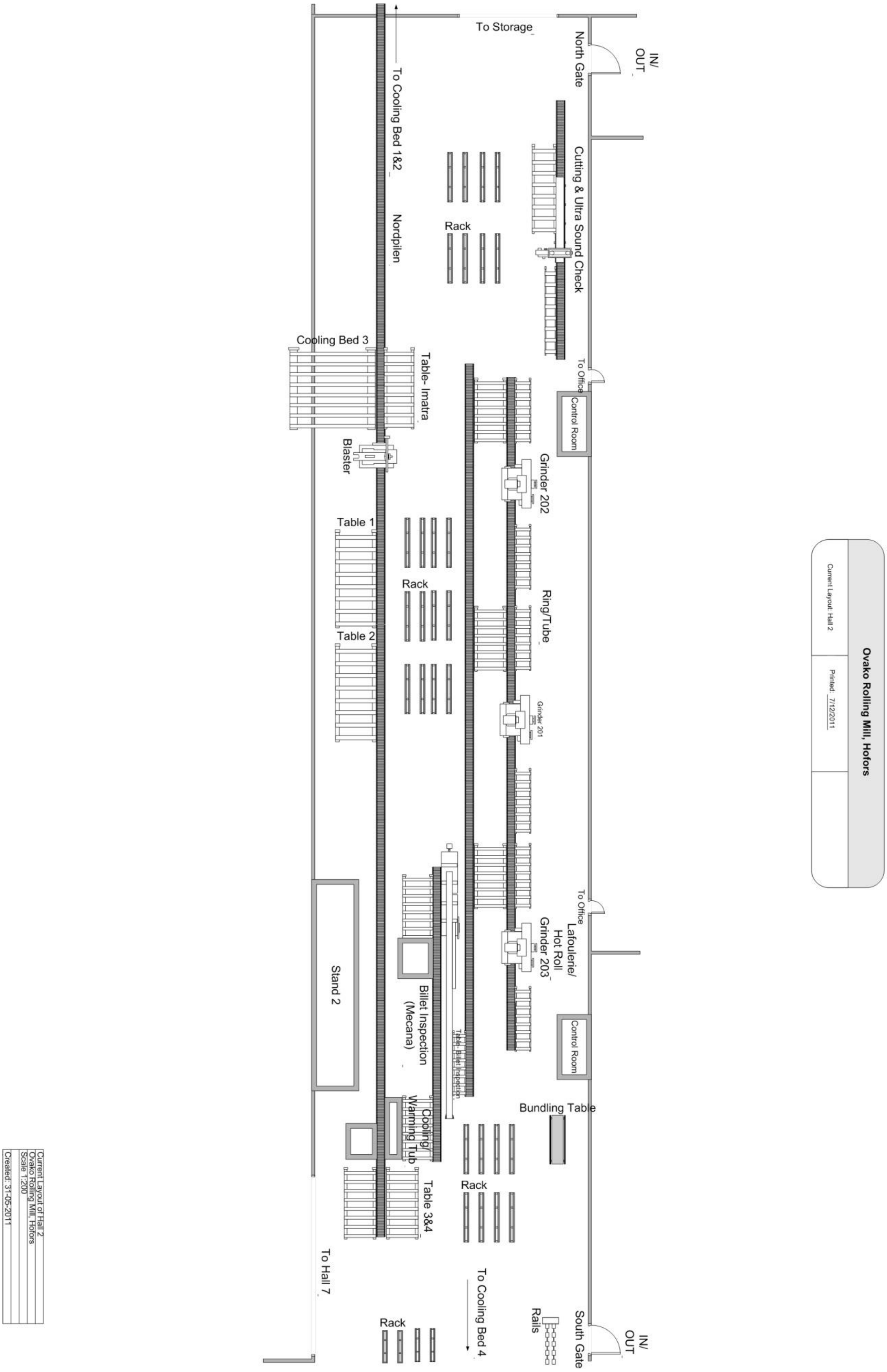
10.5 **Activity Relationships**



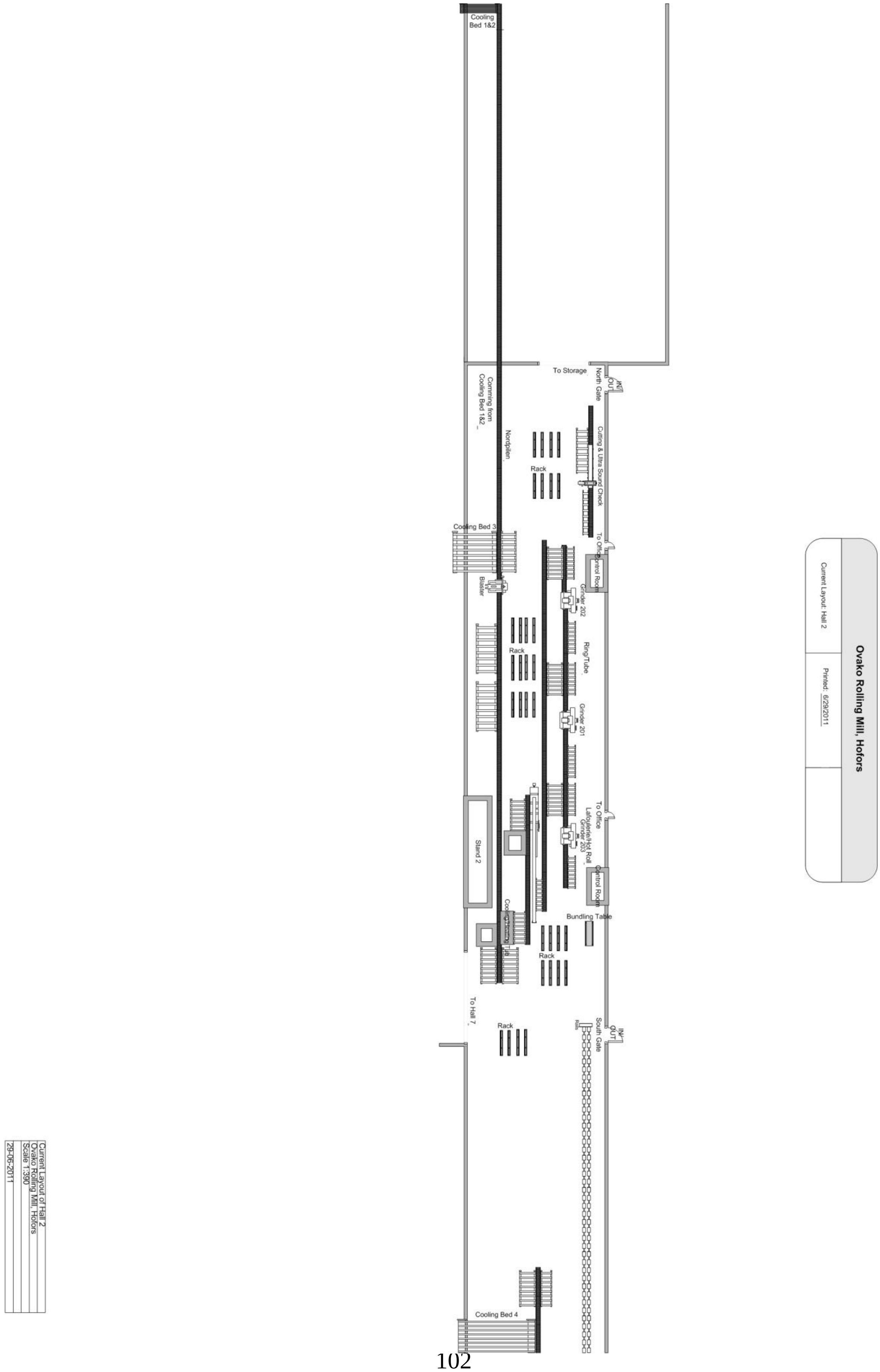
10.6 Relationship Diagram



10.7 **Current State Layout of Hall 2**



10.8 Current State Layout Hall 2, including storage and loading area



10.9 Evaluation Model