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An introduction of Lean manufacturing in the poultry processing industry

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Abstract

This report discusses a research that is done at Company X, one of the biggest manufacturers of poultry processing lines. The research is part of the study program from the bachelor study Industrial Engineering and Management (IEM), followed at the University of Twente.

Company X is interested to discover how they can contribute to their clients' manufacturing systems by developing tools, processes and providing advice. Therefore there is significant interest to understand their clients manufacturing systems on how the system is adjusted and with what goals in mind, and how and where weaknesses could be identified. With these interests, the main research question is:

What weaknesses in the current manufacturing systems can be identified and how can and should they be addressed?

To answer this question, the research performs a case study. Furthermore, it uses a Lean manufacturing approach which is a management philosophy that aims to optimize manufacturing systems and commonly known as just 'Lean', to guide the identification of customer values and to understand how they are expressed throughout the manufacturing system.

First, the current manufacturing system is visualized in a process model. Simultaneously, the customer values are identified by the study of literature, making observations and consulting experts. A list of Key Performance Indicators (KPIs) for processes and process areas (a group of strongly related processes) are identified that support the evaluation of customer values. The KPIs are categorized according to a Quality, Delivery and Costs (QDC) approach and the effect of practical measures on those KPIs are then studied.

The second step is to identify weaknesses in the manufacturing system. For several reasons the scope is narrowed down to the fillet department. Here, the breast caps are processed into products such as fillets, medallions and schnitzels. With Lean Thinking (techniques that are used in Lean manufacturing) the weaknesses are identified by first identifying so called 'wastes' in every process area. The root causes of such wastes are considered the weaknesses in a manufacturing system. Prioritizing the biggest wastes and thereby addressing their root causes is one of the reasons why in particular a Lean manufacturing approach was used, since it identifies system wide bottlenecks and eliminates non-value adding activities. This is in contrast with Company X's traditional approach to optimize the manufacturing system where the value adding activities of individual process is optimized one by one.

The major methodology that is used to identify wastes and their root causes is observing. For two days, the fillet department is observed and wastes are identified and valued as accurate as possible by recording data during these visits. The research prioritizes the six biggest wastes:

1. Frequent and long waiting times for fillet harvesters.
2. Use of buffers by the tenderloin harvesters.
3. Over processing as a result of unnecessary inspection for weight defects of trays.
4. Extremely poor capacity utilization of the trimming lines.
5. The motion and inventory wasted to fix defects from the robobatcher (batching machine).
6. The waste of motion and activities to empty red and blue crates.

Recommendations for Company X are made on how they can contribute to eliminate these wastes and thereby address weaknesses in their clients' current manufacturing system. For instance, Company X can give advice on how to plan, monitor and improve the capacity utilization at trimming stations, which increases the capacity utilization by an expected 40%. Another recommendation is to focus on creating a stable infeed speed by most importantly reducing line speeds and eliminate the need of empty shackles that are needed to distinct flocks. By doing this, the yield loss can decrease

significantly by 1 to 2% at the fillet harvesting process and the capacity utilization of this and several surrounding processes can be increased by an estimated 30%.

Other benefits and practices of using Lean Thinking are also discussed. For instance, improving the forecasting of order quantities and eliminating the wastes involved in creating, storing and using 60 to 70 tons of routine inventories.

This research is a first step to introduce Lean manufacturing in one of the clients' manufacturing system. It became evident that most customer values are neglected by Planning and Control who plan and monitor the production days. Order completeness is the only customer value that is significantly used to adjust the manufacturing system.

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1. Introduction

This chapter discusses the motivation behind the research and the problem identification (Sections 1.1 - 1.3). Subsequently the others sections discuss the scope and academic relevance (Section 1.4), the research approach (Section 1.5), the questions and methodology (1.6), the limitations, validity, reliability and limitations (Section 1.7), the deliverables (Section 1.8), and the outline of the report (Section 1.9).

1.1 The company

This bachelor report is made for Company X that is one of the biggest manufacturers of processing lines for poultry industry. Aside from the production of high-end production lines, they are known for their contributions to the industries by developing software, lending expertise and other specialized services. The further development and optimization of these lines are dependent on the expertise gained by research. Focusing on the benefits gained by increasing the control, flexibility and capacity of the processing lines, Company X can stay ahead of competitors by continuously innovate (MSPP, 2010).

1.2 Research motivation and problem context

This research is part of a PhD project aimed to optimize several practices and processes within a poultry manufacturing plant. The project started with optimizing graders (sorting machines for products) by optimizing their sorting algorithms. Then the project's scope expanded to surrounding processes and practices. One topic that arose is called 'order scheduling':

The process of deciding what broilers (e.g., chickens) and products must be processed or produced when, in which process and for which order.

The decisions made in order scheduling are based on the current situation (e.g., the order progression and flock properties), certain requirements, practical limitations, rules-of-thumbs, and the desired outcome. Order scheduling is a very broad decision-process; it is related with the whole manufacturing system. Company X aspired for optimizing and automating this process by developing tools, software and providing directed advice.

In particularly the secondary process (the processing of ready-made broilers into end products) is of interests to Company X since it is a complex, un-optimized and only partly automated process. More specifically, the fillet lines (a process area within the secondary process where breast caps are processed into end products) are the scope of the PhD's project that is collaborated with. According to Company X, most of the profit is lost within these lines. Therefore, Company X is focused on this process area and so is the focus of the research.

1.3 Problem identification

One cannot design a service or product (e.g., a tool), when it is unknown what has to be designed. It is also important to identify the weaknesses of processes and process areas that require optimization, tools or advice, and which ones should be prioritized first. For instance, a tool can be designed to support operators on a fillet trimming in their decision-making that adds some customer value, while redesigning an automated process (e.g., the process that removes wishbones) to reduce defects might add significant more customer value. Examples of questions that arise from these interests are: What are the customer values for clients of Company X? What customer value is created and wasted in a process or process area? How should a process or process area be addressed (optimized, automated, etc.)?

In consultation with Company X, some other problems are identified. First of all, the desires of Company X to advice clients on their Planning and Control strategy is impossible when operational and strategic goals are unclear. Advising on Planning and Control strategy is important, since it is common that the decisions made on operational level are focused on efficiency performance measures (operational goals), such as production costs. On strategic level, the aim is to score high on effectiveness performance measures (strategic goals), such as order fulfillment and product quality. According to Goldratt (2004), effectiveness goals must always receive priority over efficiency goals. Decisions on operational level may be the best short-term decisions, but not optimal on the long-term. In order to give advice on this topic, a rough understanding of the current Planning and Control strategy of clients is required, for instance when (events happening) and how (measures that are/can be taken) the planning is adjusted.

Company X thinks to understand what outcome (operational and strategic goals) their clients desire and try to achieve, while their clients aim prioritize other goals. For instance, Company X may expect that performing well on capacity utilization is more important to a client than their product quality while this may be the other way around. Such misconceptions lead to poor advice and wrongly designed tools. Thus, understanding the strategic and operational goals of Company X's clients may increase the quality of advice and the design of tools.

Another issue is the theoretical basis on which Company X operates and the practical basis on which their clients operate. Most of Company X's employees seldom visit manufacturing plants and see their products operating in practice, this is in contrast to their clients who experience every practical implication of Company X's products and services. This theory-practice gap is important in designing a tool or giving advice. The limitations, assumptions and scope that are considered in the design of a theoretical model contribute to their practical inapplicability (King, 1976). By closing this gap by understanding the as-is situation of the manufacturing Planning and Control, the Company X's advice and tools become more applicable to practice.

The problem identification with its interested and problems is summarized as:

Company X is willing to develop tools and give advice but this is impossible because:

1. They do not understand the organizational and strategic goals of their clients.
2. Therefore, they also do not understand the current Planning and Control strategy.
3. They do not understand what process (areas) should be optimized, and which process (areas) should be prioritized.
4. The theoretical background of Company X and its gap with the practice is an obstacle to design proper advice and tools for their clients.

The main research question is therefore:

What weaknesses in the current manufacturing systems can be identified and how can and should they be addressed?

1.4 Research scope and relevance

Due to a time limit, the whole manufacturing system is studied on a general level of detail while the emphasis lies within the fillet department. This process area processes breast caps of broilers into fillets and other products. The main reason to narrow down the scope to the fillet department is because this area is complex and by far less optimized than any other area of the manufacturing system. It is also Company X's current focus for most of their innovation. The primary process, which are the processes that prepares the broilers before they can be cut up into products, is a straight-forward process that is well optimized with tools such as Overall Equipment Effectiveness (OEE). Most problems and bottlenecks are according to Company X located in the fillet department, as well as most product value is both added and lost in this department. This is because product family of the fillet department consist of fillets that are the most valuable products. In addition, the fillet department requires most machine maintenance, labor and is known to be a bottleneck due to its low and difficult managed capacity. Figure 1.1 gives a simplistic overview of the production process and shows how the scope narrows from the whole production process (see area 1 in the figure) to the secondary process (2) and finally to the fillet department only (3).

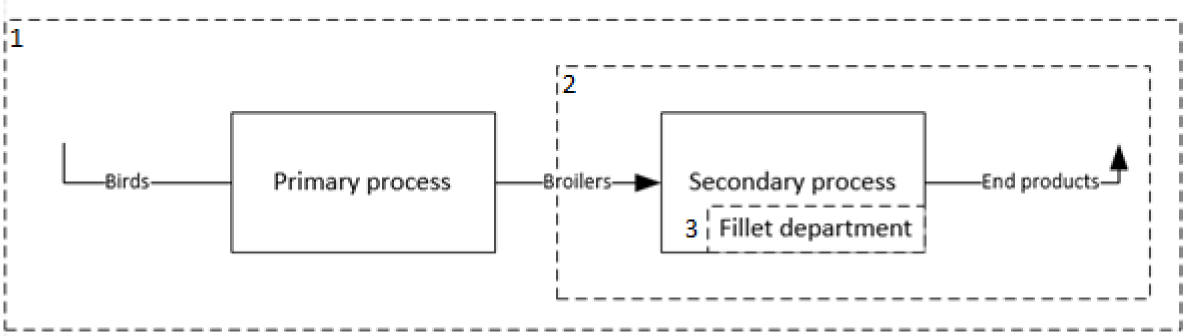


Figure 1.1 The narrowing down of the scope throughout the research.

The research is relevant for Company X since it may give new insights in and better understanding of the strategy of clients' manufacturing Planning and Control. In addition, the research findings facilitate the development of tools and constructive advice for clients by giving a better understanding of the weaknesses within the manufacturing system and how they should and can be addressed.

The research is based on a case study; one client of Company X is studied. The research can be used as a framework in studying other clients. A case study reflects the reality well and thereby contributes to further close the gap between Company X's theoretical origin and their clients practical origin.

1.5 Research approach

This research uses an Industrial Engineering and Management approach for problem-solving from the book 'Geen Probleem' written by Hans Heerkens (2012). For more elaboration on this approach the book can be consulted. It is important to understand that the last two steps ('Implementation' and 'Evaluation') lay outside the research scope due to the time limit.

1.6 Research questions and methodologies

The main research question is:

What weaknesses in the current manufacturing systems can be identified and how can and should they be addressed?

In order to identify and address weaknesses in the manufacturing system, a clear understanding of the system is gained. Both understanding the production processes and how these are adjusted by Planning and Control is important. Therefore, the first research question is:

1. How does the current manufacturing system look like?

In the research a theoretical framework is used to systematically answer the main research question. This framework is called Lean manufacturing (most of the time just called 'Lean') which is a systematic management approach that identifies value streams and waste within a manufacturing system. The research questions take into account the steps that are commonly taken in applying Lean manufacturing to a manufacturing system. Therefore, the next paragraphs roughly explain these steps.

The first step in the Lean Thinking (which is the method of implementing Lean manufacturing to an existing system by taking specific steps) is to identify the customer values. Commonly, three categories of customer values are used to analyze how a process or process area is performing. These are Quality, Delivery and Costs (QDC). Operational and strategic goals fit within one of these categories. For some clients it is necessary to add other categories, like 'Morale' and 'Safety'. If there is a need for this it is determined during the research.

The benefits of this management approach are used to break down a whole production process into smaller ones to support decision-making. More benefits of this approach are to prevent the feeling of being overwhelmed by providing a systematic approach, to facilitate the prioritization of goals (Imai, Masaaki, 1997) and add customer value to the manufacturing system by eliminating system wide bottlenecks. To execute this first step of Lean Thinking the following research question is:

2. *How are the customer values expressed throughout the manufacturing system?*
    - *2.1 What are the strategic and operational goals of the customer?*
    - *2.2 What Key Performance Indicators can be found within the process areas?*
    - *2.3 What Key Performance Indicators are used by Planning and Control?*
    - *2.4 How are customer values added by the manufacturing system?*

To answer this research question, several methodologies are used: making observations by visiting the plant, studying plant layouts, machine manuals and other information on the topic, and by speaking to experts in the field.

For the second research question, the scope is the fillet department because of the limited time-span. However, the first research question covers the whole manufacturing system with the purpose to understand the context and to support the process of identifying waste, problems and their roots.

In the second step of Lean Thinking the value streams and wastes are identified by the creation of a Value Stream Map. This is done with extensively observing processes on the shop floor. Chapter 3 elaborates Lean Thinking in more detail.

3. *What are the value streams and where can waste be eliminated?*

The goal of step two is to eliminate waste. Waste is prioritized by analyzing the added customer value that is created if it would be eliminated. After prioritizing a selective group of waste, the root cause for the problem that creates the waste is identified. Recommendations are given for addressing these root problems. By doing this, a more continuous production flow is created within the manufacturing system. Thus, the last two research questions are:

4. *Which of the wastes should be eliminated first and why?*
5. *How can the wastes be eliminated?*

Question 4 and 5 are chosen to be separate questions. It is important to take into account how easy a waste can be eliminated but commonly it is a difficult task to find the root cause of a waste and it is too time consuming to be done for every waste. Nonetheless, some overlap is to be expected in these questions.

1.7 Validity, reliability and limitations

The findings are mostly based on empirical evidence, such as observations and interviews. The validity of the findings are representative to this research; they are based on direct observations of the reality, expertise from employees and clients, and real up-to-date quantitative data. Nevertheless, people are subjective and therefore biased. Risk for internal validity issues is dangerous if the bias is found throughout the whole company. Thus, double checking the potential biased information with my own observations and other sources is important.

In addition to a person who can be biased, the information gathered from conversations with experts may also be biased by time. For instance, if there is an issue on the shop floor that occurred frequently on a day, an employee might emphasize this issue more than other issues that have been occurring on a daily basis for already years. In addition to this, a person can be biased by its own believes. A planner is not always confronted with the consequences of his work and he/she ought to believe his/her work does not cause issues or contains weaknesses.

The findings in a case study are limited in their reliability if they are applied to other cases. However, in this research the chosen sample is a good representative of a typical high-end poultry processor. Typical characteristics of such a unit are:

- Retail focused poultry processing plant, not bulk.
- High-end production lines. The studied client has a production capacity of roughly 12.500 broilers per hour.
- Typical Western plant layout.

Nonetheless, every poultry processor has its own unique production layout, strategic and operational goals, etcetera. For Company X and the researched client (case), the findings are applicable.

The research is mostly limited by time affecting the depth that can be brought into the research. Especially since the field is new to the researcher.

The research relevance is limited to Company X and its retail client. Furthermore, the research field is very specific. It is difficult to generalize the findings, since it is unknown how strong the unique characteristics of the case influence the results.

1.8 Deliverables

As a result of the previous sections, the research deliverables are clarified. The research should deliver the following:

Step 1 of Lean Thinking: identifying clients' interests/value:

- An analysis of the as-is situation in order to identify the process structure and rough planning.
- An identification of the operational and strategic goals, resulting in a list of KPIs sorted with the help of the three categories used in Lean Thinking: Quality, Delivery, Costs.
- An analysis of how these KPIs are expressed throughout the system, where tables and schemes facilitate the understanding of the relationships between KPIs and the effect of measures on KPIs.

Step 2 of Lean Thinking: identify and visualize value stream and eliminate waste

- A Value Stream Map for the fillet department of the current state.
- An evaluation of the fillet department that includes measures, events and KPIs.
- The identification of wastes within every process area.
- The identification of what wastes have high priority to be eliminated.

- The identification of their root causes and recommendations on how Company X can contribute to eliminate the wastes.

1.9 Outline thesis

The outline for the upcoming chapters is as follows:

In Chapter 2 the answer to the first research question is given by discussing the current manufacturing system.

Chapter 3 provides theoretical background on Lean manufacturing, Lean Thinking and contains the theoretical framework that is used to guide the research.

Chapter 4 executes the 1st step of Lean Thinking by identifying the clients' interests/value.

Chapter 5 executes the 2nd step of Lean Thinking where wastes are identified, prioritized and eliminated (by resolving the root causes).

Finally, Chapter 6 wraps up the research, providing a conclusion, discussion, recommendations and suggestions for further research.

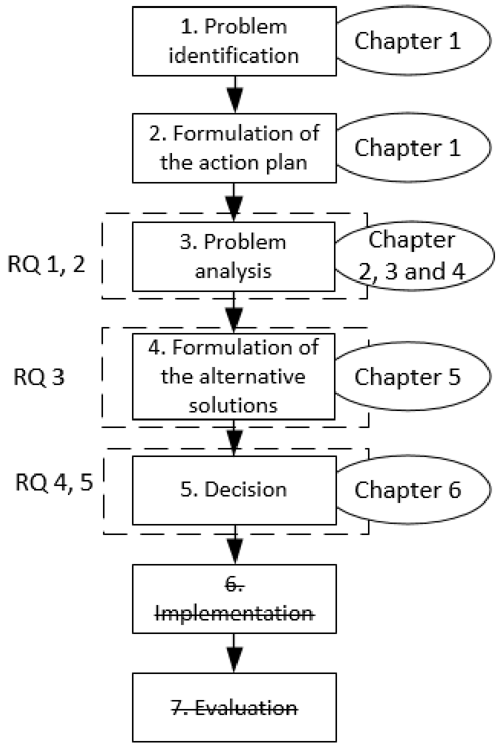


Figure 1.2 outline thesis with the ABP approach of Heerkens, research questions and chapters.

2. Current manufacturing system

This chapter gives answer to the first research question:

How does the current manufacturing system look like?

Section 2.1 introduces the manufacturing plant and industry. This section is followed by Section 2.2 that discusses the main production processes with the purpose to get a rough understanding of the manufacturing system. Section 2.3 covers the activities and current system of Planning and Control.

2.1 The manufacturing plant and industry

The poultry processing plant that is studied is one of the biggest poultry processing plants in Europe with a capacity of roughly 12,500 birds per hour of typically 2,600 gram each. An average production day is 16 hours; however it is normal to run overtimes. The plant is designed to process for the retail industry. This industry, in contrary to the bulk industry, produces over a hundred different end products. From fillets to seasoned grilled drumsticks, the plant is capable to produce nearly any poultry product. Furthermore, the retail industry is, by far, faster-paced than bulk. While industry (bulk) orders are known for days to weeks in advance, retail orders have to be forecasted and are only confirmed and must be shipped on the actual production day within a very short time-frame (commonly within 2 to 5 hours).

It is important to understand that the industry has a divergent process structure; from one bird, an endless number of end products are made (Figure 2.1 shows a fraction of the possible end products). For the food industry this is common (Akkerman, 2009), but pick any other industry and it will most certainly have a convergent production process. Take for instance the automotive industry where hundreds of small parts are assembled into one end product; a car. In addition to the fact that the industry is dealing with fast perishable goods and extreme variable demand, this makes the correct Planning and Control extremely complex. For example, if a bird is processed in order to meet the demand of fillets while the demand of all the other products is already met, the rest of the bird that is processed will be considered as overproduction. This is why a retail plant also needs bulk customers, to sell excessive and poor quality products.

Figure 2.1 product diversity (MSPP, 2010)

2.2 The production process

To get a general understanding of the manufacturing system in order to understand how Lean manufacturing techniques can be used to optimize the system, we discuss both the production processes and the Planning and Control (how productions is planned, monitored and adjusted). A process model is designed in Archimate after a first visit to the customer’s plant, a presentation of the manufacturing system by an expert, the study of the plant layout and previous literature on the topic. Archimate is an enterprise architecture language that is normally used to study information-intensive processes. While this is true for the case, the purpose here was only to get clear understanding of the production processes and their link to Planning and Control.

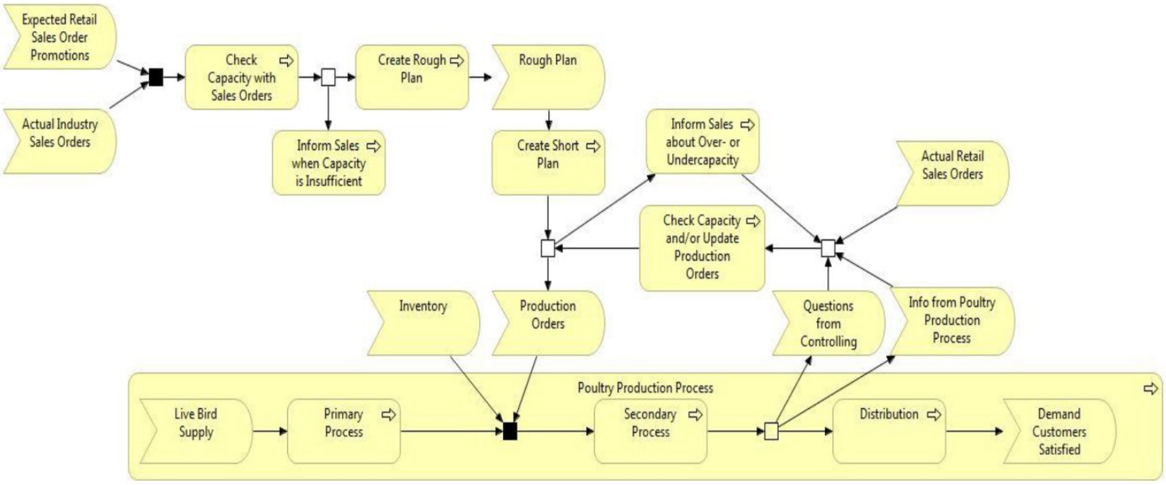


Figure 2.2 rough process model of processes and Planning and Control (Tummers, 2015)

A first process model (Figure 2.2) was previously made by Tummers (2015) who performed a Quick Scan (comprehensive investigation) of the client. The model reflects the core processes and the rough link to Planning and Control. In the process models, the arrows describe the flow of products or information. Furthermore, rounded arrow-shaped elements describe units (products or information) that can be triggered (used) or created by process, or both. Subsequently, there are square shaped elements (containing a sharp arrow) that represent production processes. Products and information are combined in the black and outlined small rectangles. In black rectangles, no decision can be made and the path of the information and/or products is already determined. If there is different paths for different units or if the path of a unit can be decided, an outlined rectangles is used. A more comprehensive description of the shapes to facilitate the understanding of this model and the upcoming models are given in Appendix A.

This process model was worked out in more detail and is split into several figures (Figures 2.3 to 2.5) for the sake of readability. It only covers the production processes, products and main events. The data model with information objects (e.g., attributes) and losses throughout the production processes are excluded. Also, a flow chart (appendix F) was made to give a good overview of what decisions can be made in the secondary process for broilers and intermediary products.

A description of the production processes from begin to end will be given next.

Live bird supply (Figure 2.3, far left)

To begin with, large trucks filled with numeral containers arrive at the plant throughout the day. Both the trucks and containers are weighted. After the containers are unloaded from the truck, the birds must rest from the trip for 2 to 3 hours to reduce stress. The amount of stress will negatively affect the tenderness of the meat, particularly this is bad for the quality of fillets. Depending on the urgency of a flock to be slaughtered, the length of the trip they had to endure and the kind of breed and quality of the flock, they may rest more or less.

A flock is linked to a truck and will come from only one farmer. The expected quality, weight and arrival time of the flocks is determined before they arrived, but the latter two are confirmed upon arrival. This information is important for Planning and Control to better adjust the production.

After the birds have rested, the container is emptied on the production ray and then cLeaned. The birds now enter the primary process.

Primary process (Figure 2.3, central area)

In the primary process birds are prepared until they are so called 'ready-made' or 'panklaar'. The process is very straight-forward and consist of seven steps.

First, the birds are stunned. The birds are positioned on a production ray that enters a gas chamber consisting of several smaller chambers. From beginning to end, the chambers' atmospheres changes, first consisting of mostly enriched oxygen and at the end consisting of mostly carbon dioxide. The birds lose consciousness and are clinically dead, meaning there is still a blood circulation and activity of breathing that sustains the bird's organs. This stunning method is called Multi-staged Controlled Atmosphere System (CAS) and is considered as an animal friendly method.

After the birds are stunned, they are hanged upside down on shackles by hand. Dead Upon Arrivals (DOA's) or birds with other significant quality issues are removed from the production process. At this stage, the birds are counted per flock and then send to the killing process.

In the killing process the birds can be killed with different cuts. Whenever a cut is unsuccessful, the bird is manually cut afterwards. Since the birds hang upside down, they bleed out through their neck for some minutes. Blood is a by-product and sold as bulk. After the bird is killed the blood circulation stops, this will start up chemical reactions that affect the quality of the meat and organs. Thus the faster the bird is processed, the better.

After the birds bled out, they enter the scalding process. Several baths of hot water will macerate and cLean the bird's skin.

A well performing scalding process is important for the proper defeathering of the birds, which is the next process. The feathers, loosened by the scalding process, will be pulled out of the birds with rubber fingers. After the defeathering process, the birds undergo electro-stimulation (RapidRidgor). Here, electric pulses are applied to the body of the bird to remove any energy left in the muscles. This ensures the tenderness of the meat and speeds up the maturation process.

Next, the head and feet are removed and processed as waste or bulk (such as skin and paws). Then, the organs and other vescera are removed in the evisceration process as well as the neck and neck skin. Most of it is sold as bulk.

The last process step is chilling and maturation that takes around 2.5 hours. At the first stage the broilers are cooled down extremely fast to stop any growth of micro-organs. Then, the chilling process is slower to speed up the breakdown of protein. The broiler maturates, to improve the quality and shelf life. Monitoring the chilling process is very important, since the birds lose moisture that is equivalent to losing weight. To prevent moisture loss, the birds receive a thin film of water internally and externally.

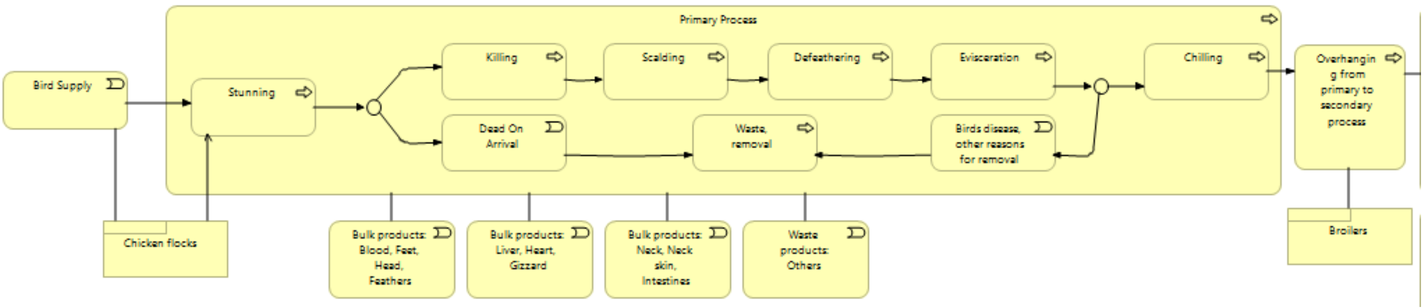


Figure 2.3 process structure of primary process

Secondary process (Figure 2.4)

The secondary process is very complex. A 'ready to cook' broiler from the primary process can be processed in endless ways. Therefore, we discuss the secondary process in low detail to keep it short and interesting.

First, the broilers are hanged over and divided between two main lines (one light and one heavy line). Next, the broilers are scanned on quality by an IRIS scanner and are weighted by a Smart weighter (see Figure 2.4, top left). From this point on, most of the information of every broiler is known and fairly accurate. Also the decoupling point is passed: the decision of how a broiler must be further processed is now demand-driven (thus dependent on the current orders).

After the broiler is weighted and scanned, it is decided whether the broiler must be processed as a whole broiler (see Figure 2.4, middle left area) or not. In this plant, whole broilers are not that common of an order with an exception during the Christmas period. If the broiler is not processed as a whole broiler, then the skin tips and leaf fat is removed and processed as bulk products. Crop skin around the neck is also removed but processed as waste. These processes are found in Figure 2.4 in the central and bottom area.

The broiler enters the wing department where the wings are scanned more accurate. Then, the wings are cut of in different ways (1st joint, 2nd joint or whole wings) or not at all, depending on the orders and quality of the wings (Figure 2.4, middle right area). Like many other products, the wings can be send to Further Processing (FP), where it is grilled, marinated, seasoned, portioned or undergoes any other off-line processing step.

After the wing department the broiler is cut into two: a breast cap that is processed by the breast-cap department that consist of several fillet lines (See Figure 2.5, bottom left area). The saddle that stays on the line. The saddle is processed into legs (split leg or anatomical leg) or drumsticks tights (See Figure 2.5, top three areas).

At the fillet lines, fillets are harvested from the breast-cap, sometimes with or without tenderloin. Then deboned and trimmed, further processed with portioning or directly batched on trays. The trays are packaged, labeled and temporary stored before they can be shipped.

Products are tracked and traced with the information systems PDS-NT and Innova. PDS-NT focuses on recording data throughout the processes, while Innova translates it into usable information. Innova also supports the decision-making of Planning and Control and therefore the whole manufacturing system. An example of the application of Innova is to facilitate the monitoring of the production by using Innova dashboards.

Other software that is used in the manufacturing system is Excel and Microsoft Outlook to support production planning, Pro Recipe to support the planning and execution of Further Processing (FP), and Navision which is the Enterprise Resource Planning (ERP) system mainly used by the Sales department.

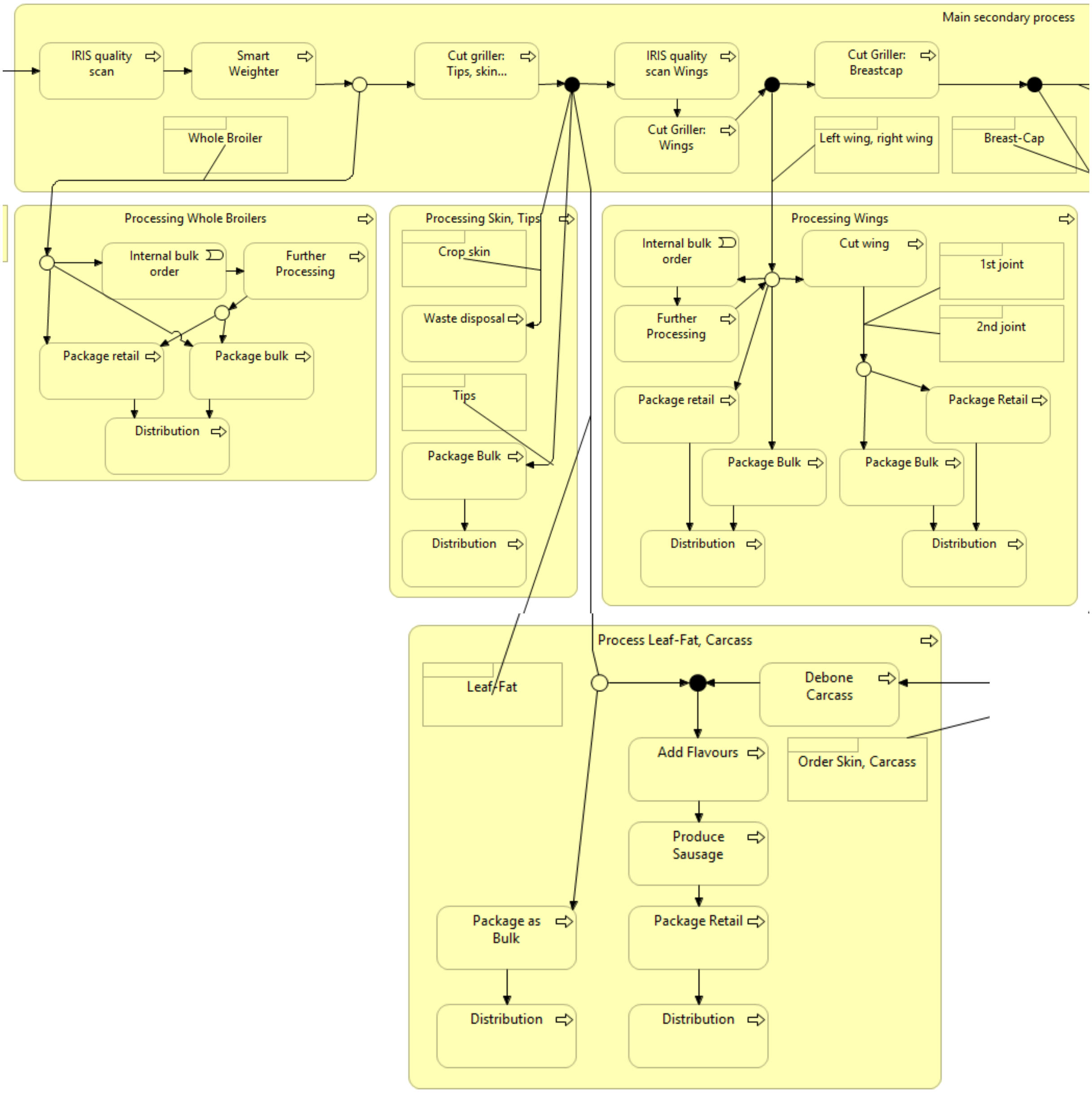


Figure 2.4 Process structure secondary process first part.

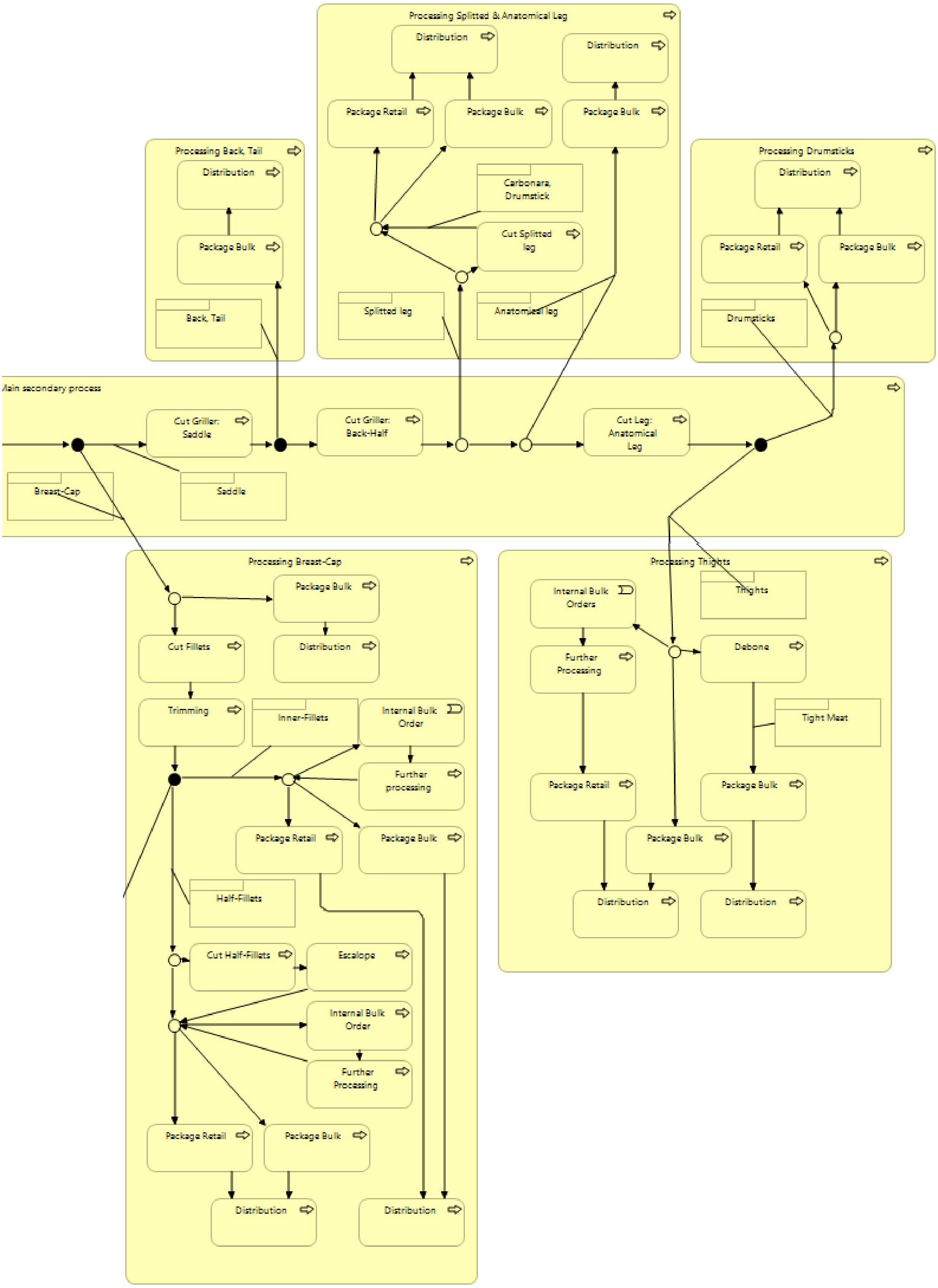


Figure 2.5 Process structure of secondary process second part.

2.3 Planning and Control

Planning activities before of the start of the production day

The production processes are adjusted by Planning and Control. Roughly 26 weeks before the actual production day, farmers are contacted to identify when they approximately can deliver their birds. The first bird plan is weekly based. However, it is roughly known on what day flocks will be ready to be supplied. Every week there is aimed for the same average quality of all flocks and for the same amount of flocks.

The rest of the planning is mostly done in the last few days before the production day. Flow charts were made to give an overview of the main planning activities before the production day (Figure 2.6a and 2.6b) and the Planning and Control activities during the progression of a production day (Figure 2.7).

A week in advance, the order quantities of retail orders are forecasted. Currently, forecasting is primarily based on an 80% rule (forecast is equal to 80% of last week's retail quantities). The reason behind the 80% rule is that the order quantities do not differ for more than 20% of the previous orders and commonly not more than 5%. This 80% forecasted quantity serves as a prognosis until 16:00 of the production day, after this the prognosis is adapted to the actual ordered quantities that are confirmed in the afternoon. Forecasting is also based on intuition, such as the planner's experience with seasonal variances. Aside from normal retail orders, there are promotional retail orders. These are confirmed on the Friday before the week of the production day on its latest. Promotional orders are also taken into account when the retail orders quantities are forecasted.

In the same week before the production day, the rough plan is made. This includes a bird plan, a raw material plan and a rough capacity plan. Planning and Control can make a rough estimation of the available raw material on the production day.

Industry orders are confirmed by customers a week to several days before the actual production day. Every industry order receives a capacity check with the rough plan before they are confirmed. This process consists of checking if there is sufficient raw material and capacity left on that day.

Roughly two days before the production day, the live bird plan is made. At the same time, the rough plan is transformed into several product specific cut-up schedules. One cut-up schedule for wings, FP and other products each. The cut-up schedules describe what products must be produced where, for what orders, in what sequence and with what capacity.

The industry order list is created in the evening before the production day. Both the inventory that must be produced for FP and the known industry order quantities will be used to make an industry order list. The industry order list, cut-up schedules and other important notes are combined into one report called the Good Morning Letter (GML) that is used to start the production day with.

Planning and Control during the production day

The GML is printed and used to start the production day. The plan is based on forecasts. Whenever there are deviations in the GML such as machine failure, deviations in flock weights and actual order quantities, the plan is adjusted and a new GML is made. Planners monitor the production with Innova dashboards, mainly to see if orders will be completed on time. They also receive feedback from the shop floor and undergo certain events (calls from customers, machine failures, delayed trucks, etc.). If the planners deem it necessary to adjust the schedule, they will adapt the plan and inform operators. Most communication is done by telephone calls. For a more detailed description of the main Planning and Control activities throughout a production day, see Figure 2.8.

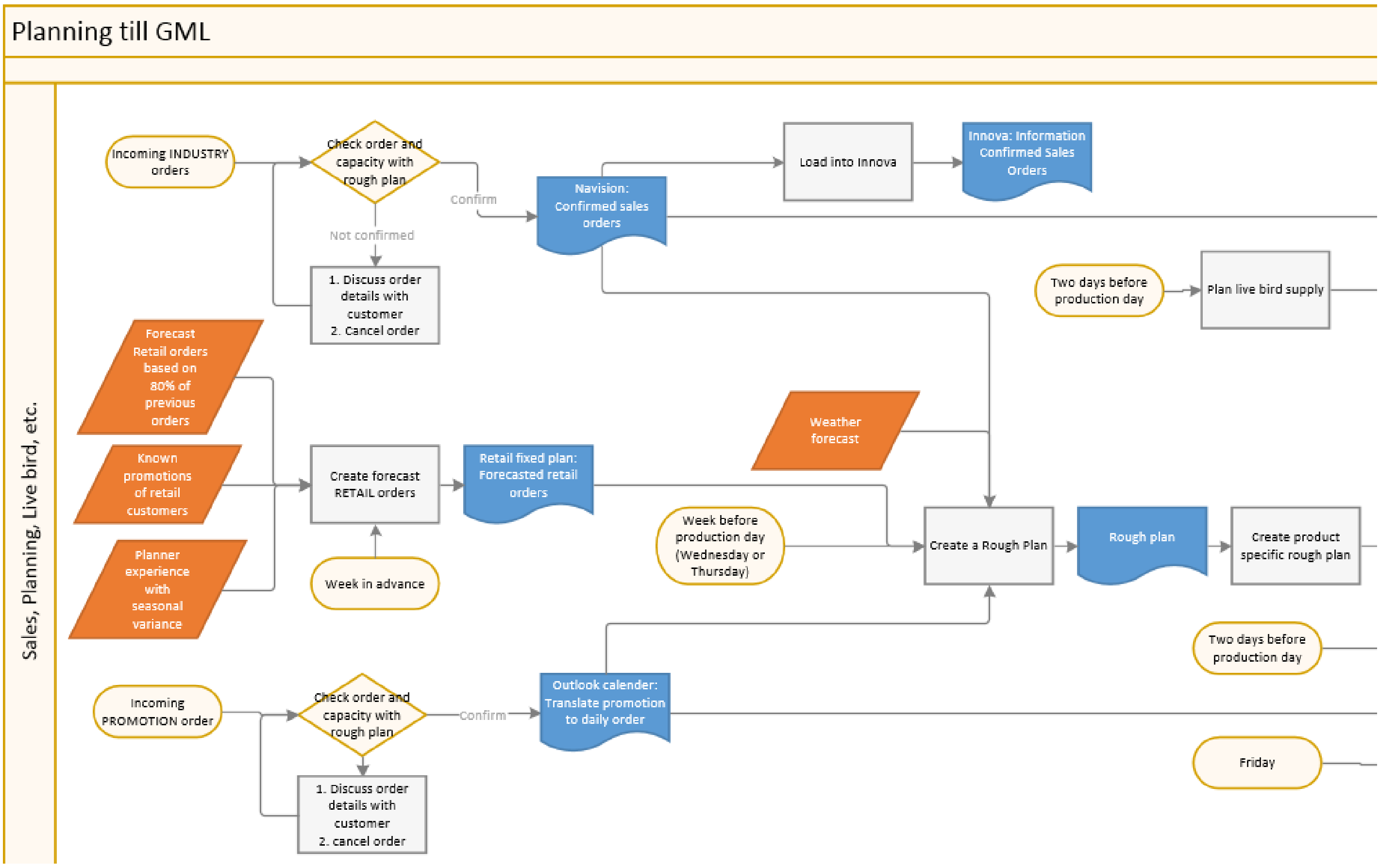


Figure 2.6a flow chart of planning activities before the production day, first part.

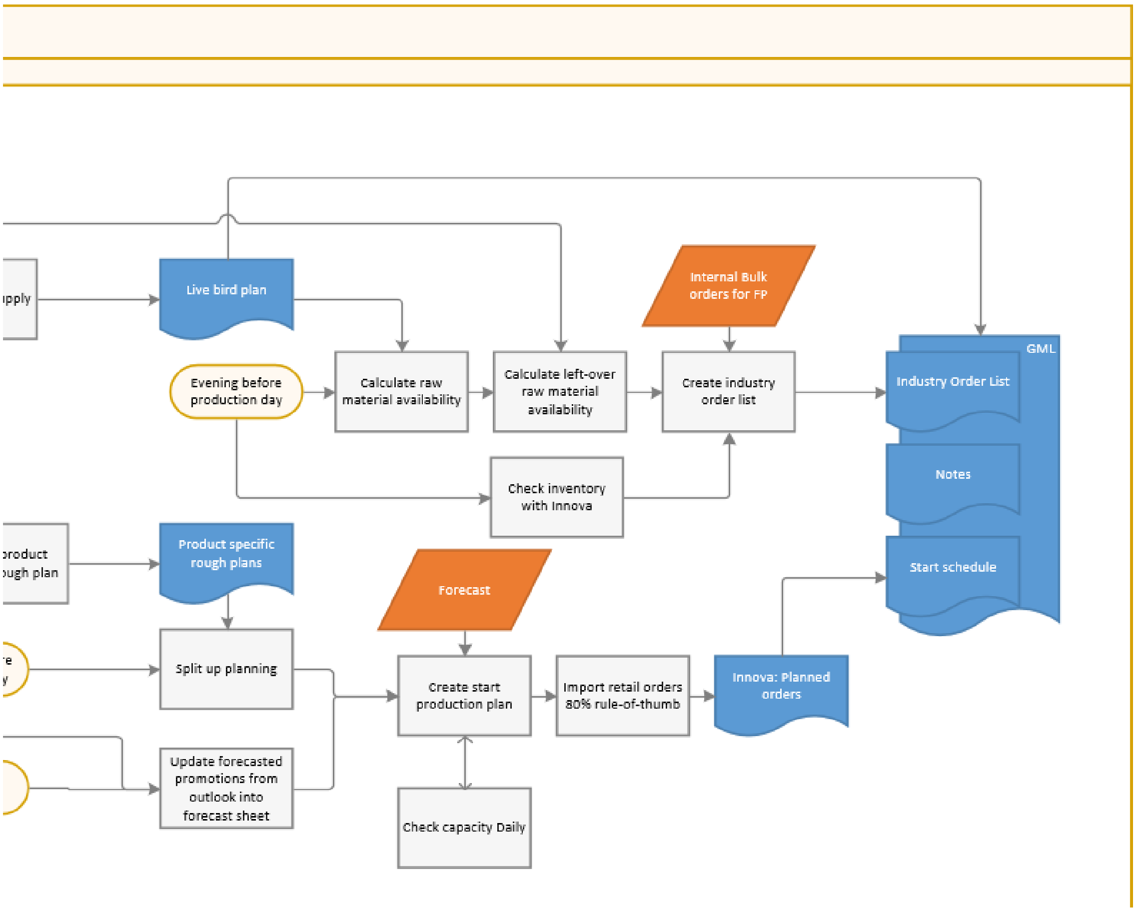


Figure 2.6b flow chart of planning activities before the production day, second part.

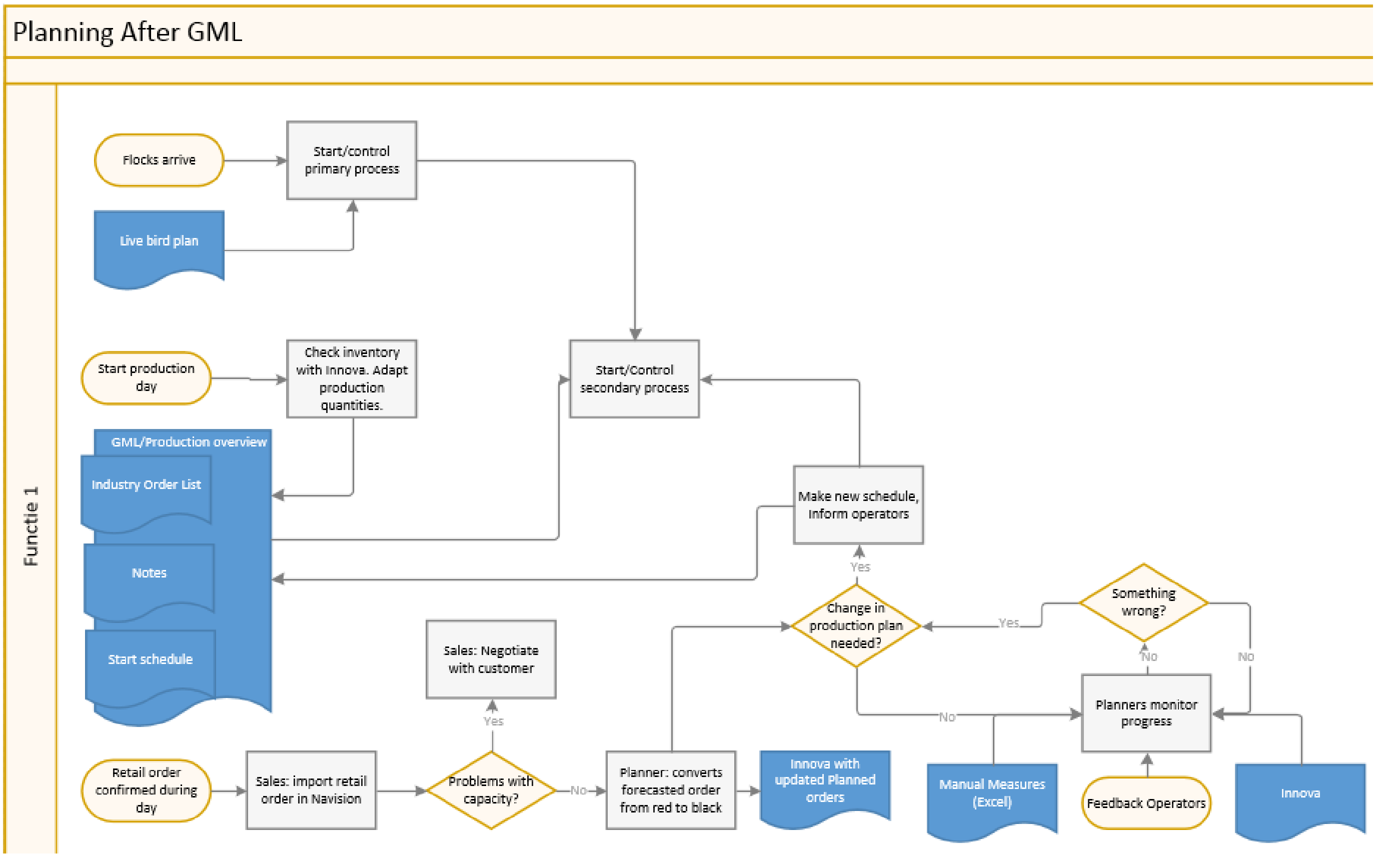


Figure 2.7 flow chart of Planning and Control activities on the production day itself.

Progression of a typical production day

The previous paragraph discusses how the manufacturing system produces on a prognosis. At some point before the production starts, the inventory is checked for left-overs from the previous day. Then, the slaughter lines (primary process) start and two hours later the cut-up lines (secondary process) start. If the production day runs smoothly, the forecasted quantity based on the 80% rule is produced at 16:00. Between 16:00 and 18:00, the retail orders are confirmed. Around 18:00, 85% of the new prognosis is produced and all retail orders are confirmed. From this point, the Planning and Control knows the exact ordered quantities. All the raw material (birds) is slaughtered on the day of arrival. This commonly results in over production.

Products are considered as left-overs for the next day if they cannot be sold by the Sales department. Figure 2.8 illustrates this method of producing on prognosis.

During 19:00 and 23:00, the production day becomes chaotic. The manufacturing system is completely focused on delivering orders on time and with enough quantities, negatively affecting the efficiency and effectiveness of the manufacturing system.

The first trucks departure around 20:00. In Figure 2.9 a timeline is provided to illustrate the progression of a normal production day.

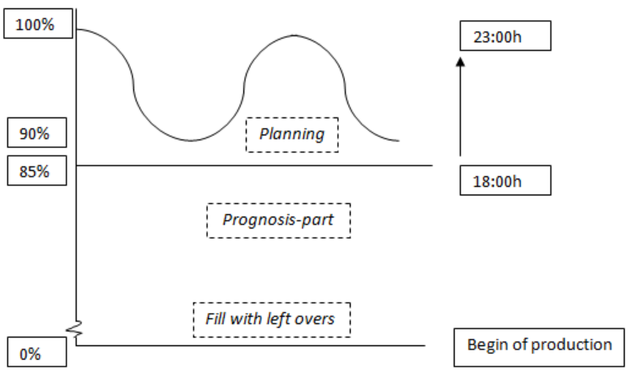
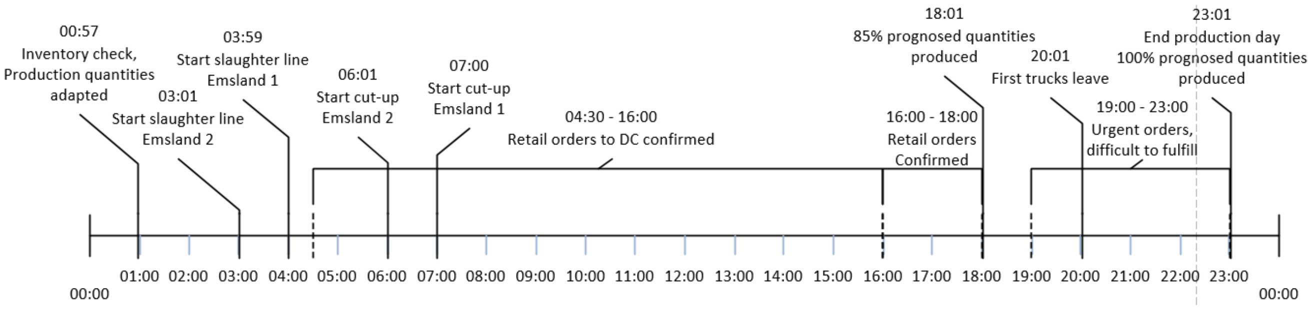


Figure 2.8 Producing on prognosis.

Figure 2.9 time line of a normal day.



3. Theoretical background

This chapter discusses the definition of Lean manufacturing and the theoretical framework that guides the rest of the research (Section 3.1). Furthermore, it introduces the principle called Lean Thinking and how it can be used as a systematic method to eliminate waste and answer the central research questions (Section 3.2). Finally, Section 3.3 discusses an approach on how the research deals with different levels of the manufacturing system (in particular levels in Control and Planning).

3.1 Definition and context

For the first time, in 1988, the principles of Lean manufacturing were united by John Krafcik in his article *Triumph of the Lean production System* (Krafcik, 1988). Lean manufacturing has two main approaches. First, the approach (Lean Thinking) discussed by Krafcik where a continuous flow for the manufacturing system is created by eliminating waste. Waste is per definition activities that do not add any customer value, but utilize resources. To clearly illustrate this concept, an example is given: If a customer has customer values, such as decreasing production costs, deliver on time and make consistent high quality products, it can improve the performance on these values by eliminating non-value adding activities, for instance removing the activity to fix product defects will save up labor and decreases the production costs as a result. In this example the waste is 'fixing product defects', the root cause for this waste could be 'a poorly designed process creates defects', and the added customer value is 'decreased production costs' if the waste is eliminated by solving the root cause.

In Lean Thinking, a set of tools facilitate the identification of process areas, their value streams and waste. The goal is to eliminate the waste by finding the root causes and solving those one by one. By doing this, a continuous flow is created where previous wasted capacity and resources are freed up. Some of the most famous tools are:

1. Single-minute exchange of die (SMED)
2. Value Stream Mapping (VSM)
3. Five S
4. Kanban
5. Total Productive Management (TPM)

The second approach is The Toyota Way, also known as the Toyota Production System (TPS). Instead of eliminating waste, the focus is to improve the work flow (or smoothness). The fundamental difference is not within the goal, but within the approach. In TPS, the waste form *mura* (uneveness) is eliminated while the general Lean Thinking approach is focused on the reduction of waste, no matter the form. TPS states that whenever *mura* is eliminated, the side-effects are the same as in Lean: a steady work flow is created and *muda* waste forms are eliminated, such as inventories, waiting times, overproduction, over processing etc. Meanwhile, Lean tackles these wastes to add value from a customers' perspective.

In this research, the first approach 'Lean Thinking' is used and further discussed in the next section. This is because the focus is to maximize customer value, while TPS is focused on improving the work flow and automation for cost reductions and productivity improvements. Furthermore, the focus of improvement in TPS is humans, while Company X is focused on the technical aspects (e.g., machines) and the perfection of the value creating activities, such as packaging, batching and portioning.

3.2 Lean Thinking context

In association with James P. Womack, Daniel Jones produced a book in 1996 called *Lean Thinking: Banish Waste and Create Wealth in Your Corporation* that discusses a widely acknowledged technique to introduce Lean manufacturing in existing manufacturing systems and is frequently referred to and consulted in this research for its principles, techniques and tools. The term, Lean

Thinking, being coined for the first time in 1988 to capture the elements of Lean manufacturing introduces a method of five systematic steps that captures the way how, where and what waste is created. Figure 3.1 describes the principles of Lean Thinking that are used step by step to introduce Lean manufacturing into a manufacturing system.

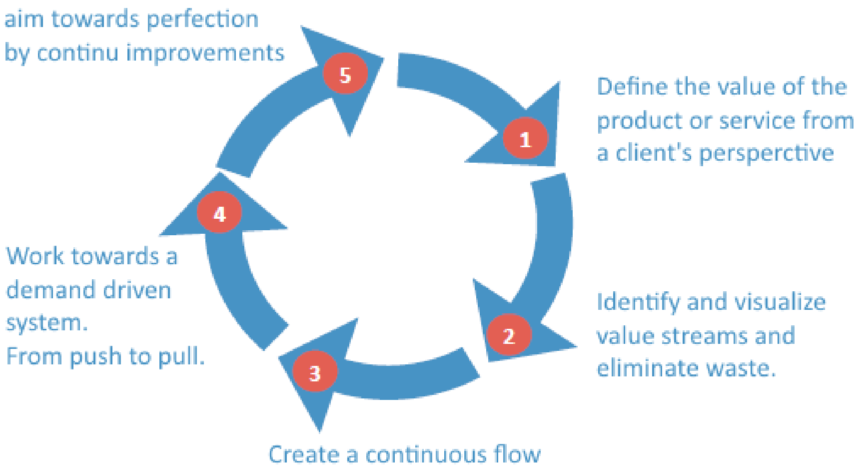


Figure 3.1 The five steps of Lean Thinking.

Traditionally, processes within a manufacturing system are separately monitored, analyzed and then optimized. According to Lean Thinking, this is an inefficient method. Instead, Lean Thinking suggest another approach. To begin with, a manufacturing system is a better system when it has a continuous flow. To understand the meaning of this, the definition of a manufacturing system and what it consists of is discussed first.

A manufacturing system is a method to organize production and consist of processes. According to Womack a process consist of three different types of activities. First, an activity can be necessary and therefore not be eliminated. Think about activities necessary to comply with safety requirements. Second, an activity can add-value and can be optimized (by eliminating waste equal to 2-5% of the total waste). For instance, a sorting process can be optimized by improving the sorting algorithms. Finally, an activity is not adding any value. An example could be the unnecessary movement of inventory for several times as a result of bad communication between the shop floor and planning department. Another example is the creation of left-overs due to bad planning. These activities are the central focus of Lean Thinking since they are good for roughly 65% of the waste that can be eliminated. Figure 3.2 below illustrates these three different types of activities that are present within a process.

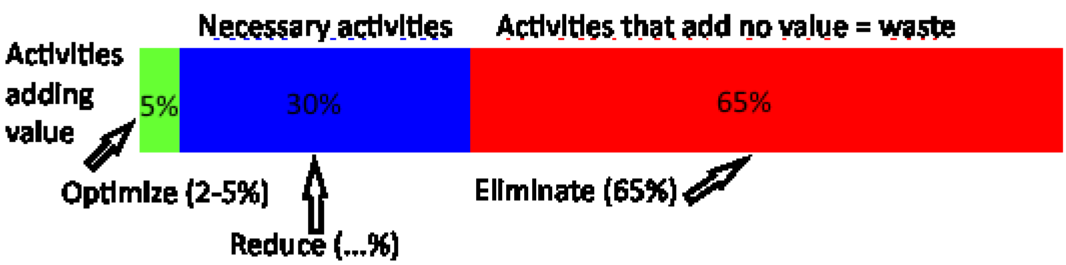


Figure 3.2 Three types of activities. Lean focuses on eliminating waste.

If waste is eliminated in a manufacturing system, it is considered as working towards a continuous flow. To further illustrate how a continuous flow should look like, let's look at the manufacturing system of a potential client. The ideal and perfect manufacturing system for the client would be if the planning for the production day would reflect the actual progression of the production day. Commonly, a lot of adjusting of the planning is needed on the production day and this creates waste. By identifying this waste, finding their root causes and addressing them it would mean that in the ideal future the planning will reflect the exact progression of a production day and is has not to be adjusted anymore. Of course, things like unexpected deviations are to blame for some creation of waste. In our case the client must probably deal with uncertainty in demand that is hard to take into account while planning. If the root causes cannot be solved completely, like demand uncertainty, or if a continuous flow is already almost perfect, then the manufacturing system should work towards a more demand driven system. This is step four of Lean Thinking: aim to go from push towards pull. Examples could be to improve the forecast accuracy, reduce deviations in raw materials, improve the flow of information, avoid the creation of misinformation and so on.

Traditionally, a process or process area will be looked into for bottlenecks or separate aspects of the planning heuristics will be improved. However, it is difficult to analyze the effect of those improvements and therefore it is difficult to prioritize what has to be addressed first. By analyzing what customer value is added through eliminating a waste, it is possible to prioritize waste and create a continuous flow step by step in a much more efficient and effective way.

Chapter 2 discusses how the first two steps are the scope of this research. Furthermore, Womack claims that only one product family should be analyzed at the time. Different product families have different customer values and it is too overwhelming and complex to address everything at once. The product family should be picked based on customer value. To our client this is the fillets products, because this is the most profitable product family with the most demand in the retail industry. Mainly for these reasons the scope of the research is narrowed down to the filleting department that represents this product family.

Next, after concluding how a manufacturing system should address their weaknesses and what an ideal manufacturing system should look like according to Lean Thinking, the first two steps of the systematic approach of Lean Thinking are introduced.

Step 1: Identify customer value

The reason why Lean Thinking starts with identifying the customer value is simple. If the goal is to eliminate waste to create added value from a customer perspective, then the stakeholder(s) must understand what the customer values are. To do so, every activity is questioned on what value it adds to the customer.

There are six principles to specifically bear in mind when identifying customer value:

1. *Deliver **what** I want*
2. *Deliver value **where** I want it*
3. *Deliver value **whenever** I want it*
4. *Reduce the **decisions** that I have to take to solve my problems*
5. *Solve my problem **completely***
6. *Do not waste my **time***

These six principles are closely related to the use of order winners and qualifiers. Here, the competitive strategy of a firm is studied. Operational and strategic goals will emerge from these principles. These can further be categorized with the QDC management approach for customer values that was introduced in Chapter 1 and consist of at least the three categories:

1. Quality

2. Delivery
3. Costs

After identifying how customer value is expressed and can be added throughout the manufacturing system, waste can be identified.

Step 2: Identify and visualize value streams and eliminate waste

A value stream is described as all the activities that are executed to transform input into output. Both the main process goal (cutting, weighting, packaging …) and related activities (waiting, inventory …) are of interest. To identify and eliminate waste, these value streams must be identified. A Value Stream Map (VSM) is a tool to support this. It will:

- Identify the process areas.
- Analyze current performance of process areas.
- Identify the current activities in the process areas.
- Identify the waste in the process areas.
- Analyze the added customer value of eliminating the waste.
- Identify the root cause, provide a solution to solve the root causes and thereby eliminating the waste.

A VSM reflects the current situation and consist of the following (M. Rother & J. Shook, 1999):

1. The Material stream, which displays the flow and transformation of material from input to output. Information can also be considered as information.
    a. Process activities
    b. Transportation activities
    c. Inventories
2. Information stream, which describes the activities that inform people what, when and how they should execute activities.
3. Timeline, displaying the throughput time of a product through a process.
    a. Waiting times
    b. Process times

Below (Figure 3.3), an example of a VSM is provided for illustrative purpose.

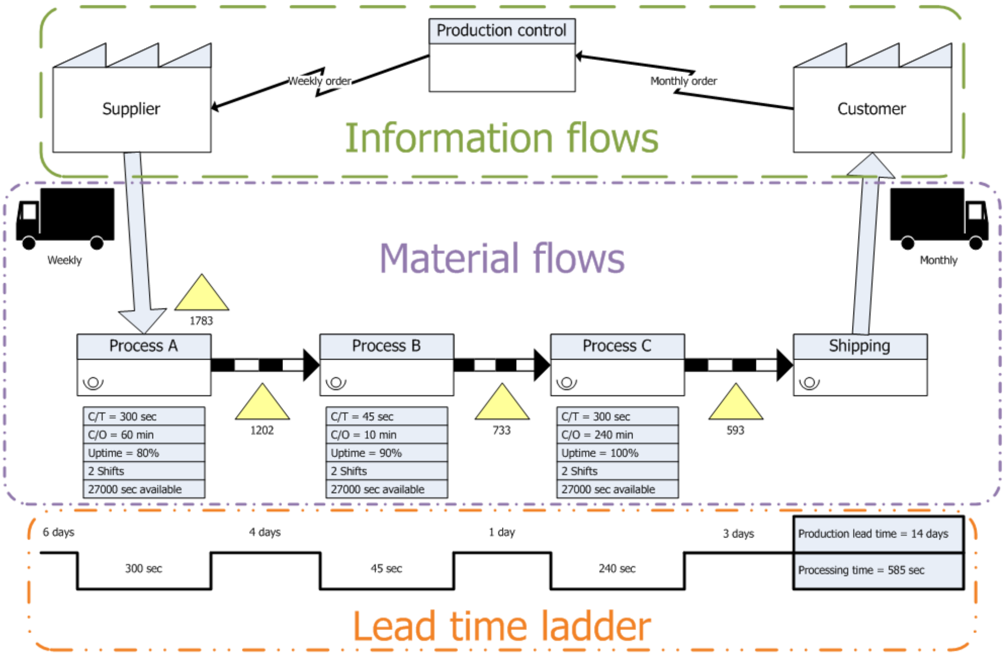


Figure 3.3 An example of a Value Stream Map in the current state (miconLeansigma,2018)

After the VSM is made, the current state is analyzed to identify *muda*. Examples of wastes are problems on the shop floor, unnecessary inventories, machine failure, waiting times, inspection of product defects and poor capacity utilization. *Muda* has seven forms of waste:

1. **Transport** (moving products that are not actually required to perform the processing)
2. **Inventory** (all components, work in process, and finished product not being processed)
3. **Motion** (people or equipment moving or walking more than is required to perform the processing)
4. **Waiting** (waiting for the next production step, interruptions of production during shift change)
5. **Overproduction** (production ahead of demand)
6. **Over Processing** (resulting from poor tool or product design creating activity)
7. **Defects** (the effort involved in inspecting for and fixing defects)

After wastes are identified it is decided what waste must be prioritized to be eliminated and how it can be eliminated. The wastes that add the most customer value to the manufacturing system if they are eliminated are prioritized. Then wastes are analyzed and the root causes are identified. In Lean Thinking the Pareto principle, also known as the 80/20 rule and the law of the vital few, is applied in this problem-solving (Koch, 1999). 80% of the waste in a manufacturing system has their root cause in 20% of the weaknesses. Solving problems at their roots is a major issue and focus in Lean Thinking. For instance, if an operator claims a machine fails because it runs out of machine oil, it is refilled because the operator thinks that this is the problem. However, the root cause of this problem is not the lack of machine oil if the problem keeps happening.

3.3 Planning, scheduling and control

Operational and strategic goals are, at Company X and their clients, described with Key Performance Indicators (KPIs). Furthermore, KPIs are used to evaluate the success of an organization, a process or a group of processes on different levels (Fitz-Gibbon, 1990). The performance on a KPI can only change if a variable changes. Thus the most interest lies in variables that can be 'played' with. For Lean manufacturing, KPIs describe the performance of a process from a customer perspective. In order to understand the processes and to identify waste forms, every process is researched on their KPIs. Also, variables, activities (Planning and Control measures) and events that affect the performance on the KPIs, thus creating waste, are studied to identify waste and their causes.

Company X stated that the most difficult task will be the identification of the customer value and to understand what and how customer value is added in processes. For Company X, the results of step 1 (identifying the client value) has emphasis.

To provide a more structured overview, a production day with its variables and KPIs will be approached on three different levels of aggregation; *Planning, scheduling* and *control.*

At the level of *Planning*, most of the production day will be defined by a rough schedule that is based on forecasts. The live bird plan, cut-up schedule and everything else covered by a so called Good Morning Letter (GML) are based on planning variables, such as the *forecasted retail order quantities* and *expected flock quality*. Thus, planning is based on forecasting the progression of a production day.

In *scheduling*, the planning is executed on the production day and there is reacted on deviations. Examples of deviations could be unexpected failure of machinery or deviations in the expected flock quality and weight. Thus, scheduling will execute the planning and will start adjusting whenever there is an unforeseen deviation in the planning.

At *control*, the given production schedule is executed on a local level. Controlling individual processes (machines) can, for instance, be done by allocating resources like labor and by dynamic routing of products to the right processes.

The three levels of aggregation; planning, scheduling and control can be interpreted as aggregate forecasting, aggregate realization and detail realization, respectively.

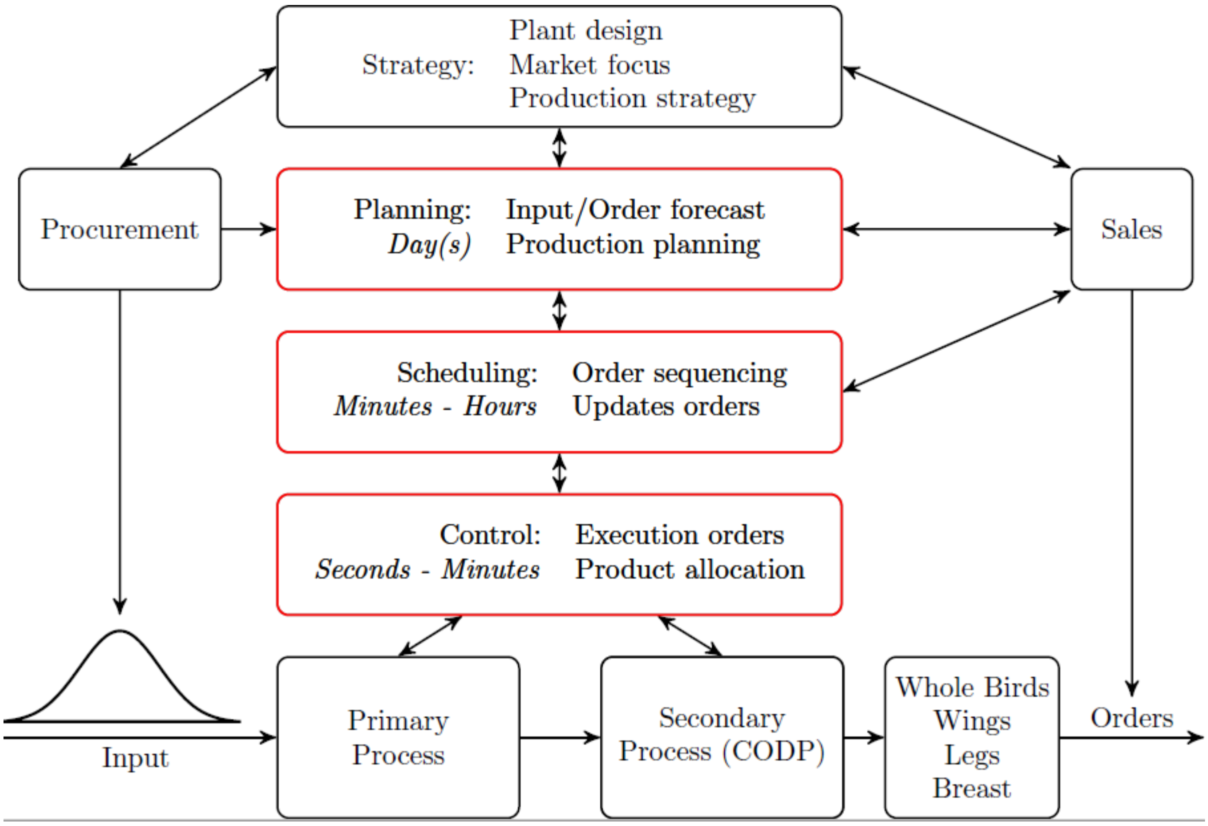


Figure 3.4 Planning, Scheduling and Control levels. Figure received from ir. K. (Kay) Peeters in January 2018, University of Eindhoven.

4. Identify customer value

This chapter discusses the execution of the first step of the Lean principle: identifying the client value. First, the strategic goals (Section 4.1) and operational goals (Section 4.2) are identified by observations, the consultation of experts and the study of literature such as machine manuals and a Quick Scan of the client. Chapter 3 discusses the theory of effectiveness and efficiency KPIs and their relations to operational and strategic goals. Here, this theory is applied to distinct KPIs from each other and categorize them systematically. After the goals are identified, they are sorted according to the QDC management approach.

An important aspect of this step is to identify the KPIs that are used to reflect the performance of the processes or process areas. By doing this, it becomes clear how customer value is and can be added throughout the manufacturing system. In addition to this, a clear overview is gained of how a process (area) can be adjusted with what measures, what KPIs are monitored by Planning and Control, and therefore how waste is created, affected and monitored. In short, the following is done to cover all of this:

1. The KPIs for every individual process (area) are identified.
2. The KPIs that are used by Planning and Control are identified.
3. The measures that are available on Planning, Scheduling and Control level are identified.
4. The expected effects on the KPIs, if the measures are used in different scenarios, are identified.

There is a realization that the effect of a measurement on different KPIs is dependent on the event that could trigger the measure. Therefore, per process (area) several realistic events are used, the measures that could be triggered by these event are listed and their effect on KPIs are studied. The results are put in tables.

This first step of Lean Thinking is very important and emphasized in the research because it facilitates the execution of step 2 enormous. How customer value is monitored, added and influenced in the manufacturing system is the basis to identify waste and their root causes, understand the added value of solving the causes and evaluating the effects of the Lean improvements (solutions). On the other hand, Company X has only a limited understanding of these topics. They express interests in a comprehensive overview that could support future research.

Currently, Company X is focusing on optimizing every process while still plenty of waste can be eliminated. For instance, the scan accuracy of an IRIS quality scanner is optimized to detect as may defects as possible to prevent any poor quality products passing the process. However, more waste is created due to the rejection of fillets that could not be scanned for several reasons (e.g., wrongly positioned fillets, fillets that were too long or fillets that were too close to each other to be scanned correctly). The activity of providing a better infeed quality (rate at which input pieces are fed correctly to the process) is probably poorly designed or executed. This may cause waste in forms of 'over processing' if the process is wrongly designed or 'defects' since all the fillets are inspected for defects and fixed if necessary. Instead on eliminating defects, Company X is focusing on inspecting and fixing defects better. This identification of customer values is important to support the decision the decisions what wastes should be eliminated and in order to get rid of the traditional but inefficient method of optimizing processes by optimizing activities that add value.

4.1 Strategic goals

The long term competitive strategy of a company can be described with competitive variables that can be split up into order winners and qualifiers (Hill, 2000). A company can participate in a market segment when they meet the competitive standards, known as the order qualifiers. In addition, the company must be able to differentiate themselves from other competitors with order winners. For the studied client, their competitive strategy mainly consisted of producing high-volumes and also providing high deliver reliability. The manufacturing plant is one of the few that is partnered with Lidl and Aldi, due to their order winners: high reliability of delivering on time with consistent product quality and extreme big volumes.

For the retail industry, a qualifier is to be able to deliver on time most of the times. Supermarkets for example follow a strict schedule with short time-frames at which orders must be unloaded. The truck with poultry products from the plant is not the only truck with ordered products that must be unloaded. A commonly strict schedule has slots of 15 minutes where only small delays of several minutes are allowed, if longer the order can be rejected by the customer.

In the study of the Planning and Control department and their activities during a production day made it very clear that delivering an order on time and completely (deliver all ordered quantities) is very important. Several KPIs are used by the planning department to monitor the progression of a day, including the progression of order completeness that is expressed in several forms.

Order fulfillment

If an order is distributed, the produced quantities may not comply with the actual ordered quantities. According to one of the notes that were taken during an earlier dated plant visit and discussion with one of the head planners (2015) there is a threshold for this KPI that sits on 90%. The progression of the orders is followed with the Innova information support system. If an order is shipped, the order fulfillment is calculated.

Order Punctuality

This KPI indicates how much orders are delivered on time. In fact, there is monitored how much orders are 'shipped' on time, since the departure time of trucks is used to calculate this KPI. **Shipment time** and the **driving time to customer** could be used as extra KPIs to facilitate the monitoring of order punctuality. According to employees of Company X, punctuality should be considered as a restriction, instead of a KPI. It is so important, that orders should be delivered on time no matter the costs. Nevertheless, the client claims to score 99.5% on punctuality (Tummers, 2015).

Throughout the first visit at the plant, several control measures that were used throughout the day to increase punctuality were observed. One example was located at the packaging department. Here, trays will enter the packaging system and are sealed with plastic. However, some trays are stored after being sealed while others are directly labeled and stored on pallets of specific customer. By doing this, the packaging department creates flexibility that is needed in the late production hours since trays of specific weight and with specific products can complete several different orders. The unlabeled but already sealed trays are labeled for the urgent orders.

Another flexibility measure that is created during the day is located within the fillet lines. Whenever an order is expected to be not completed on time, the planning department will try to adjust the shop floor. They will communicate the urgent orders with operators on the shop floor. On control level, the operators can decide to prioritize specific orders. For instance, portion cutters and batchers can produce for several orders at the same time. If an order becomes urgent, the operators can change the processes so that more input pieces (e.g., incoming fillets) are processed for one of the orders. On a higher level, the Planning can control the streams of products. They can increase the feed of products to specific lines or processes with urgent orders.

During the visits of the plant, only the adjusting of the shop floor on scheduling and control level was observed with the goal to increase order punctuality. From conversations with employees of Company X and observing the shop floor it indicated that schedulers (sometimes called planners) are adjusting whenever orders were expected to not be completed on time or fully. They seem to be 'satisfied' fairly quickly whenever these two KPIs are performing well enough, even when there is space for significant improvements on other KPIs.

Order reliability

The last form of order completeness is reliability. This KPI is a combination of both fulfillment and punctuality. If an order is delivered on time and completely, it is considered as successful.

Order completeness for delayed & quantity adjusted orders (proposed)

Some KPIs are expected to be encountered in the manufacturing system, but did not come forward during the research. Maybe they are non-existent or not used. Therefore, some KPIs are proposed in this section and provided with an argumentation why they should be looked into. One of them is discussed here.

When a retail order comes in at the Sales department, they are communicated with Planning. The first activity of Planning is to perform a capacity check. If the order cannot be completed on time or if there is a lack of raw materials, the first measure of Planning is to inform Sales to negotiate the order details. Commonly, the order quantities are decreased or the delivery deadline is changed. This is also a measure that is commonly used whenever an already confirmed retail order becomes urgent.

The fact that this measure is used without considering any other possible measures (e.g., the negotiation of more flexible industry or DC retail orders) is a very unpleasant sight for the customer value. If this measure is used, it is not monitored if negotiated orders are indeed delivered on time and/or completely.

The retail industry is dominated by some manufacturers and their customers have a lot of power. If Sales has to negotiate the order details it is unpleasant for the customer. But if the order is both negotiated and still delivered to late or incompletely, the retail plant might lose their client. Therefore, the orders that are already negotiated should receive more priority over normal retail orders.

Product quality

For the client, product quality is important. Their customers judge the quality of their ordered products on different aspects:

- *Freshness*
  The expiration date that is labeled on the product package represents the product's freshness. The temperatures of processing areas are consistently monitored. Every area has a different temperature, to ensure the quality and freshness of the products.
  Every bird is processed on the same day of arrival and left-overs and bulk inventory for FP are either cooled or frozen (at the cost of other aspects of product quality such as taste and color).

- *Taste*
  The taste of the meat must comply with the demanded quality and should be consistent.

- *Tenderness*
  Similar to taste, the tenderness of the meat is highly dependent on the performance of the maturation and electronic stimulation process, and the bird's quality.

- *Esthetic of packaging and products*
  The quality of the product esthetic consists of several components. The packaging and their labeling should be of quality, without defects (e.g., from transportation). The position of products within the packaging is representable to the consumer. The product color and shape are consistent and as expected.

- *Hygiene*
  The hygiene of products is important for safety. A customer will only buy their products from a plant with certificates that assures product quality, especially hygiene-wise.

These KPIs are measured with quality checks. Most checks are done by sample testing, such as color testing with color cards, hygiene tests by checking the activity of Micro-organism and pull & press tenderness tests. Throughout the production process, several processes and tasks ensure or improve the product quality.

Avoidance of bad publicity

No retail client is willing to co-operate with a firm that has a negative reputation. Especially in the meat industry that is very sensitive to bad publicity, this must be avoided. While it cannot be measured with a KPI, a good reputation is certainly an order qualifier. Both players, the manufacturing plant and its customers, can take each other down if one's reputation is assaulted.

Profit

While most strategic goals are identified by order winners and qualifiers, another option is to take the perspective of the client. The client is a private firm and a private firm's goal is to make profit and therefore profit must be KPI for the client. This can be expressed in many forms; profit accounting, financial accounting, cost accounting, Lean accounting ... (Vanderbeck, 2008; Maskell, 2013; Goldratt, 1990). In the research no KPIs were encountered in the manufacturing system related to monitoring profit making. The KPI has no direct impact on the customer value of the firm.

The client probably follows the traditional cost accounting method or another method that is based on mass production thinking. Lean accounting, on the other hand, breaks the rules of traditionally thinking. As a result, such traditional methods are usually actively hostile to Lean changes (Maskell, 2012). Instead of directly expressing profit in (normally) time or money, Lean accounting uses the same approach of Lean manufacturing by expressing profit with value streams. Traditionally, decisions related to things such as make/buy, investments, introduction of new products or pricing are based on cost information. Often, the wrong decisions are made. In Lean however, decisions are made to eliminate or reduce waste and free up capacity within the manufacturing system which automatically impact the company's finance.

The client should consider **Lean accounting** if Lean manufacturing is introduced to the manufacturing system. For now, the company should try to introduce KPIs that can be used to support decision making in the manufacturing system. For instance, a profit KPI might support the planning department by indicating the profitability of an order and decide what orders should be prioritized over others.

4.2 Operational goals

The client has a significant amount of operational goals and related KPIs. While operational goals are important, they should not be prioritized over strategic goals. To illustrate this, some examples:

- An operational goal is maximizing capacity utilization. At the shop floor, one fillet line can be turned off and another line's capacity can be utilized better. However, the total capacity is lower and now an order is not expected to be completed on time. While order completeness is a strategic goal, therefore this should not be allowed to happen.
- A planner decides to accept a retail order anyway after it barely came through the capacity check. Now the order is expected to not be completed on time, but it will prevent any expected left-overs from before.

Yield

The first and most important operational goal is minimizing yield loss. Around 65-75% of all costs are the buy-in of raw materials, while roughly 10% is labor and the operational costs are responsible for the rest. For this reason is yield so important to the client. In several dashboards, both the terms 'yield' and 'raw material utilization' were used to describe the same.

The percentage yield is the total amount of supplied raw material minus the amount lost throughout the production process. The performance on the KPI is dependent on specific events, most of which are also considered KPIs;

- *Loss of raw material due human error.*
- *Dead Upon Arrival (DOAs).*
- *Quality issues (sickness, poor quality).*
- *Loss of raw material in automated processes (e.g., loss of meat in the portioning of products).*
- *Natural loss of raw material (e.g., the loss of moisture in the chilling process).*

Through Innova a component is provided to monitor yield values per process and the total yield. A process can have a so called Yield Point that monitors the following:

- *Day in*, describes the current production day input weight.
- *Day throughput*, which refers to the current production day throughput.
- *Day yield*, is the current production day yield.
- *Running throughput*, known as the running throughput for the current process period.
- *Running yield*, which is the Running yield for the current process period.
- *Lot Out*, is the Current lot output weight.
- *PO in*, refers to Current purchase order input weight.

Giveaway

Giveaway is also a yield KPI, however it is somewhat special since it is only used in the batching processes. Here, giveaway is the main KPI. It describes the difference in weight between the target weight of a pack (end product) and its actual weight is known as the giveaway.

Scraping yield

At a scraping yield station (which is a fairly new process area), it is possible to show and monitor the total weight or average yield from the configured Yield Points per product. Based on the product type, a scraping minimum and maximum yield is set and used to compare the performance of the scraping yield station. A higher scraping yield will somewhat reflect the performance on yield in the main process. Less scraping yield can be related to less yield loss in the preceding main process. Because of this interesting relation between overall yield and scraping yield, it felt important to address even while the scraping process is out of our scope.

Throughput

The throughput is the amount of processed kg or pieces per time unit. The throughput can either reflect the speed at which an amount of input pieces is processed or the same speed at which output products are processed. Striving for a higher throughput is important to increase the order completeness, but it also reflects how well the process is adjusted to the incoming raw material.

The throughput is closely related to the KPIs **infeed speed** (kg/h or pcs/min that enters the process) and the **reject rate** (rate at which input pieces are rejected). Some reasons for rejecting input pieces are:

- The input piece was positioned incorrectly and could not be processed (e.g., scanned). This is described as the **infeed quality.**
- The process was too busy and could not process the input piece.
- The input piece did not meet the requirements of the program (e.g., the piece being too heavy).

Capacity utilization

Optimizing the allocation of resources is important, especially labor-wise, since there is limited available. The utilization of labor can be interpreted in different ways:

- How well labor is assigned to the processes where it is needed. With the right scheduling, labor can be saved in different ways. Also, there is a maximum amount of labor available. Thus, a goal could be to utilize as much of the available labor as possible.
- How well the assigned labor is utilized. Thus, the rate at which employees are busy when they are assigned to a process. This indicates how well the throughput fits the capacity of the assigned labor, and vice versa.
- How well labor is assigned, based on employee's characteristics. For instance, the throughput of employees differs per process. Assigning the right employees to the right processes will optimize the production and resource utilization.

The number of employees that are assigned to processes is constantly monitored and tried to be kept to a minimum. In addition, the utilization of every employee's capacity is adjusted by operators on the shop floor.

A process has a maximum capacity. Utilizing the available capacity efficiently will reduce certain costs, like operational costs. For instance, if two packing stations are processing at medium capacity, one packing station might be able to process both capacities together on its own.

Furthermore, planning the right infeed speed for processes will enhance the throughput and finally the order completeness. Scattering, for instance, input pieces between fillet lines to utilize their capacity efficiently might result in better throughput. For fillet lines, however, it is also important to feed input pieces from a not too-wide weight and size distribution to improve the accuracy of processes. The capacity utilization can also be affected by the **speed of lines**. If a line is running fast, the products lead times are lower. However, a higher line speed negatively affects the capacity utilization, yield and reject rate. Thus, trying to utilize more of the available capacity is commonly a trade-off with other KPIs.

Both maximizing capacity machine and labor-wise are very important to the client, but this comes with trade-offs (commonly throughput or yield are affected). The capacity of the filleting department was frequently addressed as one of the bottlenecks and therefore making the capacity and resource utilization very important to the client.

Availability

The availability of a process describes the state at which a process is in, whether it is planned to be operational or not functional due failure time. The states will be discussed later on.

In general, activities such as maintenance, calibration or failure of preceding processes affect the availability of processes.

The *Availability* of a process can be described with several different KPIs:

- *Operation time* is the time the process is available for use.
- *Unscheduled time* is the time a process is available for use, but not utilized (e.g., overcapacity)
- *Manufacturing time* (also known as Loading time/Planned production time) is the time you want to use the line.
- *Not scheduled time* is the time a process is not planned to be used (e.g., maintenance).
- *Line restraint time* is when a line is functional but cannot produce at full capacity due a limited or no input, or the output rate is restricted.
- *Idle time* is when the line is fully functional, but is waiting for an event (configuration changes, quality issues, lack of operators).

- *Failure time* is the time when a process is not functional and cannot be (used).
- *Production time* (running time) is the time the process is producing something.

The processes within the primary process (from living birds to 'panklaar' broilers) are monitored with an Overall Equipment Effectiveness (OEE) tool. This tool evaluates how effectively a process is utilized. At the plant, the OEE currently consist of only three components:

1. *Quality of process* refers to the number of manufactured products vs. the number of products that can be used.
2. *Performance of the process* reflecting the actual speed (pds/min) vs. the capacity of the machine is used.
3. *Availability of the process*

OEE and its KPIs are frequently used in conjunction with Lean manufacturing. If OEE is implemented within a manufacturing system, it significantly facilitates the investigation for root causes of wastes. Also, the identification of waste is easier and OEE pulls separate processes together with a single metric. And finally, OEE facilitates the reporting and validation of the success and impact of Lean improvements.

Currently, OEE is slowly introduced in the secondary process making it (even more) interesting and obvious to introduce Lean manufacturing to the system. The secondary process uses a set of different tools, Innova dashboards and a so called LED Panel to evaluate the quality, performance and availability of processes.

Flock weight and quality

Especially the weight distribution of flocks is important to the client. The primary process has one line, but the secondary process has one heavy and one light line. Every processing line has its weight range, who somewhat overlap. A bird with a weight that fits within both these ranges may be processed by both lines. A bird that is too light for the heavy line will be processed by the light line and vice versa. The Planning will try to aim for an average of 2600 gram broilers so the capacity of both lines can be utilized properly.

A wider weight distribution of flocks will affect the process in different ways. Capacity utilization, give-away, throughput, yield and many more factors are affected by the wideness of the weight distribution. These relations are further discussed in Appendix E.

The flock quality is both important to the client and farmer. The expected quality is one of the KPIs considered in planning flocks. If the quality is worse than expected (A lot of DOAs, birds with bruises or anatomical defects, etc.) it affects the manufacturing process. Less raw material is available than expected that might cause problems down the line. The farmer is held accountable for the poor quality, but the client has to deal with the consequences. The same goes for significant deviations in the actual weight and flock count from the expected values.

Utilization of piece quality (proposed)

This is not a KPI that is currently measured, but could be implemented support decision making in Planning and Control. One of the issues on the fillet department that was observed during the second visit to the plant and previously addressed by an employee from Company X was the lack of products of specific quality at the end of the day. Some orders with specific quality requirements were difficult to fulfill. If an input piece of a certain quality is processed for an order with the same quality, the piece's quality is considered as utilized efficiently.

The KPI could be a good indicator that can alert planners of potential problems at the end of the production day. A comparable KPI could be designed that provides indicates on how much input pieces of certain qualities are still expected and how many are required to fulfill all the orders.

After asking more questions about the issue it proved that the breed type of flocks (e.g., Beter Leven or BIO) was also considered as 'quality' and related to the discussed issue.

Inventory costs (proposed)

Inventory costs were not encountered as a KPI used in the manufacturing system. In the financial chapter of a QuickScan of the client, the plant manager claims that 99% of their products are stored at a maximum of seven hours (Tummers, 2015). Throughout the night roughly 70 ton of products are stored. Throughout production there are also temporary inventories and buffers created. All of this results in production costs that are not monitored.

Operating expenses (proposed)

Activities in Sales, Planning and Control and other parts of the manufacturing system are good for significant costs in any firm (Goldratt, 2004). It is important to make this measurable in order to value, optimize, reduce or eliminate activities.

Process stability (proposed)

The atmosphere on the shop floor is important. A chaotic shop floor may have negative consequences for the capacity and accuracy of employees. Chaos can also result in the creation of misinformation and poor adjusting of processes. In Lean, measures are proposed to monitor the atmosphere on a shop floor. For instance, a KPI could monitor the frequency on which a process is adjusted with new information and the rate at which this information was misinformation or incorrectly used.

Safety (proposed)

For the plant, safety is important. While the processes are designed with clearly high safety standards, it is not measured with KPIs. Examples of KPIs for safety could be:

- Near misses ('almost' accidents, recorded on shop floor by employees)
- Accidents
- Emergency stops

4.3 Customer value with QDC

The goal of categorizing the operational and strategic goals with Quality, Delivery and Costs is to provide a structured non-overwhelming overview of the customer value. For instance, the throughput of a process is important to evaluate how well the current capacity of the process is utilized but it is also related to order completeness. Therefore, it can fit in both Costs and Delivery.

A second reason for using the QDC approach is to facilitate the prioritization of customer value. The sequence of Quality, Delivery and Costs represents the order at which customer value should be prioritized according to Lean Thinking. If 'Safety' is a clear customer value it would come up-front in the sequence (resulting in SQDC) where it is prioritized over all other types of customer value. Important to understand is that the types of customer values are in balance with each other. If Delivery is prioritized and customer value is added within this category, it will most certainly also add customer value on Costs. Take for instance the maximization of availability that will also increase order completeness. On the other hand, if one customer value is excessively focused it will negatively affect other customer values. Order completeness could easily be 100% if the plant would use enormous inventories and safety buffers, but this will negatively affect Costs and Quality to an unrealistic scale.

Per category (Quality, delivery and costs) the main customer values are identified. Some of the operational and strategic goals are directly affecting each other. For instance, the strategic goal is to make profit while most of this goal is covered by the operational goal to minimize costs.

In Table 4.1 below an overview of the main customer values of the whole manufacturing system is given.

Quality	**Delivery**	**Costs**
Product quality - Freshness - Taste - Tenderness - Esthetics - Hygiene	Max. order completeness - Order fulfillment - Order punctuality - Order reliability	Max. yield[1]
		Max. capacity utilization
		Max. availability
		(Min. inventory costs)
		(Min. operating expenses)

Table 4.1 QDC table with main customer values.

1. Max. Yield refers to the utilization of raw material. Any loss of weight is considered a loss of raw material. In most processes, both value is added and lost. A loss in material, thus lower yield, might be caused by a poor cut accuracy, quality defects, machine failure, human failure, etc.

Next, an overview is provided of all KPIs that are monitored and located within a process (area). Mutual relations between KPIs are also provided. Below the table of portioning (Table 4.2) is listed. In Appendix B the tables for the other processes are provided. Footnotes located within the tables are discusses below the tables and give additional important information on KPIs. Some of the Innova dashboards that are used to monitor processes with KPIs and are used as one of the sources to make the tables are listed in Appendix G.

Portioning		
Quality	**Delivery**	**Costs**
<u>Product quality</u> *Freshness* 1. Throughput[1] a. Reject rate b. Infeed speed *Esthetics*	<u>Order completeness</u> 1. Throughput a. Reject rate b. Utilization of pieces quality c. Infeed speed	<u>Yield[5]</u> 1. Cut accuracy a. Scan accuracy 2. Weight accuracy[3] 3. Reject rate[4] a. Infeed speed b. Infeed quality

1. Cut accuracy[2] a. Scan accuracy 2. Weight accuracy[3]		
		<u>Capacity utilization</u>[6] 1. Throughput
		<u>Availability</u>[5]

Table 4.2 QDC table with customer values and KPIs in portioning

1. A higher reject rate will result in lower throughput. It also takes time to fix rejected products.

2. If the cut accuracy is bad, the portion cutter will make bad cuts. The portion cutter will make even worse cuts if the scan accuracy is bad, since the cuts are off point.

3. If the weight accuracy is inaccurate, the piece is cut with an error. The piece can get an undesired under- or overweight. In overall, this increases the deviations of weight between the final products. Meat is also lost, if case of an under- or overweight.

4. Rejected input pieces at the portion cutter can either be redirected to the portion cutter, but are commonly processed for industry orders. Since the client cannot use this product for retail orders, it is considered as yield loss.

5. The overall yield and availability is monitored with yield points for almost every process by Planning and Control.

6. Capacity utilization is monitored with dashboards by Planning and Control. Throughput is used to calculate the capacity utilization.

In every process (area) of the filleting department there are numbers of KPIs used to monitor the process and support decision making. They are all related to the discussed customer values in their own way. Also it is discussed how these KPIs have mutual relations. If these relations are clarified and quantified as good as possible then it supports the identification of waste, analyzing of root causes and understanding of the added customer value when a waste is eliminated. For this reason, every process is further analyzed by answering the following questions:

1. What KPIs are used to support decision making on Planning, Scheduling and Control level?
2. What measures are taken on Planning, Scheduling and Control level to adjust the KPIs?
3. What are the qualitative relations between these KPIs?
4. What are the qualitative effects of these measures on KPIs?

To answer the first two questions, schemes are made for every process (area). These schemes reflect the KPIs with their mutual relations. It also shows the measures on planning, scheduling and control that can be taken to influence the performance on these KPIs and thus affecting customer value.

The following scheme (Figure 4.1) is from the process ‘portioning’:

Portioning

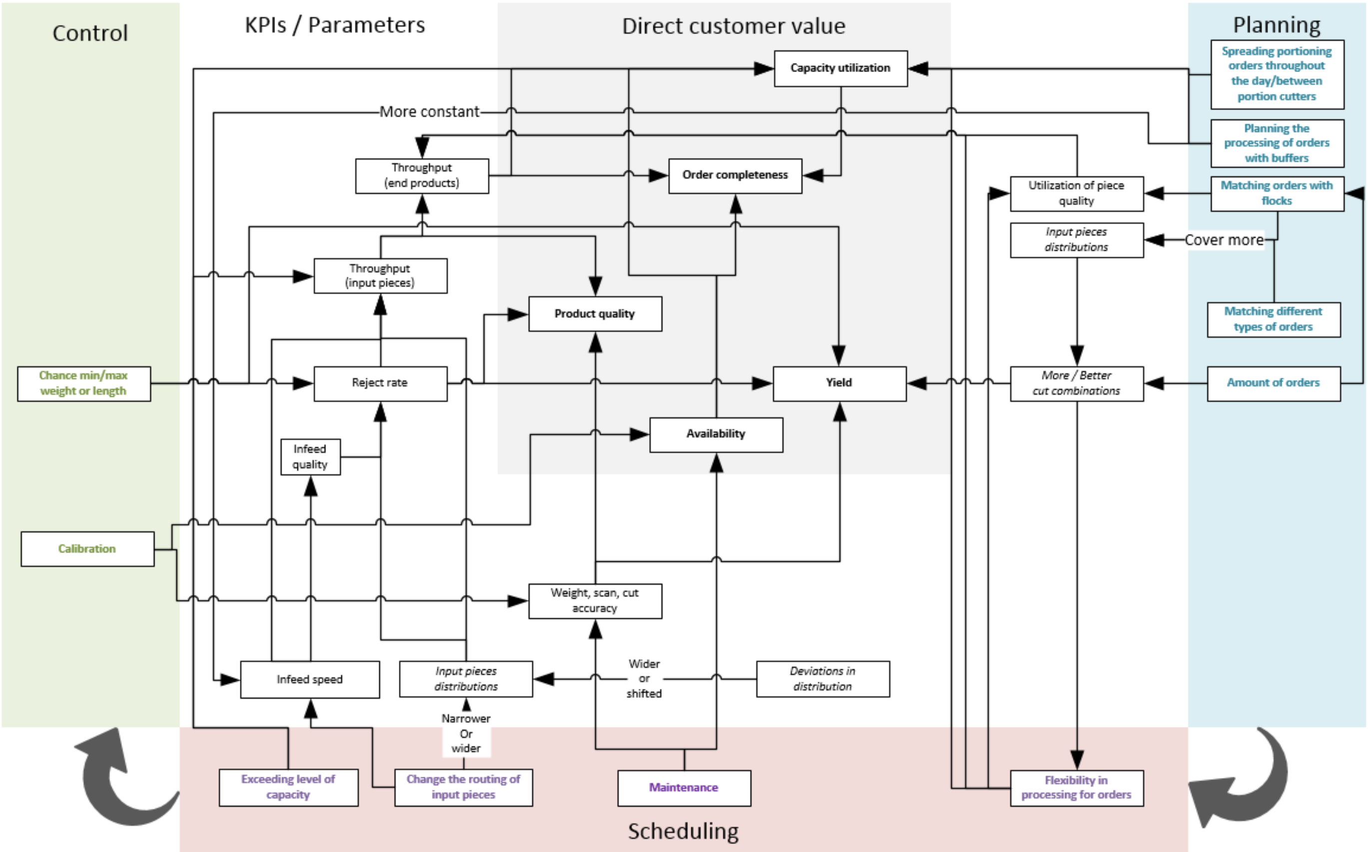


Figure 4.1 Scheme with relations between KPIs, events, customer value and measurements.

In the blue rectangle on the right, the measures that are taken on planning level (before the production day started) are listed. The scheduling measures are listed at the bottom, these are the measures that the planners (who monitor and adjust the production) will consult to adjust the fillet line on a low level of detail. The control measures are listed in the left green rectangle. These are the measures that can be taken by operators to specifically adjust within the process. KPIs that directly reflect customer value or affect other KPIs are located in the white area. Some variables that affect KPIs are also presented in the white area but have an *Italic* font. The main customer values are presented in the gray area with a **bolt** font. This scheme and the schemes of other processes are presented in Appendix C in full-size. Relevant relations are graphically displayed by the QDC tables in Appendix B and further clarified in Appendix E.

The next step is to value these relations. For every process, the most important KPIs are taken. Some of those KPIs are directly reflecting the added customer value (e.g., order completeness and yield) and some indirectly (e.g., reject rate). Some KPIs are added to show that they are important to the process but not monitored, such as ‘process stability’. Providing different kind of KPIs per process felt necessary to get a clear overview of what KPIs are in particular important to what processes.

Every table has several events that trigger the possible measures and that reflect the effect on KPIs. An event, for instance ‘order is expected to not be completed’, will trigger a set of possible measures on different levels that might solve the event. The tables are represented this way because Company X asked for a clear table overview of measures, KPIs and cause-effect relations that an operator or planner could use to support their understanding of the consequences of their decision.

Again, the process portioning is taken as example. Below two tables are located: one with the measures (Table 4.2) and the second one with the events, KPIs, numbers of the measures that are taken and their effect on the KPIs (Table 4.3). If the table is used by an operator or planner he will take the following steps:

1. An event triggers the planner or operator to make a decision.
2. The operator will find this event (if listed) in the second table.
3. The operator will find the possible measures that can be taken to solve the event in the second table.
4. The operator can see the effects on KPIs if the measure is taken. This goes from negative to positive: ---, --, -, +, ++, +++. Some effects are valued with -/+, this is when the effect is somewhat more complex and strongly affected by the current situation. Appendix E clarifies these effects and relations.
5. The measure is identified by its number with the second column of table one.
6. Appendix E can be consulted to understand the cause-effect relations and the values.

The tables for the other processes are found in Appendix D.

<u>**All measures on control level**</u>	**Measure Nr.**
Chance min/max weight or length: (a) Increase max., (b) lower min.	1
Calibration	2

Table 4.2 Measures for portioning on control level (first table).

Measure Nr.	**Order completeness**	**Yield**	**Giveaway**	**Product quality**	**Reject rate**	**Throughput**	**Availability**	**Weight, scan, cut accuracy**
Order is expected to not be completed on time								
1a, 1b	++	--	+		--	++		
Threshold of yield/giveaway is passed								
2		++	-	+			---	++

Table 4.3 Events and available measures for portioning on control level and their effect on KPIs (second table).

4.4 Chapter conclusion

In this chapter the customer values are identified and categorized with the SQD management approach. Next, every process is analyzed for its KPIs and their mutual relations. Furthermore, the processes are analyzed on how they can be adjusted by measures on different levels (planning, scheduling and control) and their effect on customer values and KPIs. The results are presented in schemes and tables for every process (area). Additional information is provided in Appendixes.

<u>It is now clear how customer value is and can be expressed throughout the manufacturing system on different levels</u>. The results also facilitate the execution of step 2 of Lean Thinking: identifying value streams, waste and their root causes. This chapter is consulted to quantify the added customer value that is created if a waste is eliminated.

It is remarkable how several KPIs look important in monitoring the production or support Planning and Control in their decision making but are not measured by the client. Some examples are KPIs to reflect inventory costs and profit. Also, Planning and Control is barely trying to improve the progression of a production by adjusting it whenever it is satisfied with the performance on order fulfillment and punctuality. Lastly, the additional information below the tables of Appendix B provided interesting insights of KPI relations within and between processes.

5. Identify and visualize value streams and eliminate waste

This chapter has five sections. First, Section 5.1 introduces the Value Stream Map of the current state. Next, wastes are identified for every process area in Section 5.2. From these wastes, the most important ones are prioritized. Their root causes are identified and recommendations are made on how to address these root causes. This is covered in Section 5.3. At last, Section 5.4 discusses other aspects and practices of Lean Thinking that are considered important to the manufacturing system.

5.1 Value Stream Map

Before value streams are identified and visualised with a value stream map, the process areas are defined. In Lean Thinking a process area is not a cluster of related practices that share the same goals that are considered important for making improvement in the area. This definition of process area is not used in Lean Thinking can be interpreted very broad when it is applied on a manufacturing system. For instance, the whole fillet line is sharing the same goals, but waste is hardly identifiable if this process area is not split into pieces. Therefore a special designed method to identify process areas was introducted to by P. Womack. First, try to identify between which processes clear intermediate products are located. Second, identify between which processes a significant new level of skill is required.

In Chapter 1 and 3 the scope of the research discusses how and why it is narrowed down to one product family: fillets. This limits the scope to the fillet department. However, the preceding process *bird supply*, *primary process* and *secondary process until fillet lines* are also visualized in the VSM to make it more comprehensive and understandable. The same matters for *packaging* and *shipping* that are somewhat out of the scope due to the time limit.

In addition to the process areas stated above, the following areas are identified (see gray areas in Figure 5.1): the **Breast cap cutter & placer,** where the broiler is cut by a breast cap cutter module and fed to the fillet lines with the help of an employee. Next there is the **Filleting system & manual harvesting,** where the breast cap enters the filleting system to be deskinned and to receive cuts and which is then harvested for fillets (or sometimes whole breasts). Then, the breast caps enter the **Tenderloin system & manual harvesting** where the harvested tenderloins are also batched in trays and weighted (excluded from Figure 5.1 since it is comparable to Filleting system & manual harvesting). The trays with tenderloins are transported to the packaging department while the fillets enter the process area of **Trimming & deboning.** Here, all the fillets are trimmed and scanned on quality. After that, fillets can either go to **batching** to be batched into trays, crates or sacks, or they are transported to **Portionning** to be portionned into other products like schitzels and medaillons. Portionned products are batched after being portionned.

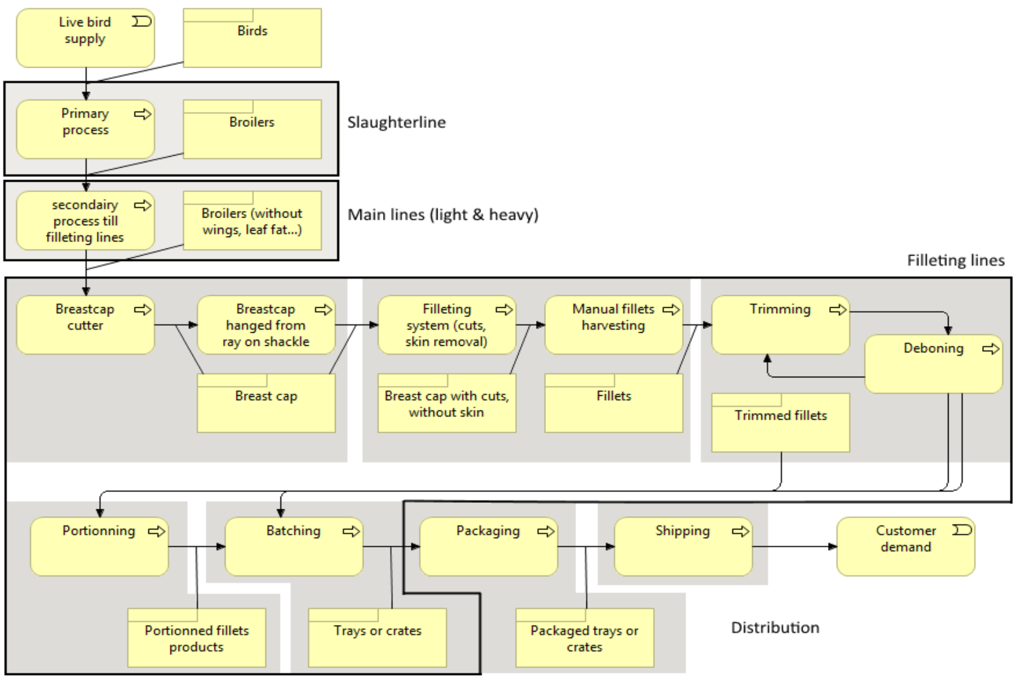


Figure 5.1 process structure fillet department. Gray areas are the identifieid process areas.

The value stream map (VSM) consist of information flows, material flows and a lead time ladder (Rother & Shook, 1999). See Chapter 3 for more information on VSM. The information flow is created with the help of the flowcharts from Planning and Control (Section 2.2) and the material flow is created with the process structures (Section 2.1).

In creating the VSM, some important decisions are made. First of all, the lead time ladder is not considered very important, since the production speed of the lines are variable. Thus, the lead time is dependent on the speed of the lines. In addition to this, the lead times for products in the fillet lines are also dependent on the allocated capacity (including available labor) and capacity utilization. The sequence of activities within the process areas are worked out and timed. In example, how long it takes for an employee to move a crate with rejected products from the end of a process to the beginning, and how long it takes to make the pieces re-enter the system. If forms of muda are observed, they are valued. For instance, if on a frequent basis unnecessary inventory is observed, then the average storage time of a product is recorded and estimated. Also, mudas like motion and transport are valued with, in example, time or distance.

Another important decision is made to consider the retail customer as the only customer for the manufacturing system and thereby excluding the industry customers. In Chapter 2, the focus on retail customers is discussed. The manufacturing system is adjusted on Scheduling and Control level with the goal to prioritize the satisfacation of retail customers. Industry orders are fulfilled with products that could not or were not able to be processed for retail orders, for instance the products with poor quality and by-products. Rejected products are commonly processed for industry orders. For some processes the reject rate has a threshold. Therefore the reject rate could be considered as some form of yield loss, since most of the rejected products were supposed to be processed for retail orders but are now fulfilling industry orders. Industry orders are simply the side-effect of retail orders. Nonetheless, the manufacturing system tries to perform as well as possible on industry orders too.

Figure 5.2 on the next page visualizes the basis of the Value Stream Map for the current situation.

Due the limited available information the VSM covers the **Cycle time (C/T)** that is interpreted as the lead time of a product, **Yield loss**, **Capacity utilization (C/U), Uptime, Waiting time (WT)** and **defects** for the process areas that are studied. In the future, other information can be collected for process areas to identify their current performance. Examples are change over times, set up times, scheduled changes, corrent information (% of the job instructions being accurate/corret and how many times there is asked for clarification), Inventory, etc.

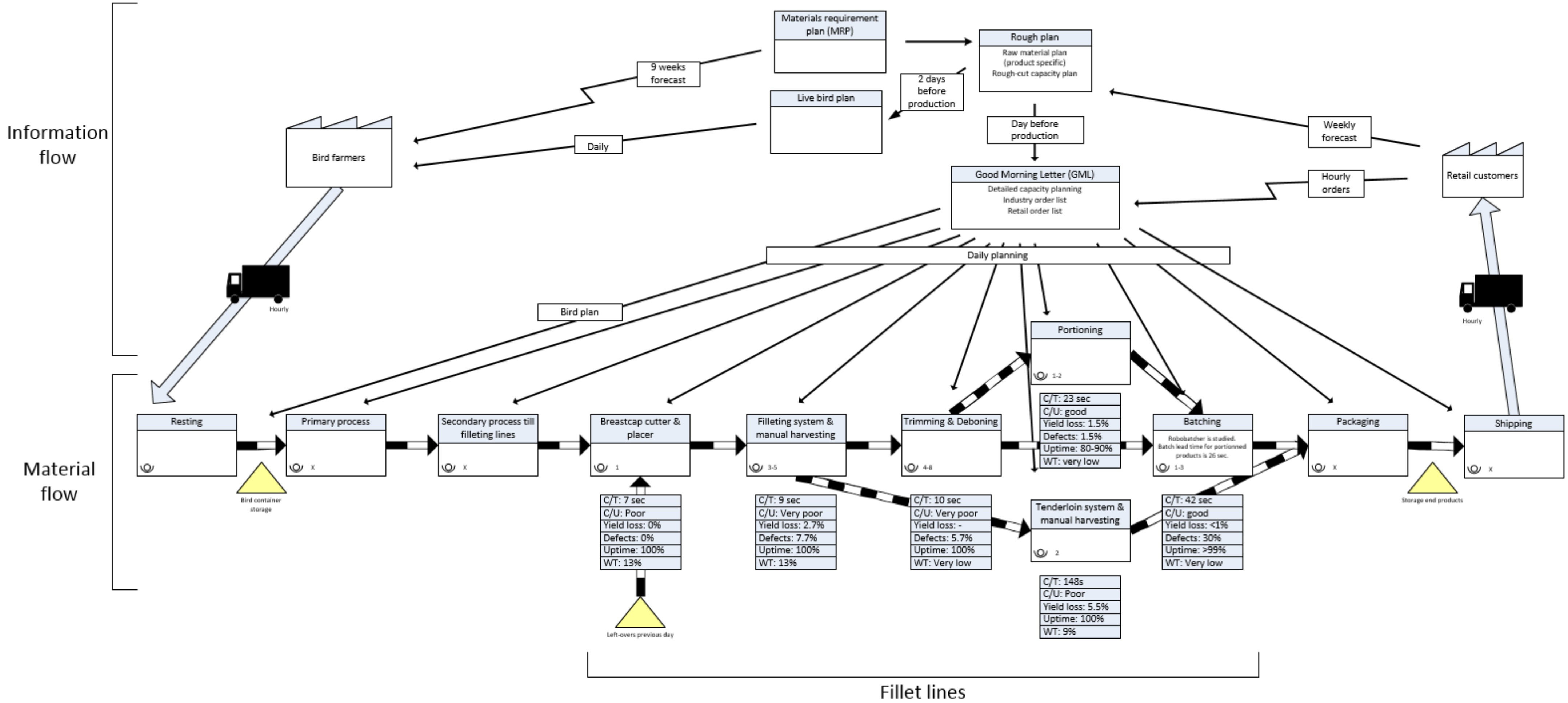


Figure 5.2 Value Stream Map current waste. Process areas of Fillet department were studied.

5.2 Identifying waste

There are several tools to identify waste in a system. No matter what tool is used, the most valuable methodology to identify waste is considered making observations (Hines, 1997). With the pre-knowledge of potential problems and waste, what the customer values are, how it is expressed throughout the fillet lines and a considered understanding of the overall manufacturing system supports this process of identifying wastes. The clients' plant is visited for two full days to observe the shop floor and watch what is happening and questioning why things happen. All the process areas of the fillet lines are analyzed according to the basic steps of Process Activity Mapping (Hines, 1997):

1. First, a preliminary analysis of the process is undertaken, where every regular process step is listed.
2. Throughout the time, problems are observed and forms of waste were identified.
3. A tally is kept of how many times these problems or forms of waste occur.
4. If possible, the waste is valued. In example by recording the time taken, distance moved, people involved, capacity utilized…
5. lastly, every waste is questionned on what expected customer value is added by eliminating it.

By eliminating a certain waste it will add certain customer values, depending on the kind of waste. For instance, the elimination of a **transport** waste will commonly decrease the lead time of products by some seconds. This add customer value in forms of **order completeness** and **product quality** (freshness)**.**

The result is two tables for each process area: one with the general process steps that describes the flow of a product, and another table with the identified and analyzed wastes. In addition, a layout of every process area was made with every process step numbered within the layout. A waste is also located at and related to some process step(s). These numbers are provided in the table to illustrate the location of process steps and wastes.

In the first tables the column *Flow* describes the type of process step: Transport (T), Operation (O), Delay (D), Storage (S) or Inspection (I).

In the second tables the column *Added customer value if eliminated* is the added customer value that is expected to be added when the waste is eliminated.

The tables (Table 5.1-5.2) and figures (Figure 5.3) of one process areas, trimming & deboning, is fully provided. The results for this and the other process areas are found in Appendix H.

Trimming & deboning

#	Step	Flow	Process	People	Lead time	Recorded Max. capacity & C/U[1]	Comments
1	Transport from fillet harvesting to trimming line	T			12 sec		
2	Trimming line distributes ALL products between trimming stations	T	Trimming line		2 sec		
3	Employee trims fillets	O	Trimming line	6-8	2.5 sec	21 fillets/min p.p. 55% C/U on average. Between 6 to 8 employees were assigned to each line throughout the day. Infeed speed was 77 fillets/min on average per line.	The dashboards were both checked for 12 times throughout the day. Actual speed and max capacity was recorded.
4	Employee places trimmed file on ray and disposes waste in gap.	T	Trimming line		0.5 sec		
5	Fillet transports to scanner on ray	T			3 sec		
6	Fillet is scanned	O	Trimming line		2 sec		

Table 5.1 Activities list for process area Trimming & Deboning.

1. C/U stands for Capacity Utilization.

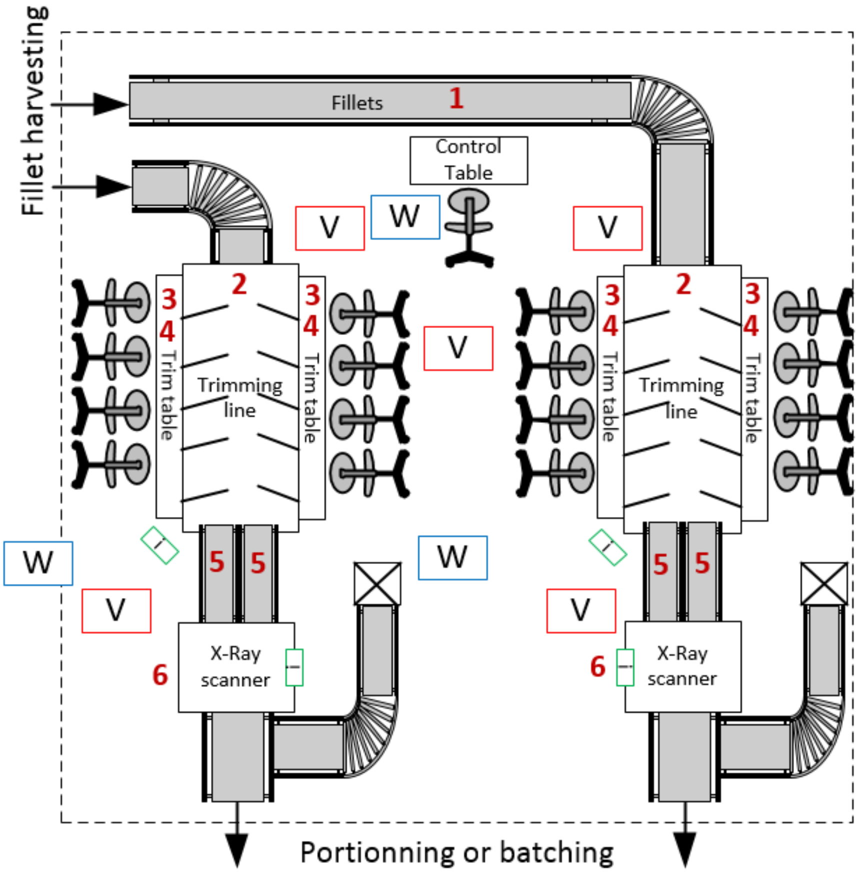


Figure 5.3 Plant layout with process area: Trimming & deboning.

Waste description	TRANSPORT	INVENTORY	MOTION	WAITING	OVERPROD.	OVERPROC.	DEFECTS	Location of waste	Comments	Added customer value if eliminated
Employee throws input pieces that cannot be processed as fillets in blue crate.			■				■	3	3 times 4 employees were observed for 15 minutes. Per person, they rejected 9 input pieces on average. In nearly all cases, these defects were whole carcasses originated from the FHF lines. This is **roughly 5.7%** of all input pieces. Aside from carcasses, tenderloins and legs were found in the trimming line with most fillets coming from the FHF line.	Significantly better C/U. 5,7% of the capacity is not wasted anymore to such defects.
Employee has to trim rejected fillets from X-Ray scanner which are temporary stored in a crate.				■			■	3	On the X-ray scanners, the 'Zufuhr qualität' (infeed quality) and 'Knackenfrei' (crack free) is monitored. The infeed quality is monitored for both 'Vorne' (top) and 'Hinter' (back). If a piece is rejected, it is transported to a crate. The employee will then trim the piece. The reject rate is recorded throughout the day for 11 times. The average for both machines throughout the day: Knackenfrei: 97,4% Zufuhr qualität Vorne: 99,7% Zufuhr qualität hinter: 99,8% Zufuhr qualität together: 99.5% Remarkable was how the trimming line that had most of the input pieces from FHF, scored significantly lower (96.5%) than the other trimming line that was mostly connected to AMF lines (98.3%).	Shorter lead time for 0.5% of the trimmed fillets. Slightly better order completeness.
Trimming line operator is walking around to check settings, communicate order progression and watch other processes.			■					-	-	-
Trimming employees have poor capacity utilization.				■				**3**	**55% C/U of the fillet lines. A lot of employees are not needed. Only in the later afternoon, the capacity was 79% at highest.**	**Extremely better C/U for a labor-intensive process.**

Small buffers at employees		■						3	Small buffers reduce the throughput of fillets. They occur if employees take a break or are distracted by something else.	Slightly shorter lead times for some products.
Blue/red crates are manually emptied, while they are (by far) full.			■					-	In 32 minutes, blue crates were emptied 3 times. Red crates 1 times.	Better C/U.
Fillets are always inspected, but do not always have to be trimmed.						■		-	If not all the fillets have to be trimmed, then fillets that have to be trimmed can be considered as 'defects'. Some products are inspected, which are not trimmed. This is a waste of time. However, in 8 minutes only 8% of the inspected fillets did not need a trim.	Better C/U.

Table 5.2 List of wastes for process area Trimming & Deboning.

5.3 Prioritizing and eliminating waste

Significant wastes that would add customer value in the Quality category were not observed. However, six wastes add significant customer value in the other categories Delivery and Costs if they would be eliminated. They are listed below and provided with the reasoning why they should be prioritized. These wastes can be found back in the tables in Appendix H, in addition of the previous tables and figures. The 4th waste is within the process area of Trimming & Deboning and received a **bolt** font in Figure 5.2.

1. Frequent and long waiting times for fillet harvesters.
   At this process area, for 13% of the operating time employees are idle (waiting) and the capacity utilization is extremely poor (lowest of 35%). If it is eliminated both the operating time and capacity utilization (which is a customer value) will increase.
2. Use of buffers by the tenderloin harvesters.
   At almost any time, tenderloin harvesters would build up inventory/buffers that increases the lead time of tenderloins by nearly 4 minutes. If this is eliminated, order completeness can significantly increase. In addition, the tenderloin harvester's capacity is lowered by the time involved in waiting and using the buffers.
3. Over processing as a result of unnecessary inspection for weight defects of trays.
   A fair amount of products are inspected on defects at the wrong places. Employees are located at the wrong places doing the wrong tasks, resulting in poor capacity utilization. Eliminating this waste will spare on employee, reducing costs. Also, products are touched less and the throughput is increased by several seconds.
4. Extremely poor capacity utilization of the trimming lines.
   The capacity utilization of the trimming lines is 50% while it is easy to monitor. Eliminating the waste can increase the capacity significantly.
5. The motion and inventory wasted to fix defects from the robobatcher (batching machine).
   30% of the fillets at the batching machine are rejected for not locating a matching tray. The order completeness can significantly be increased if the reject is decreased. Also, it reduces the activities involved in fixing the defects, for instance when they are again fed to the batching machine later on the day.
6. The waste of motion and activities to empty red and blue crates.
   This waste was not particular significant, but it caused a general chaotic environment on the shop floor. Employees are wasting a lot of time to search for the right crates to dispose their products in and the crates are emptied inefficiently.

The root causes of these six wastes are identified and the research provides solutions on how to possibly address the root causes.

1. Frequent and long waiting times for fillet harvesters

The extremely poor capacity utilization of 35% and 38% of the fillet harvesters that was recorded in the morning and afternoon increased but remained poor during the rest of the day. The estimated capacity of the filleting harvesting process, which is almost always operated by 5 employees, is 66 breast caps per minute. While the fillet line ran between 59 to 68 breast caps, the actual utilization of these lines was also poor. Fillet harvesters are almost never fed a number of breast caps per minute that reaches close to their capacity, with the exception of some periods in the late evenings.

One cause that can explain the poor capacity utilization is the very inconsistent infeed speed of breast caps to the process. One of the preceding process steps is placing the breast caps from the ray on breast cap holders. This employee is frequently waiting for breast caps. In 34 minutes a total of 7 times was waited for long periods equal to 13% of the operation time. In these waiting times, no breast caps are mounted on the breast cap holders. As a result, both fillet harvesters and tenderloin harvesters have to wait too. Taking steps back to further preceding processes, the same problem of waiting times was observed. After finally arriving at the hanging process located after the stunning process the root cause is identified. Here, several empty shackles of the primary lines are left empty to indicate that a new flock is hanged on the line while the capacity utilization of hangers is consistently high for the rest of the time. The empty shackles seemed to be the main cause of the problem. Also, from observing the overhanging process it became clear that heavy big broilers have a significant lower lead time than light small broilers in the process. This affects the equal weight distribution of the broilers on the lines. This can become significant when the broilers are distributed over the two lines. There are small gaps in the distribution, altering between the light and heavy line. Currently, Company X is working on a tracking system that will eliminate the need to use empty shackles to distinct flocks from each other. However, the small gaps in the distribution are still to be expected when the hangers follow this practice. They should try to alter between heavy and light flocks when hanging them on shackles. Providing a more consistent flow for the filleting process will significantly affect the whole process on capacity utilization. The change-over times of mounting and emptying containers on the primary process was not significantly impactful, since the hangers are almost always still processing the previous bird load onto the shackles while the new bird load is already arriving.

The poor capacity utilization can also be explained by the poor capacity utilization and high speed of the fillet lines. As discussed before, the lines have a C/U between 35% to 97% with an average of 70%. The speed of the line is important to the harvesting process. A relation was observed between the speed of the line and the rate of fixing defects. Fillets are torn apart very frequently when the employee fails to quickly harvest the fillets. 5% of the fillets are incorrectly harvested, then trimmed and processed as poor quality fillets or disposed in red crates. This rate can be decreased by reducing the speed of the fillet lines. If the line speed is decreased to the actual infeed speed of the filleting system, the harvesters have more time to correctly pull of fillets. In Chapter 4, the positive effect of decreasing the speed of the fillet line on the deskinning process and the accuracy of cuts made by the filleting system are also discussed. This all reduces the length and amount of activities performed by fillet harvesters to fix defects, thereby increasing the capacity of every employee. Even when the capacity utilization is extremely low on average, 4 or 5 harvesters are required to deal with extreme peaks of the infeed speed (and thus capacity utilization). By reducing the line to its average, employees can be assigned to other processes. However, this only ships the problem from the harvesters to the breast cap placer who has now to deal with the same peaks in the infeed speed with a slow running line. He will need to create and use temporary buffers, but it does provide a stable flow down the line.

The excessive capacity can be utilized in another way. They can be temporarily allocated to other processes or they can perform other small tasks (re-arrange or empty blue and red crates, transporting raw materials from the warehouse, utilizing the inventory in front of the lines, cLeaning the filleting system, cLeaning the process area…). However, it seems that there is consistently too much capacity allocated to the harvesting and tenderloin process. This is probably the cause of poor capacity planning. At the moment, one problem in capacity planning is the difficult task to estimate how much capacity is needed. Planning and Control uses Innova and Excel to create a rough capacity plan and creates the work schedules with it. They do this 7 days in advance, while they make a more detailed capacity planning 2 days in advance. According to one of the shop floor employees, the work schedules never change throughout the week. Therefore, it is suspected that the capacity planning is only used to plan the speed and capacity of machines and not used to reschedule employees.

At the plant, almost 40% of the employees on the work floor are a fixed group of employees. 60% of the employees are temporary hired and outsourced. While the total hired employees is fixed on a day and cannot be changed, it could be a practice to still reschedule employees on different processes and in different shifts.

If this waste is eliminated then:

- A stable infeed speed is created that eliminates long waiting times. For the breast cap placer, fillet harvesters and tenderloin harvesters this is respectively 13%, 13% and 8% of the total operation time. This is good for the **capacity utilization**.
- The speed of the lines is adapted to the current capacity, resulting in fewer defects created by the fillet system, tenderloin system, fillet harvesters and tenderloin harvesters. Less and shorter trimming activities and faster harvesting will slightly increase the capacity of employees. The yield loss can significantly decrease (1-2%) if the fillet system can properly deskin breast caps and harvesters can correctly harvest fillets without tearing them apart. It increases the **order completeness, capacity utilization** and **yield.**
- Better capacity planning and a stable infeed speed make it possible to eliminate the consistent overcapacity of 1 to 2 harvesters. Adapting the required capacity to the throughput of the filleting system (or capacity of the fillet lines) will prevent the excessive capacity at the process. Re-assigning employees to other processes and providing side-tasks for employees will increase the **capacity utilization** even more. Estimated to be roughly 30% better C/U.

2. Use of buffers by the tenderloin harvesters

A significant amount of waste was identified at the tenderloin harvesting. Most importantly, the lead times are relatively high for this ‘continuous’ process. The tenderloins are harvested, trimmed and then batched in trays. If a tray is full it is placed on a temporary paused ray. The ray will start running now and then to transport the trays onto another ray that runs through the other processes.

The tenderloin harvesters were struggling to place the trays on the ray, since it was almost always full. 9 trays fitted on the ray with an average lead time of 1.5 minutes. Roughly every 2 minutes the ray was emptied. The lead time of a tray when it was batched and weighted was nearly 3.5 minutes before it was put on the ray. A pile of trays was always visible on the workbench of tenderloin harvesters. According to what is observed, the ray is put on a cool down after it is emptied, but this cool down is not in line with the throughput of the tenderloin harvesters. This results in the buffers on the workbench. One solution by the employees is to put the trays on another running ray that is in close proximity, but still some 2 more meters away. This results in a waste of motion and time. Another solution that could be designed is a button to start the ray when it is full or a weighting system that determines if the ray is full. However, in Lean Thinking all inventories and buffers should be tried to be eliminated. Redesigning the process should try to exclude the use of buffers. Therefore it is suggested to introduce a simplistic system where a ray is put on a holder and is then directly pushed on an already running ray or something similar to eliminate the waste of inventory.

Frequently, a pile (buffer) of tenderloins was created when the infeed speed was too high for the tenderloins to harvest, batch and weight at the same time. It is expected that the capacity of the tenderloin harvesters combined is too low. It was estimated to be 58 breast caps per minute, while the line is running higher when its capacity utilization is high. Some activities of the tenderloin harvesters seemed unnecessary. First of all, the trays are put on a bench scale to weigh the trays. The weight is fixed and then transported back to the workbench or on the ray. Unnecessary transportation of the tray is a waste of motion. Second, the harvesters follow their intuition to decide whether it is time to weight the tray. If the trays are weighted at the same time they are batched it will prevent from removing a tenderloin from the tray due overweight.

Thus, a redesign of this process by batching directly on bench scales will eliminate the activities of removing tenderloins from the tray and transporting the tray between the workbench and the bench scale (see red areas in Figure 5.9). The harvesters will need at least 1.5 seconds less per tray, since this was the recorded transport time of the tray from the work bench to the bench scale and back.

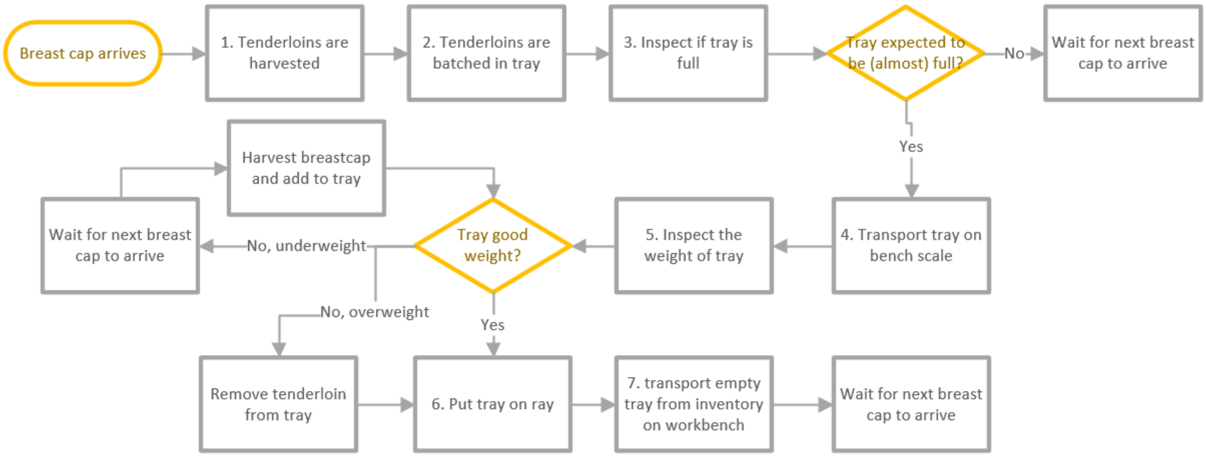


Figure 5.8 Flow chart of current activities for tenderloin harvesters.

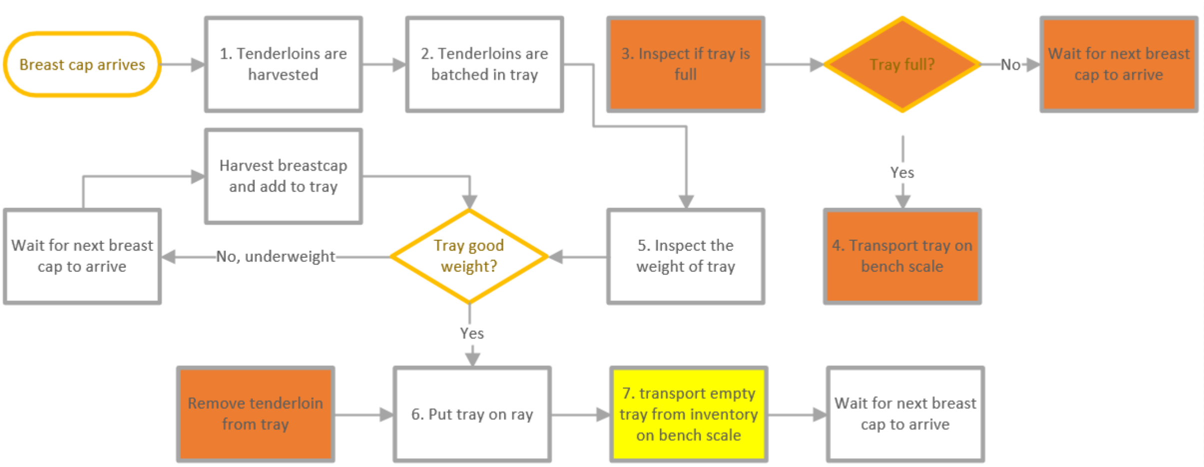


Figure 5.9 Flow chart of proposed redesign of tenderloin harvester's activities. Red marked elements are eliminated. The activity marked with yellow is changed.

If this waste is eliminated then:

- Waiting times are eliminated for trays on the ray. This will decrease the lead time of products for 2 minutes. This is good for the **order completeness.**
- The creation and usage of buffers of trays and tenderloins on the workbench is prevented. This will reduce the lead time of buffered products by nearly 2 minutes by eliminating unnecessary inventory and it will reduce the waste of motion involved. This is good for **order completeness.**
- The capacity of harvesters is increased and the lead time for trays is decreased. This thanks to the elimination of activities related to inspection for and fixing of defects. A rough estimate of the increased capacity of harvesters is 4 breast caps per minute per harvester. This is good for **capacity utilization, order completeness** and **product hygiene.**

3. Unnecessary inspection of the weight of filled trays with tenderloins

Filled trays with tenderloins are inspected for up to three times. First, the tenderloin harvesters roughly weight the tray when it is batched. Then, the tray is can be rejected by the X-ray scanner (22% was rejected throughout the day on average). If the tray is rejected, the quality and positioning of the tenderloins is inspected but also their weight. It re-enters the system, goes through the X-ray scanner and is weighted by the automated scale bench. 36% to 39% is rejected for over- or underweight and fixed by two employees.

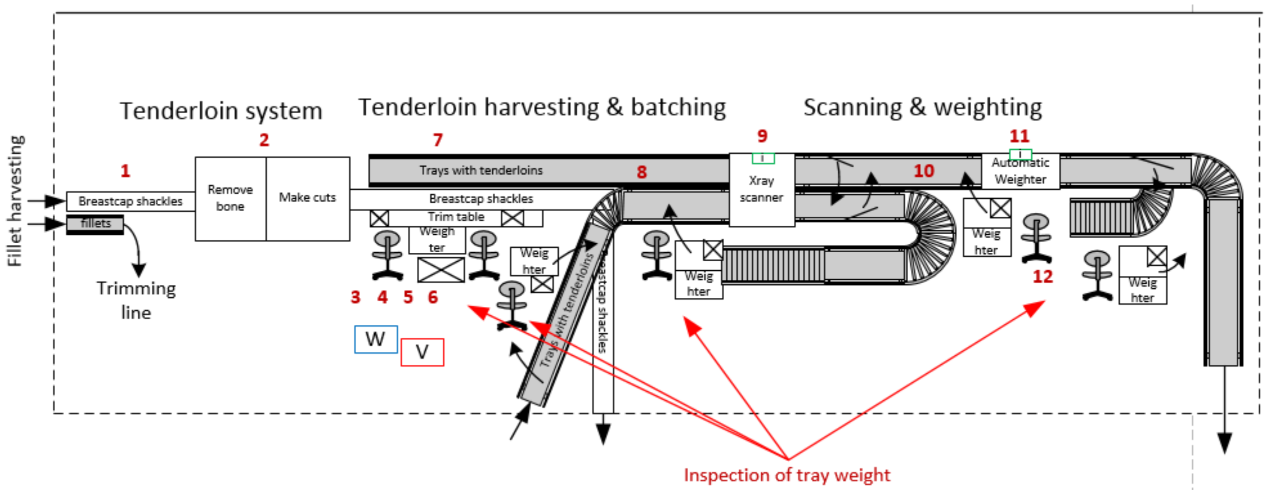


Figure 5.10 Current plant layout of tenderloin harvesting. Four locations for inspecting and fixing weight defects.

The most wasted activity is the employee that weights trays from another ray at the bottom left in Figure 5.10. This employee picks trays from the ray, roughly weights them and puts them back on the same ray. This is simply over processing since the ray is inspected again on its weight at the automatic bench scale. A redesign of the activities involved in inspecting and fixing weight defects is advised. The ideal scenario would be that the tenderloin harvesters accurately weight their trays. This eliminates the whole need to inspect for defects. However, the trays are inspected on quality and their weight might change due this. Therefore it is more ideal if the trays are weighted accurately after their quality is inspected. Thus, the employee on the bottom left should not be there to inspect weight. The employee should be located after the automatic bench scale with the other two employees. The employee that inspects the trays on quality, should only concern about the quality and not the weight.

Even more ideal would be if the quality inspection and weight inspection would be combined into one acitivy. For instance, three different rays can be located after the Xray scanner and automatic bench scale. Here, one ray is for quality defects, one for weight defects and one for both. The system can track the trays and sort them in these rays.

This redesign is graphically presented in Figure 5.11 to illustrate how it might look like if implemented.

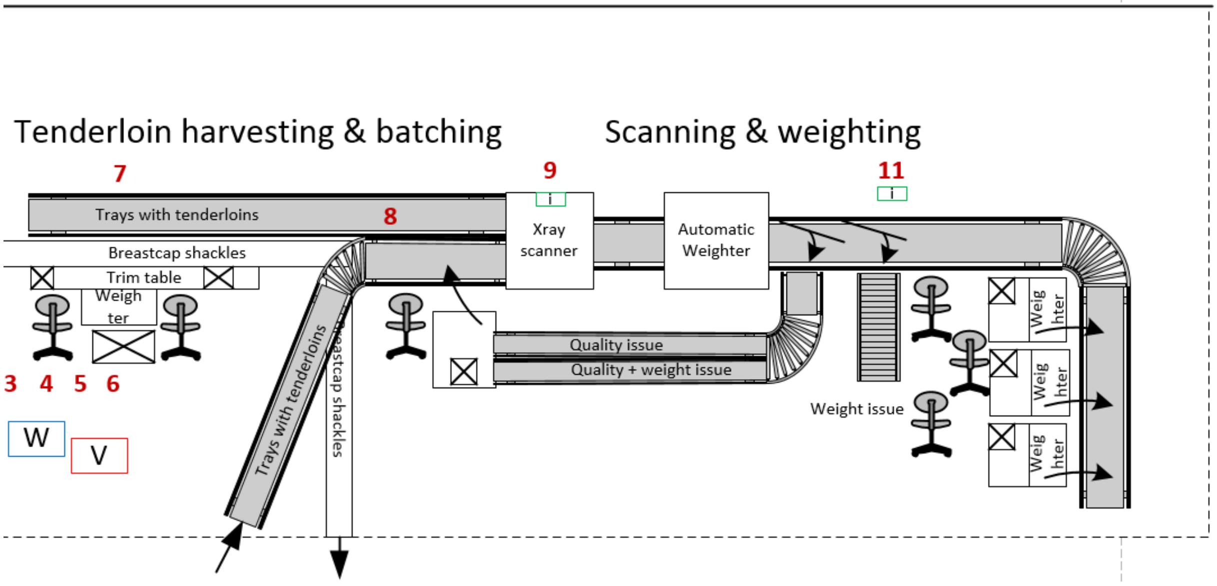


Figure 5.11 Redesign of plant layout. Two locations for inspecting and fixing weight defects.

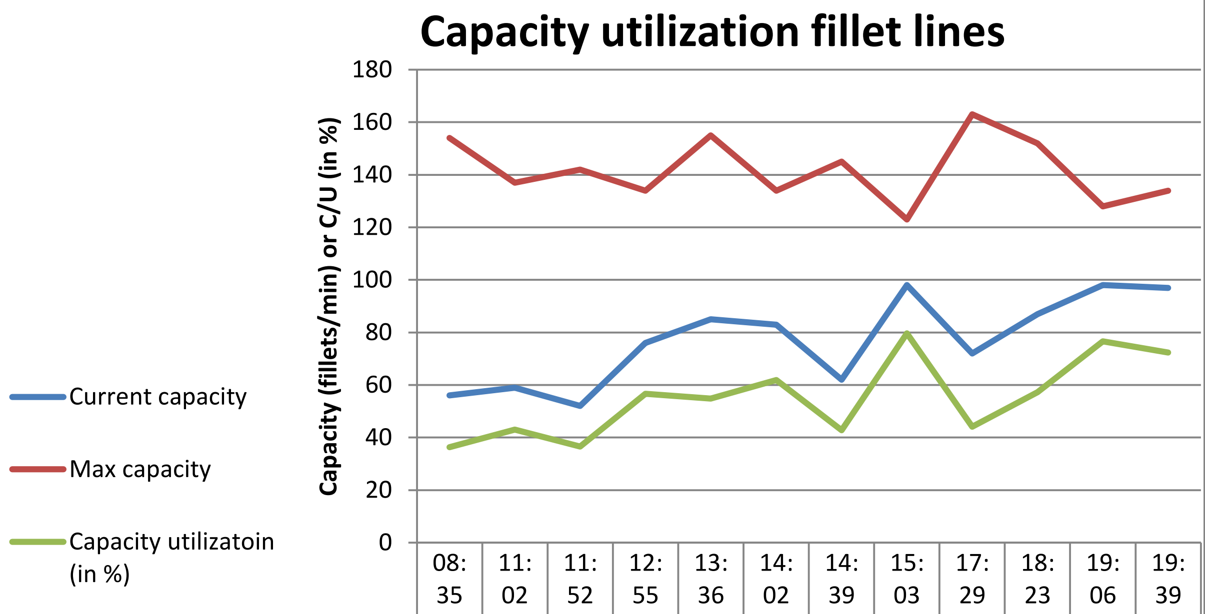
Eliminating this waste will increase the **capacity utilization** significantly of employees. It also reduces the lead time and increases the throughput of trays with tenderloins, which is beneficial for **order completeness**. Unnecessary activities involved in the inspection for and the fixing of defects are eliminated, which is beneficial for the **product hygiene**. Of course, the ideal situation is to avoid any creation of weight defects. A better redesign of the system could try to accurately batch and weight the trays at the tenderloin harvesters. Then the quality is inspected by the X-ray scanner. If the quality is poor and the weight of the tray is changed, it is inspected and fixed. Then, all the trays should be fine on both weight and quality and no weight defects are created. A shorter lead time of several seconds for a significant amount of products is expected, which is beneficial for the order completeness.

4. Extremely poor capacity utilization of employees at the trimming lines

The infeed speed of the trimming lines was on average 77 fillets per minute. This speed fluctuated between 52 and 98 fillets per minute throughout the day (12 recordings). The capacity utilization, actual capacity and maximum capacity of trimming lines throughout the day are visualized in the graph below.

The recorded average of a trimmer was 21 fillets per minute. At almost all times, 7 employees were assigned to the trimming line. According to the trimming capacities of the line that was recorded by the dashboards and taking into account the total assigned employees to the trimming line at the time, the capacity of a trimmer was calculated to be 20.2 fillets per minute.

As can be seen in the Figure 5.12, the capacity utilization was extremely poor throughout the whole day. An average of 55% C/U of the trimming line was recorded. On the dashboards next to the trimming lines, the maximum capacity and current capacity of the trimming line is displayed. This dashboard should give the trimming operator an idea of the capacity utilization. Different measures, such as adjusting employees between lines or processes were addressed in previous interviews with planners and were expected to be enforced during the day. In addition to this, the profiling of employees on their throughput and giveaway was not used to adjust the trimming lines. Never was any employee assigned to another process. On average an excessive capacity of 3.2 employees (65 fillets/min) was assigned to the trimming lines.



	08:35	11:02	11:52	12:55	13:36	14:02	14:39	15:03	17:29	18:23	19:06	19:39
Current capacity	56	59	52	76	85	83	62	98	72	87	98	97
Max capacity	154	137	142	134	155	134	145	123	163	152	128	134
Capacity utilizatoin (in %)	36.4	43.1	36.6	56.7	54.8	61.9	42.8	79.7	44.2	57.2	76.6	72.4

Day time

Figure 5.12 Recorded capacity, max capacity and capacity utilization of fillet lines throughout the day.

A cause of the problem is that the trimming line is not adjusted by the operator. The dashboards that display the poor C/U and throughput and yield loss of every employee are not used to adjust employees around. An operator can decide what percentage will be distributed of all incoming fillets to which employee. An employee with higher throughput should receive a higher percentage of the incoming fillets. In contrary to this, an employee with high yields should reduce its throughput to focus on reducing its yield loss. While the operator is available almost all the time, he/she is busy with other tasks: inspecting other processes such as the X-ray scanner, communicating with control, checking in on order progression etc.

This might be a big cause, but the root cause is not the operator. The fact that 3.2 excessive employees on average are scheduled for the trimming lines is a planning problem. This problem was addressed before: the schedules are made 7 days in advance while the detailed capacity plan is made 2 days in advance. The schedule is not adapted to this detailed capacity plan.

Eliminating this waste will increase the **capacity utilization** of the trimming lines by roughly 40%.

5. The motion and inventory wasted to fix 'defects' from the robobatcher

The infeed speed was on average 112 fillets per minute. From these fillets, 69 were batched in trays. The other 43 fillets per minute (38%) were not batched and were transported to the end of the ray. Information about the process was displayed on the dashboards next to the two robobatchers. According to the dashboards, an average of 88% of all the rejected fillets (34 per minute) was rejected for 'no bin range'. This means that the fillets could not be batched because there were no suitable matches available. A small portion (4%) of the fillets was rejected because the robobatcher was too busy. The rests of the rejects was mostly for fillets that were too heavy or too light and therefore suitable for industry orders. Figure 5.13 illustrates the flow of products and the reject rates. Figure 5.14 shows the recorded reject rate throughout the day. Note that during the whole day the reject rate was high.

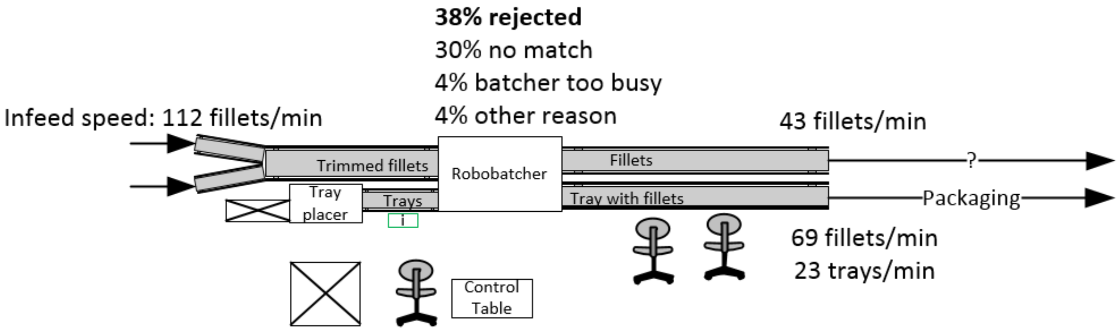
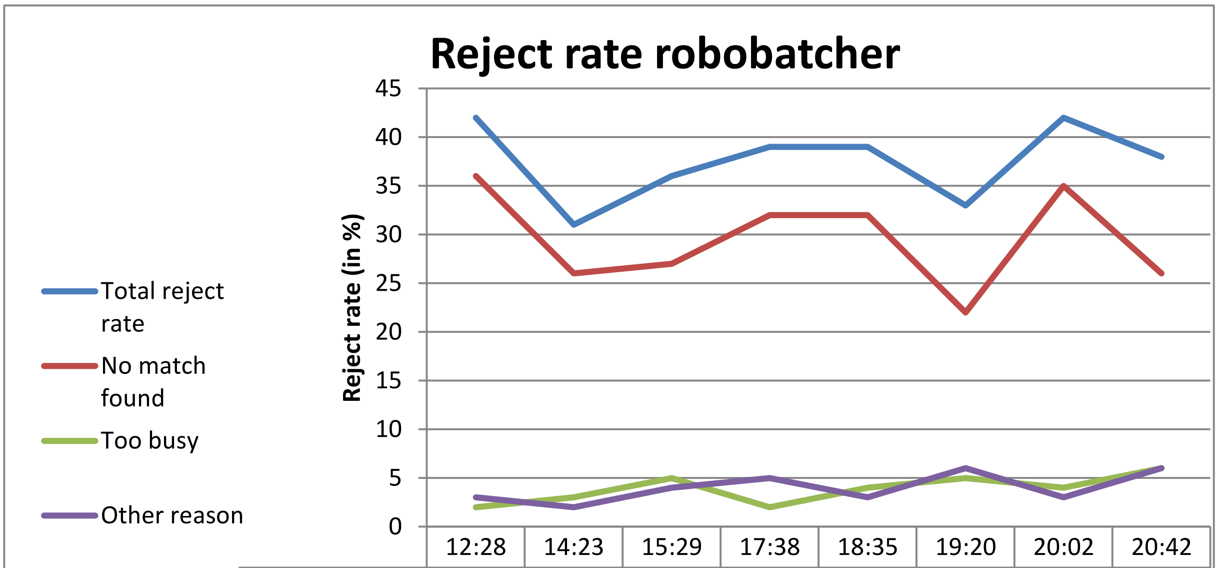


Figure 5.13 Infeed speed, reject rate and output of the process area Batching (robobatcher)



	12:28	14:23	15:29	17:38	18:35	19:20	20:02	20:42
Total reject rate	42	31	36	39	39	33	42	38
No match found	36	26	27	32	32	22	35	26
Too busy	2	3	5	2	4	5	4	6
Other reason	3	2	4	5	3	6	3	6

Figure 5.14 Recorded reject rates of the robobatcher throughout the day.

Currently, this process is tried to be optimized by Company X on giveaway. The giveaway reflects yield that is important to the client. Nevertheless, the client considers order completeness as more important. This was also observed in the settings of the robobatcher. In the evening, the range for over- and underweight was clearly wider for retail orders resulting in a higher giveaway. However, the target weight was never played with. The operator monitored the performance of the process by a trial-and-error approach. He played with the tray patterns and the under- and overweight restrictions. The process was controlled and solely based on intuition and experimenting.

The reject rate of the robobatcher can somewhat be considered as a reflection of the created defects. Especially because a significant portion of fillets that were suitable to be batched in trays for retail orders ended up as industry orders or somewhere else. Dealing with these defects was done in different ways. In the morning until the early afternoon, the rejected fillets were batched in big crates of 12kg and fed to portioning in the afternoon. In the late afternoon, the rejected fillets were stored in the same 12kg crates and stored in the warehouse. During the same afternoon, sometimes the fillets were batched in crates and sacks and distributed as industry orders. In the evening until the end of the production, the fillets were processed for industry orders.

First of all, it is a waste of motion and activities to fix defects. The rejected fillets are batched in crates by employees and the same crates are emptied again later on. Here, big wastes in the form of inventory, motion and transportation are located. These should be eliminated.

Two root causes were identified. First of all, the creation of the unwanted reject rate (defects) should be reduced. The operator should not work with a trial-and-error approach. The settings for every order are communicated with control, but the operator is free to 'play' with the settings. The operator is in need of a tool that supports him in decision-making. The trade-off between throughput and giveaway is important, but currently the operator does not understand how an optimum can be reached in this trade-off.

A second root cause for this waste is the way how defects are 'fixed'. If the fillets are rejected and batched with the purpose to re-enter the process at portioning or batching, a ray could be linked between these processes. This eliminates the activities involved in batching, transporting and storing the fillets. If the rejected fillets are distributed as industry orders, then there is no waste involved. If the rejected fillets are stored as left-overs for the next day, then the activity of producing left-overs can be criticized.

If this waste is eliminated then:

- Fewer defects have to be 'fixed' and the throughput at the robobatcher for retail orders increases. This results in significant better **order completeness.** If the right tool is designed to support the operator in his decision-making, then the **yield** can be increased.
- If the operator is not wasting time by following a trial-and-error approach, then unnecessary activities and the creation of defects are eliminated.
- If the system of fixing the defects is redesigned, a lot of motion, inventory and transport are eliminated. This results in significant lower lead times, thus better **order completeness**.

6. The waste of motion and activities to empty red and blue crates

In every process area, defects that cannot be fixed are thrown into red and blue crates. These crates are spread throughout the area without designated places. Several forms of waste were identified related to the inspection and fixing of these defects.

First of all, the crates are randomly positioned throughout process areas. Employees, such as trimmers and harvesters, throw defects in crates. Commonly, employees had to search for the right crates. Especially at the trimming station several red crates are available for different types of defects. Looking for the right crate costs time and as a result reduces the capacity of employees.

Second, employees frequently failed to throw the defects in the crate. Defects that could be processed in red crates but fell on the ground have to be cLeaned and processed by blue crates.

Third, the crates are emptied at random intervals without proper routing. In 32 minutes, the blue crates were emptied 3 times and the red crates once at the trimming lines. At the process area of fillet and tenderloin harvesting, the blue crates were emptied twice and the red crates 3 times in 28 minutes. Every time the crates were emptied, they were barely full. Also, it takes very long to empty the crates since they are randomly spread over the process areas. Even more inefficient is the emptying of red crates. Every red crate is for a specific type of defect. The employee empties only one type of red crates, then switches the order of crates on his 'car', empties another type of red crate, switches to another red crate on the car etc.

In Lean a tool is used to support the organization of a shop floor called '5S'. The 5 steps in this method are translated from Japanese into: Sort (Seiri), Set in order (Seiton), Shine/Sweeping (Seiso), Standardize (Seiketsu) and Sustain (shitsuke) (Hirano, 1988). For the client, this method is advised to be used for a more stable and organized shop floor. The main elements of this theory and how it can be applied are discussed below.

1. <u>Sort (Seiri)</u>
- Make work easier by eliminating obstacles, such as pillars or bad positioned inventories. At the plant, empty inventories such as crates are located at random places which should be avoided.
- Remove all parts and tools that are not in use, such as transportation racks.
- Segregate material that is not wanted from the workplace. In example empty knife holders at the trimming station.
- Define a red-tag area to place unnecessary items that cannot immediately be disposed of. For instance, empty crates and tools.

2. <u>Set in order (Seiton)</u>
- Arrange the work stations so that tooling and equipment is in close proximity. Thereby, the unnecessary loss and waste of time is eliminated. This step is important for the waste that was observed. The red and blue crates should receive a designated area (e.g., marked with tape).
- Place components according to their frequency of use. In example, red crates should be closer than blue crates at the tenderloin harvesting. However, more defects that were disposed in blue crates were found at the trimming stations. The blue crates should therefore be in closer proximity than the red crates.
- Make it easy to find and access components. Inventories, crates and tools should always be located at the same location. A red crate for legs should always be at the same place, inventories of empty crates, sacks or trays too.
- Every movable and necessary item, tool or component should have a marked area if it is not used. In example cLeaning tools should always be stored back at the same place.

3. <u>Shine/Sweeping (Seiso)</u>
- CLean the workplace on regular basis or time to time. Thus, routine cLeaning tasks instead of randomly cLean whenever a random employee has some spare time.
- Use cLeaning also as inspection. Put crates on the right places, inspect machines for potential risks of failure or creation of defects, etc.
- Anyone **not** familiar to the environment should be able to detect any problems within 5 seconds in proximity of 50 feet. Thus, if something is going wrong anyone should be able to notice this. If employees need help, operators should notice this quickly to save time and maintain a smooth work flow. The use of signals, such as lamps, should also be used by employees and not machines only.

4. <u>Standardize (Seiketsu)</u>
- Probably the most important S to make it all work is to establish procedures and schedules. This ensures the consistency of operating the first three S's. For instance, make schedules for cLeaning activities and refilling of inventories. Introduce standardized routing for employees when they perform such activities.
- The new practices should become part of the daily routine. Therefore, a work structure must be developed that is easy understandable, where everyone knows how to take their responsibility and how the work place should look like.
- The implementation of the 5S's and the performance of the work structure should be reviewed on a regular basis.

5. <u>Sustain (Shitsuke)</u>
- Training and discipline is needed for the 5S's to work. Everyone should do what they are expected to do, without being told. In particular within the plant it is a challenge to train and discipline every employee when new employees arrive on a daily basis.
- Be open for improvement. Follow the process and listen to feedback. Observing the shop floor happened to be a very valuable source to discover problems in the research.

In specifically Lean, the theory behind using the 5S is "Dirty, cluttered, or damaged surfaces attract the eye, which spends a fraction of a second trying to pull useful information from them every time we glance past. Old equipment hides the new equipment from the eye and forces people to ask which to use." (Wallen, 2014). For instance, when new tools or dashboards are placed on the shop floor and the employees do not understand how or why to use them, they will never be used and only cause problems on the shop floor. At the end of Chapter 5, the locations of the root causes and their solutions are illustrated on a VSM.

5.4 The manufacturing system and Lean

From a Lean perspective there are several major practices embodied in the manufacturing system that are considered issues and are in need of improvement.

Deviations in the planning

In Lean Thinking, deviations of the planning are tried to be reduced. By finding the root causes for the six wastes, it was expected to run into root causes that were strongly related to the planning with an exception of poor capacity planning. If the client will apply Lean manufacturing to the whole manufacturing system by including the primary process, secondary process, packaging and distribution process areas, then the client will probably run into root causes located within the planning. Lean Thinking states that, besides eliminating waste to create a continuous flow, the deviations of the planning should be reduced simultaneously. By increasing the forecast accuracy of variables, which are used to make the rough plan and the Good Morning Letter, the deviations in the planning on the actual production day will decrease. Thus, it will reduce the required adjusting on the actual production day and creates a more continuous flow. Deviations can be reduced in several ways:

- Increasing the forecast accuracy of flock characteristics (and their distributions) could be done by:
    - Closely monitoring and profiling farmers.
    - Keeping informed of on on-going epidemics and other events, and their effect on the flocks.
    - Taking into account the effects of time and periods on flocks such as seasons, months, weeks, days and weather.
    - Understanding the growth patterns of the size and weight of flocks, i.e., by understanding the effects of flock types or specific environment characteristics (space, fodder …) on growth patterns.
- Increasing the forecast accuracy of expected (retail) order quantities could be done by:
    - Using historical data of orders to forecast quantities and find (customer order) patterns. Thus, profiling orders and customer's order behavior.
    - Taking into account the effects of time/periods at what orders are placed by customers, such as the time in the month or week. Thus, finding patterns in order behavior of customers.
    - Finding trends in product demand, like increasing product popularity. Also understanding the consequences of repeating events on the consumption. Thus, understanding (other-wise) unpredictable increases or decreases in ordered quantities of specific products by customers. Examples of events could be the Fipronil-scandal in the egg-industry that negatively affected the poultry industry and the yearly repeating Christmas-period that increases the consumption of specifically whole chickens.
    - Taking into account sales and promotional offers.

- Take into account the expected deviations, in example by planning with the worst-case scenario in mind. In example by taking into account the expected DOA's and other expected yield losses when making the raw material plan and planning the cut-up schedule.
- Increase the responsiveness and flexibility of the planning. In example, communicate with the farmers until a shorter time-frame to reduce the deviations of the forecasts or reschedule employees to different shifts and processes.
- Reduce the occurrence of unexpected deviations. For instance, improve the maintenance of the production line to prevent unforeseen availability issues.

Inventory for FP and left-overs

Inventory is a form of waste. The creation, transportation and usage is a waste of motion and thus a waste of capacity. Inventories are a waste of space, material, time and costs money. It also increases the lead time of material or products, affecting the final product quality. Nonetheless, the manufacturing system of the plant is dependent on inventories made the last day. Processing the inventories of the previous day at Further Processing and making the inventories for the next day is done at the same time. It is reported that over 60 to 70 tons of raw material (mostly fillets, legs and drumsticks) are stored for over 7 hours during the night with the purpose to be processed by Further Processing. In addition, several tons of left-overs are created during a production day as a result of excessive raw material (birds). An employee at the fileting line reported that it was daily routine to use the big inventories (100kg crates) of left-over breast caps to feed the fillet lines.

The left-overs are a planning mistake, probably due to poor planning and deviations. It is strange that the making and using of left-overs is a daily routine meaning that there is consistently too much raw material planned or we are unaware of a practical restriction. Of course it is difficult to plan flocks and estimate the required material months to weeks in advance for one production day. The forecasted quantities of retail orders and the actual quantities can deviate for over 15%.

Improve the forecasting could be a solution. Furthermore, the plant can try to sell any expected left-overs to retail clients for a lower price. Currently, left-overs are stored or sold to industry customers since the client is disposing them at the end of the production day. If the quantity of left-overs can be estimated at an earlier stage of the production day then they may be sold to retail clients. Another option is to come to terms with a client to deliver at least some amount, but if they have left-overs they can deliver more.

The inventories that are created and used by Further Processing are enormous. If the inventories are created at the same time other inventories are processed, then the processes could be linked together without intermediate inventories. Of course, creating the inventories takes longer than processing them. Therefore it could be a first step to create half of the inventory on the previous day and the other half at the beginning of the day. This will reduce the lead time of products and costs for storage.

Urgent orders and chaotic shop floor atmosphere

During the visits, the early hours of the production day were very relaxing while the late hours were significantly more chaotic. Besides more employees being present, there were more inventories and other material and tools transported, more employees walking around, more processing lines were in use and were running on higher speeds (and C/U). This issue was also addressed in one of the older interviews with a planner. Here, she stated that in the late hours the urgency to complete every order is high. Especially the time between 19:00 and 23:00 are rush hours.

These late production hours are by far a definition of a continuous flow. Obviously, there is produced on prognosis and it is uncertain if the evening will be a normal, quiet or busy one. Accurate forecasting practices will reduce this deviation in the prognosis. For instance, the plant can produce on prognosis for up to 95% of the expected orders instead of 80%. Then, there is enough time left to produce for any deviations.

Missing Key Performance Indicators and poor adjusting of production day

In the research, the KPIs that are important to monitor processes were identified. It became clear that some KPIs were missing, such as inventory costs, profit, yield and throughput for the fillet harvesting process, etcetera. If Lean is ever applied to the process, it is recommended to review every process area and understand how customer value can be monitored and is expressed in their processes.

Furthermore, the KPIs that are available to Planning and Control to adjust or plan the production day are barely used. Order completeness is, at the moment, the only KPI that matters to Planning and Control during the day. Some thresholds were found on control level for other KPIs, such as giveaway at the robobatcher and the reject rate at the X-ray scanners. It was clear that yield was an important KPI for some processes on the shop floor, but the KPI capacity utilization was totally neglected. Almost all the available flexibility measures at control level that were listed throughout the research were not practiced or at least not observed during the visits. There were some exceptions, for instance the use of a wider range of under- and overweight at the robobatcher and different infeed speeds for some lines by changing bin ranges.

Relations between KPIs and variables, and the effect of events and measures on those are in need to be studied and quantified. For instance, it was expected that a less busy employee at the trimming line will make more accurate cuts with less yield loss but in reality the yield was recorded the same no matter the capacity utilization and speed of the lines. A second example is the same trimming employee creating small buffers in order to take a short break if the capacity utilization is low. This increases the lead time of those products as well as it decreases the recorded throughput of the employee, which is both the opposite effect that was expected from an employee with low capacity utilization. These relations should be studied in order to find root causes for in example the cause of defects and inventories.

Motives to introduce Lean manufacturing

In this research a first step is made to introduce Lean manufacturing to the current manufacturing system, but it was limited to one product family and excluded several process areas. It is highly recommended to apply Lean manufacturing in specifically this manufacturing system because:

- Lean manufacturing identifies true weaknesses in a manufacturing system and resolves system wide bottlenecks. Company X is currently optimizing process by process instead of analyzing the whole manufacturing system. The company is optimizing value adding activities instead of eliminating activities that add no value at all but cost resources.
- Decision making in Lean manufacturing is based on customer value. Company X has trouble to understand what the customer value of their clients is and how it is expressed throughout the manufacturing system. If they want to give advice and develop tools, they have to understand what is important to their clients.
- Company X uses Overall Equipment Effectiveness (OEE) in the primary process. This method of monitoring the manufacturing system is very suitable to be combined with Lean. Waste and root causes can easily be identified and the effect of Lean improvements can easily be monitored.
- It became clear that the manufacturing system of the studied plant had, by far, a continuous flow at the studied process areas. There are plenty of Lean improvements that can be implemented and monitored on their actual added customer value.
- Lean improvements can lead to the development of new tools, redesign of processes and practices.

- Lean facilitates a way to convince higher management of the benefits of Lean improvements. Expected added customer value can be well substantiated and the advice is directed and in-line with higher managements goals.
- The ideal and perfect manufacturing system for the client would be if the planning (Good Morning Letter) for the production day would reflect the actual progression of the production day. Lean uses this reasoning to optimize the manufacturing system, instead of the traditional method to optimize processes separately from each other with different goals.
- In Lean, observing is considered as the most important methodology to find waste and causes. During the visits, a long list of observations was made with potential causes. Most of them are expected to be the cause or root cause of several wastes. Some examples are:
    1. Breast caps are thrown very roughly from crates on the ray. This will probably affect the quality of the breast caps.
    2. Buffers are transported between lines, while the weight distribution of such buffers is different from the line of destination. This affects the performance of the processes and the final destination of the material/products. It creates false information if products are switched between lines. This complicates the monitoring of the production system.
    3. Employees frequently sign other employees to inform them that their crates have to be emptied, their inventories have to be refilled or they need something else. These are typical practices that should be done without being told to.

5.5 Chapter conclusion

In this chapter six of the biggest wastes along many others are identified together with their root causes. This is followed by Section 5.3 where methods are proposed to eliminate these wastes. Finally, Section 5.4 criticizes the current manufacturing system on different topics: the use of enormous inventories, a chaotic shop floor, missing KPIs, inefficient control during production and extremely poor forecasting practices. Also, this section discusses some motives how introducing Lean manufacturing is beneficial to the manufacturing system and Company X.

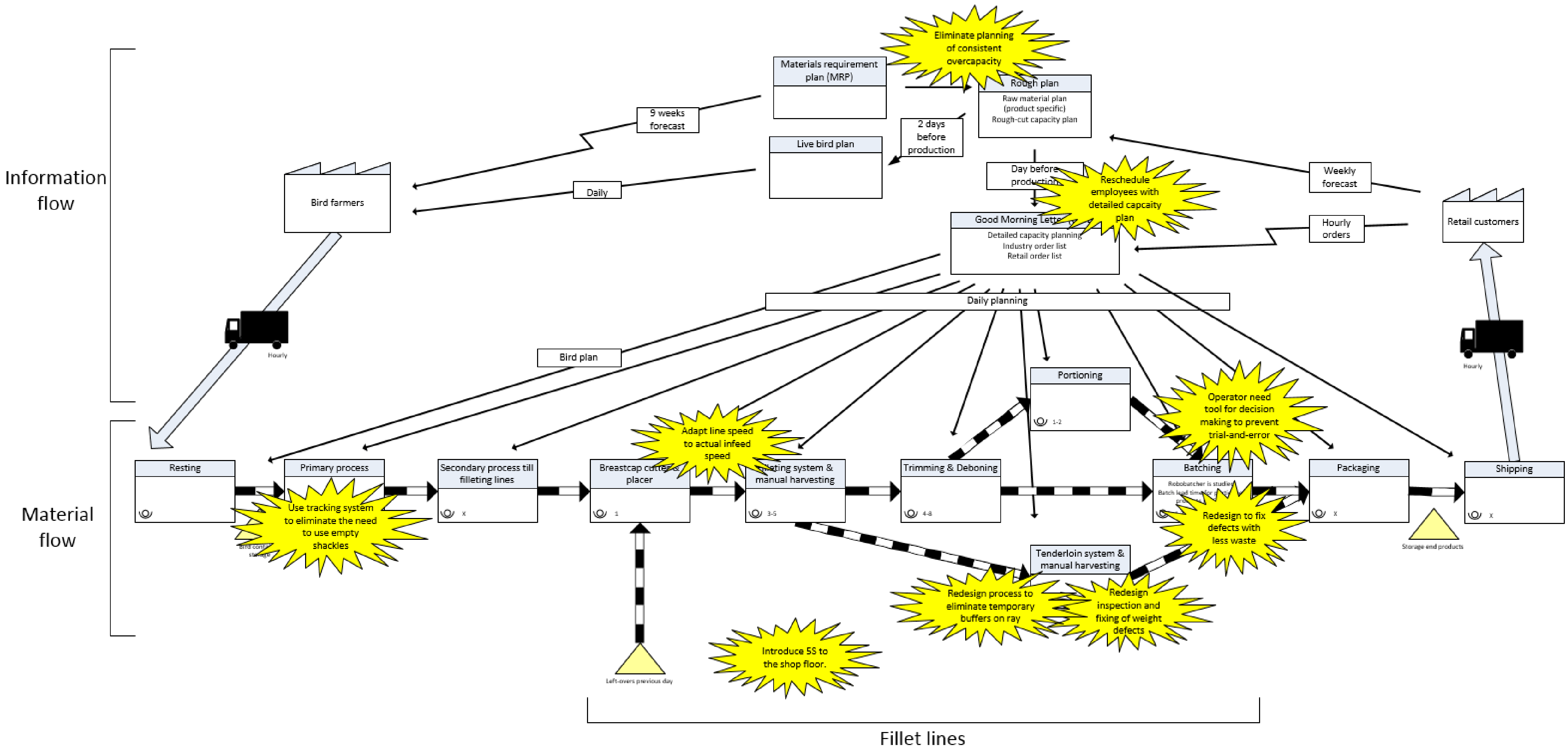


Figure 5.15 VSM with located root causes and solutions.

6. Conclusion and recommendations

This chapter covers the findings and answers to the main research question. First a conclusion is drawn in Section 6.1 about the research questions and their answers. Section 6.2 discusses the recommendations for Company X and the possibilities for and potential of future research. Finally, in Section 6.2 several aspects of research are discussed.

6.1 Conclusion

In this research the current manufacturing system is studied by a visiting the poultry plant, consulting experts and by studying previous literature on the subject. The first two steps of Lean Thinking, the approach that was used in the research and applied to the manufacturing system, are executed. Here the first step is to understand how customer values are expressed and affected throughout the manufacturing system. The scope is narrowed down to the fillet department where every process is analyzed on Key Performance Indicators and how these are and can be influenced on three different levels; Planning, Scheduling and Control. It came to the attention that several KPIs that were expected to be consulted were non-existent, for instance profit, shop floor stability and inventory. Also, Order Completeness is the only KPI that is used to adjust the manufacturing system on Scheduling and Control level. Planning and Control will increase line speeds while the actual capacity utilization of the line is extremely poor, both labor and capacity wise.

The second step of Lean Thinking is to identify and eliminate waste in the current manufacturing system. To do this, the fillet department is observed for two days. Due to a lack of available information, estimates were made to value the expected added customer value if a waste would be eliminated. By doing this, it was possible to prioritize the six biggest wastes. These are:

1. Frequent and long waiting times for fillet harvesters.
   At this process area, 13% of the operating time is waited and the capacity utilization is extremely poor (lowest of 35%). Capacity utilization can be increased by an estimated 30% if the waste is eliminated.
2. Use of buffers by the tenderloin harvesters.
   The use of inventory/buffers increases the lead time of tenderloins by nearly 4 minutes and reduces the capacity of tenderloin harvesters. Order completeness can significantly be increased.
3. Over processing as a result of unnecessary inspection for weight defects of trays.
   Capacity is wasted on fixing defects at the wrong locations. The lead time and required capacity can significantly be reduced.
4. Extremely poor capacity utilization of the trimming lines.
   The capacity utilization of the trimming lines is 50% while it is easy to monitor and manage. Eliminating the waste can increase the capacity by an estimated 40%.
5. The motion and inventory wasted to fix defects from the robobatcher (batching machine).
   30% of the fillets at the batching machine are rejected for not locating a matching tray. The order completeness can significantly be increased if the reject is decreased. Also, it reduces the activities involved in fixing the defects.
6. The waste of motion and activities to empty red and blue crates.
   This waste causes a general chaotic environment on the shop floor. Employees are wasting a lot of time to search for the right crates to dispose their products in and the crates are emptied inefficiently.

These wastes came to the attention in the first visit and were extensively monitored at the second and third visit. This to find the root causes for the wastes. For every root cause, a solution is provided that is in-line with Lean Thinking and that eliminates the wastes.

Furthermore, the research discusses how the manufacturing system and Company X could benefit from practicing Lean Thinking and how they can contribute in solving root causes and eliminate wastes. Here, better forecasting and the elimination of traditional enormous inventories were emphasized.

6.2 Recommendations and future research

The main recommendation I would give to Company X, is to review the solutions that are discussed in Chapter 5 for the six wastes and are listed below. In addition, Company X is recommended to review the other observed wastes and to realize the benefits and opportunities that lie within introducing Lean manufacturing to the system of their clients. Lean Thinking will, both for Company X and their clients, reveal opportunities for improvements. Company X can provide advice, design tools and redesign processes to eliminate wastes and to improve the monitoring of processes with KPIs that matter.

A list of recommendations on how Company X can contribute to eliminate wastes is given:

1. Eliminate waiting times for fillet lines by using an advanced tracking system that eliminates the need of using empty shackles to distinct a new flock from the previous flock.
2. Give advice on how to properly monitor the capacity utilization at trimming stations. The dashboards are currently neglected and a consisted poor C/U is recorded.
3. Give advice on how to adapt line speeds to the actual capacity of fillet lines, to increase yield, capacity utilization and shorten lead times.
4. Redesign the processes to inspect and fix weight defects of trays with tenderloins. This to significantly shorten the lead times and to save capacity.
5. Redesign the tenderloin harvesting process by eliminating the temporary tray buffers. This significantly reduces the lead times which is beneficial for mainly order completeness.
6. Introduce 5S method to the shop floor. It will eliminate the waste of motion of employees and equipment. It will improve the organization of the shop floor and increases the capacity of several labor-intensive processes.
7. Redesign the processes of fixing defects from the batching process to save capacity, reduce the creation and use of inventories, and increase order completeness.
8. Develop a tool and/or give advice to support a batching operator in his decision making. Instead of working with trial-and-error, plan the activities of the operator and make him understand how to control the process. This is very beneficial for a better order completeness. Currently Company X focuses on yield to optimize the process, which is in practice not more important than order completeness.
9. Reschedule employees to other processes or shifts to increase capacity utilization.
10. Support Planning and Control in eliminating the consistently planning of overcapacity.

In Section 5.4 the main benefits of implementing Lean manufacturing into the manufacturing system are discussed. I would suggest using Lean Thinking as a method in further research to improve the current manufacturing system. Many companies, including the biggest competitor of Company X, are already investing to introduce Lean Thinking as a basic method for improving manufacturing systems.

If Company X is going to use Lean Thinking, I would like to emphasize the importance of identifying customer values first. Methods to monitor the process, such as OEE, are fundamental to use Lean Thinking efficiently and effectively, but are useless if the customer values are not well understood.

Furthermore, this research narrowed down the scope to one department. For future research it would be interesting to review the manufacturing system as a whole for one product family. Also, this research had limited access to data to accurately value the added customer value if wastes were eliminated. It is interesting if the observed wastes are complemented with more wastes and valued more accurately on their added customer value.

At last, because order completeness is so important to the plant it is advisable to consider the importance of the concept of Takt Time. This is the rate at which a finished product needs to be completed in order to meet customer demand (available time of production/required units of production). Takt Time is commonly used to plan capacity and speeds of lines to make sure products are finished on time. Also the 'processing time' and 'production lead time' for products can be considered as useful measures in future research to understand how much time is used by value adding activities and how much is wasted in non-value adding activities such as inventory and transport.

6.3 Discussion

Below I address some aspects of the research that came to discussion.

At first, the goal of the research was to identify Key Performance Indicators, understand how they could be influenced and what these relations were. However, there was a lack of information available to quantify such relations. Therefore, most relations were tried to be understood with observations, conversations with experts and literature. Some of those observations were never confirmed. The unavailable data to quantify relations was the same data that was needed to accurately value the added customer values if a waste was eliminated. In two visits, data was collected manually by observing the processes. This was enough to properly prioritize the most important wastes, but was not enough to quantify relations related to KPIs.

Another obstacle in the research was the preparation and the actual execution. In the preparation, I was informed that the above discussed data was easily accessible and available. However, the only quantitative data that was received was the data of some flocks, an example of orders and an outdated excel sheet used by planners. Therefore, the initial research approach changed significantly to deal with the lack of data and useful data was mainly obtained with observing.

Making a good link between KPIs, the three levels of Planning, Scheduling and Control and the elimination of waste was difficult to make due these two obstacles.

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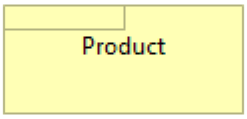
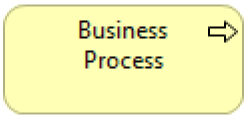
Appendixes

Appendix A. Legend for BPM, flow charts & VSM

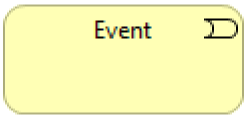
Legend for Archimate's (process structures)



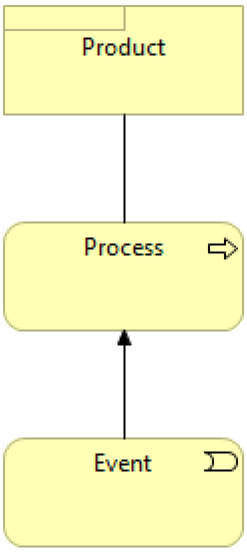
Product
A passive structure that represents a unit that is created, accessed or used by or associated with active and behavioral structures. It can be intangible (e.g., information) and tangible (e.g., materials).



Business process
A behavioral structure representing a workflow or value stream consisting of smaller processes.



Event
An event is a behavioral structure that represents something that happened and may the business processes.



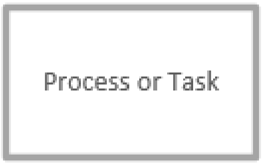
Association relation
This relation is recognized by a straight line without arrows between structures. Both structures are associated with each other, for instance a product is created or used in a process.

Trigger relation
The preceding structure triggers another structure.

Relationship
Incoming products are distributed to different processes by choice.

Relationship
Incoming products are distributed to only one follow-up process.

Legend for Flow Charts



Process or Task
Describes a task, activity or group of tasks and activities.

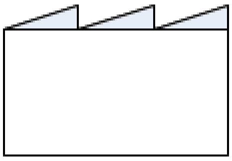
Event
Something that happens that triggers something else, for instance a process or decision.

Decision
A decision that must be made by a role. The outcome of the decision will normally lead to different processes or events.

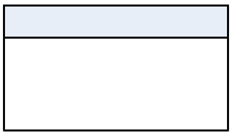
Product (documents)
A unit that is created by a process. It can also be accessed by processes or decisions.

Data or Information
comparable to a product, however it is commonly not directly available to be used. It is accessed by processes or decisions and sometimes processed into a product (document). Some data can be directly accessed and used without requiring a product.

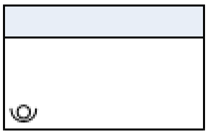
Legend for Value Stream Map (VSM)



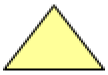
Customer/supplier
A player that generates material or consumes products.



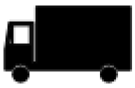
Production control
Part of the information flow, these structures consist of information that adjusts the production processes (material flow).



Process
A process (area) that consist of a set of production steps, activities and/or steps which are related to each other.



Inventory
A temporary or long-term inventory for raw materials, intermediate products and end products.

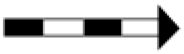


Shipment truck

Electronic information (flow)

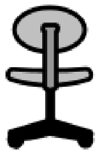
Manual information (flow)

Arrow for shipping

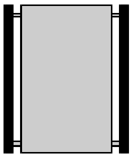


Arrow for push

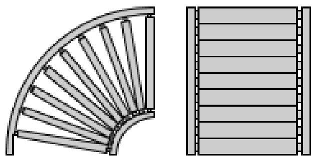
Legend for plant layout



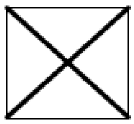
Employee



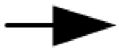
Automated Ray
Raw materials and products are transported on rays.



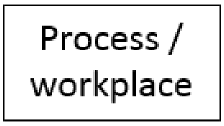
Roller ray
Raw materials and products enter roll rays.



Inventory / buffer
Different types of inventories and buffers are present on the work floor. Inventories are commonly crates of 12 kg and 100 kg. Buffers are created on movable cars.

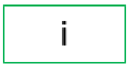


(Possible) flow of raw materials or products



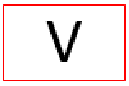
Process / workplace facilities
Processes and work facilities such as work benches and bench scales are displayed by quadrangle shapes.

Shackle lines / holders
If a product or material is not transported on a ray, it is transported on a shackle line or a line with breast cap holders.



Dashboard
Several dashboards are available for employees to monitor a process (area) and can be used to adjust the process (area).

Blue crate
Crate for the disposal of extreme defects (waste).



Red crate
Crate for the disposal of defects with significant value.

Appendix B. Customer value QDC tables

Fillet system & harvesting		
Quality	**Delivery**	**Costs**
Product quality *Freshness* 1. Throughput[1] a. Infeed speed b. Reject rate *Esthetic* 1. Throughput[2] a. Infeed speed 2. Reject rate[1]	Order completeness[5] 1. Throughput d. Reject rate e. Infeed speed 2. Availability 3. Speed of line[8]	Yield[3,6] 1. Cut accuracy[4] 2. Reject rate 3. Throughput[2] 4. Speed of line[8]
		Capacity utilization[7] 1. Throughput 2. Availability 3. Speed of line[8]
		Availability[7]

1. The performance of the leaf fat removal module (preceding process that removes fat below the skin) is related to the performance of the breast cap deskinning module. If the leaf fat remover did a poor job, the skin can be incorrectly removed or not at all. Meat from the breast cap can be ripped off in the process, resulting in yield loss and product esthetic. Sometimes the skin cannot be removed and the breast cap is rejected. The skin is then manually at the cost of yield and throughput.

2. A high throughput will result in a hastier manual harvesting process. This costs yield and product esthetic. More defects are generated with the hastier process.

3. In contrary to the trimming lines, employees are not monitored on their throughput and yield. This is strange, since the harvesting of the fillets is a really un-precise process that costs a lot of yield. In addition to this, at the beginning of the process the reject rate of the breast cap deskinning module is monitored but not the yield loss of the process. While the reject rate somewhat reflects the performance of the process, it does not reflect how bad it affects the yield. Understanding how much yield is lost by pulling off the skin (incorrectly) could be useful to monitor the process.

4. The filleting system makes cuts into the breast cap to facilitate the manual harvesting of fillets and tenderloins. A bad accuracy results in poor harvesting and yield loss.

5. A lower throughput is bad for the order completeness.

6. The overall yield is monitored with yield points for almost every process.

7. Availability and capacity utilization are monitored with dashboards. Obviously, a higher availability will increase the throughput and thus order completeness. But also increases the capacity utilization, for instance when a line is restrained, the capacity of the labor assigned to that line is wasted.

8. A higher speed of the line will negatively affect the yield. Fillets are pulled of and commonly torn apart. Also, the fillet system creates more defects resulting in yield loss and decreased order completeness. The capacity utilization can be poor if it is not equal to the infeed speed. Increasing the line speed will decrease the lead time of products but results in more defects. Thus, it both negatively and positively affects the order completeness. This relation is significant for the fillet and tenderloin systems and harvesting processes.

Normally, the speed of lines is defined by the infeed speed. Several lines run on fixed speeds. The portioning process is significantly affected by the infeed speed (amount of input pieces per time unit), but not by the line speed. The same counts for batching and most of the other processes.

Trimming & Deboning		
Quality	**Delivery**	**Costs**
Product quality *freshness* 1. Throughput 2. Reject rate[1] a. Infeed quality *Hygiene*[2] 1. Reject rate 2. Throughput	Order completeness 1. Throughput[3,5] a. Reject rate b. Infeed speed	Yield[3,5] 1. scan accuracy[4] 2. Reject rate a. Infeed quality
		Capacity utilization 1. Throughput
		Availability

1. The infeed quality for the debone scanner is strongly affected by the infeed speed. The input pieces must be positioned correctly on the production ray to be scanned. If the pieces cannot be scanned correctly, they are rejected. They will re-enter the process later on.

2. A rule-of-thumb on the shop floor is to reduce any contact with the meat to prevent any unnecessary damage to the products hygiene. More trimming is more contact, therefore if a product is rejected and must be trimmed again it is bad for the hygiene. Even more interesting is the preceding process step before the pieces enter the debone scanner. Their position is manually corrected by an employee to reduce the reject rate caused by products that could not be scanned. At a low throughput, only a few input pieces must be corrected and thereby the hygiene is not affected that much.

3. The throughput and yield of the trimming line is strongly dependent on how well preceding processes have done their job. Mainly a poor performance of the wishbone removal module and the manual harvesting of fillets by employees significantly increase the amount of trims needed. More trims is more yield loss and lower throughput.

4. A bad scan accuracy will affect the ability of an employee to locate the bone(s) in rejected fillets. The trimming activity will become less efficient and causes more yield loss.

5. The throughput and yield is monitored for every employee and displayed with monitors on the shop floor. Currently, this is used to profile employees and adjust them around (within lines and between lines) to increase yield, throughput and capacity utilization. Remarkable is how this is not used in the preceding processes: manual fillets and tenderloin harvesting.

Portioning		
Quality	**Delivery**	**Costs**
Product quality *Freshness* 1. Throughput[1] c. Reject rate d. Infeed speed *Esthetics* 1. Cut accuracy[2] b. Scan accuracy 2. Weight accuracy[3]	Order completeness 1. Throughput a. Reject rate b. Infeed speed 2. Availability	Yield 1. Cut accuracy a. Scan accuracy 2. Weight accuracy[3] 3. Reject rate[4] a. Infeed speed b. Infeed quality
		Capacity utilization 1. Throughput 2. Availability
		Availability

1. A higher reject rate will result in lower throughput. It also takes time to fix rejected products.

2. If the cut accuracy is bad, the portion cutter will make bad cuts. The portion cutter will make even worse cuts if the scan accuracy is bad, since the cuts are off point.

3. If the weight accuracy is inaccurate, the piece is cut with an error. The piece can get an undesired under- or overweight. In overall, this increases the deviations of weight between the final products. Meat is also lost, if case of an under- or overweight.

4. Rejected input pieces at the portion cutter can either be redirected to the portion cutter, but are commonly processed for industry orders. Since the client cannot use this product for retail orders, it is considered as yield loss.

<table>
<tr><td colspan="3">Batching</td></tr>
<tr><td>Quality</td><td>Delivery</td><td>Costs</td></tr>
<tr><td><u>Product quality</u>
Freshness
1. Throughput
Esthetic
1. Giveaway[1]
a. Weight accuracy
b. Scan accuracy
2. Throughput[2]
a. Infeed quality
b. Infeed speed</td><td><u>Order completeness</u>
1. Throughput[3, 4]
a. Reject rate</td><td><u>Yield</u>[3]
1. Throughput
2. Giveaway</td></tr>
<tr><td></td><td></td><td><u>Capacity utilization</u>
1. Throughput[2]
2. Availability</td></tr>
<tr><td></td><td></td><td><u>Availability</u></td></tr>
</table>

1. Fillets and other input pieces are placed in trays or batched into crates for industry orders. Depending on the weight accuracy, the final product can have an over- or underweight. A higher error of the weight scanner will result in more under- or overweight products. The error is monitored by comparing the scanned weight to the actual weight. Poor scan accuracy will affect the product quality, since the overall weight of products will less closely to the desired weight.

2. In case of a robobatcher, products are placed into trays by robot arms. If the throughput is increased, this process becomes hastier. The placement of input pieces is less accurate and requires more capacity of employees to fix the displacements of pieces in trays. The esthetic of how precise products are placed in trays is expected to be worse in a hasty process.

Also, more labor is required to fix the trays if some level of capacity is exceeded. This will affect the capacity utilization.

3. The throughput is also dependent on the infeed quality and speed. Comparable to the debone scanner, input pieces are positioned on a production ray that has bounds. If a piece is positioned outside the boundaries or too close to other pieces, it cannot be processed correctly by the robobatcher, resulting in the rejection of input pieces. Higher infeed speed is poorer infeed quality.

4. A significant amount of settings can adjust the batching process, in case of the robobatcher. Most of the measures will increase (or decrease) the giveaway, reject rate and throughput. An operator will therefore have to make several trade-offs between customer values if he is adjusting the process.

If the throughput exceeds some capacity, the robobatcher can become too busy and cannot process the stream of input pieces that enter the process. They are rejected and then stored or processed for industry orders.

Appendix C: KPIs and customer value relations schemes

Fillet system & harvesting

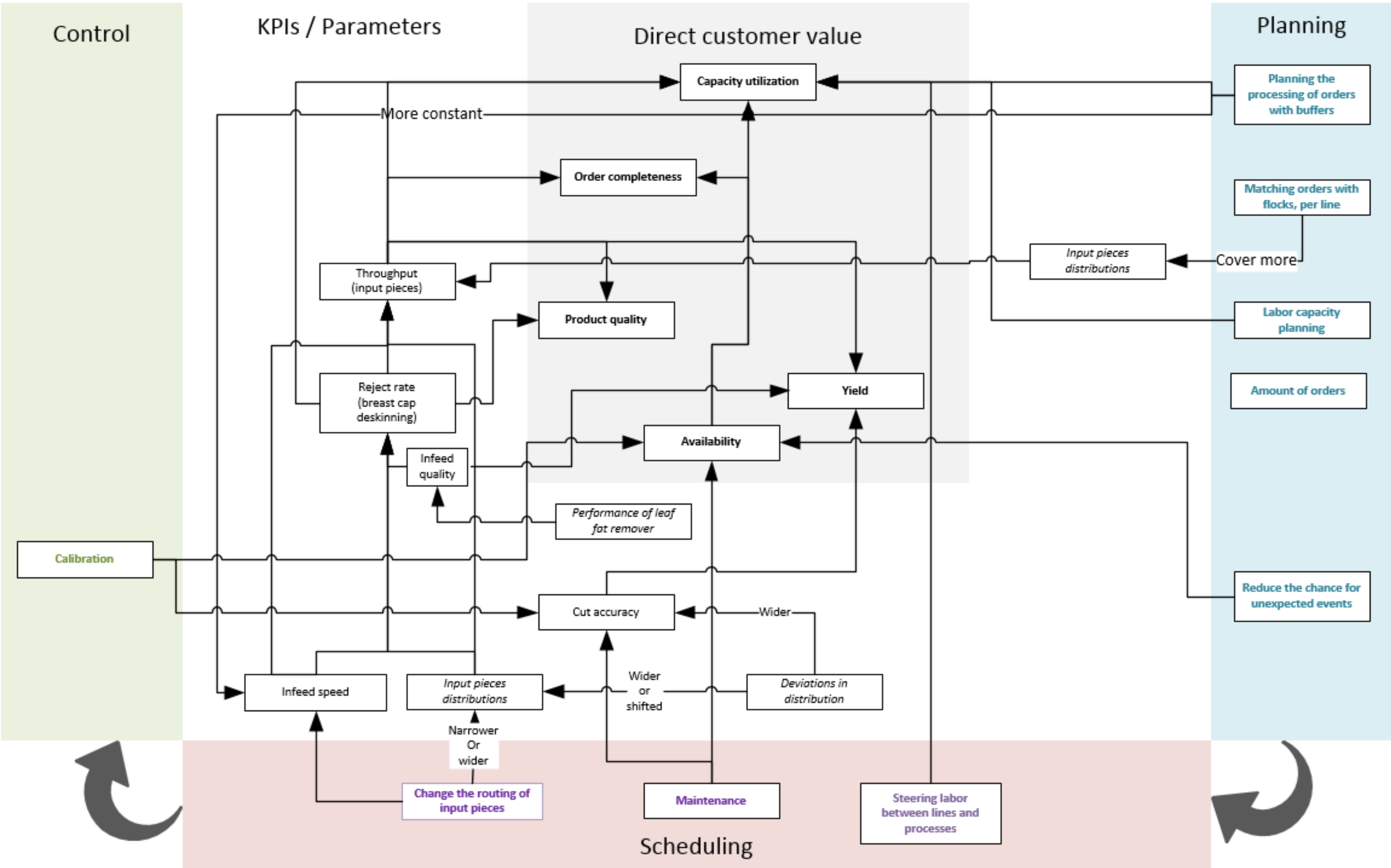


Figure C.1 Relations scheme for process area: Fillet system & harvesting

Trimming and deboning

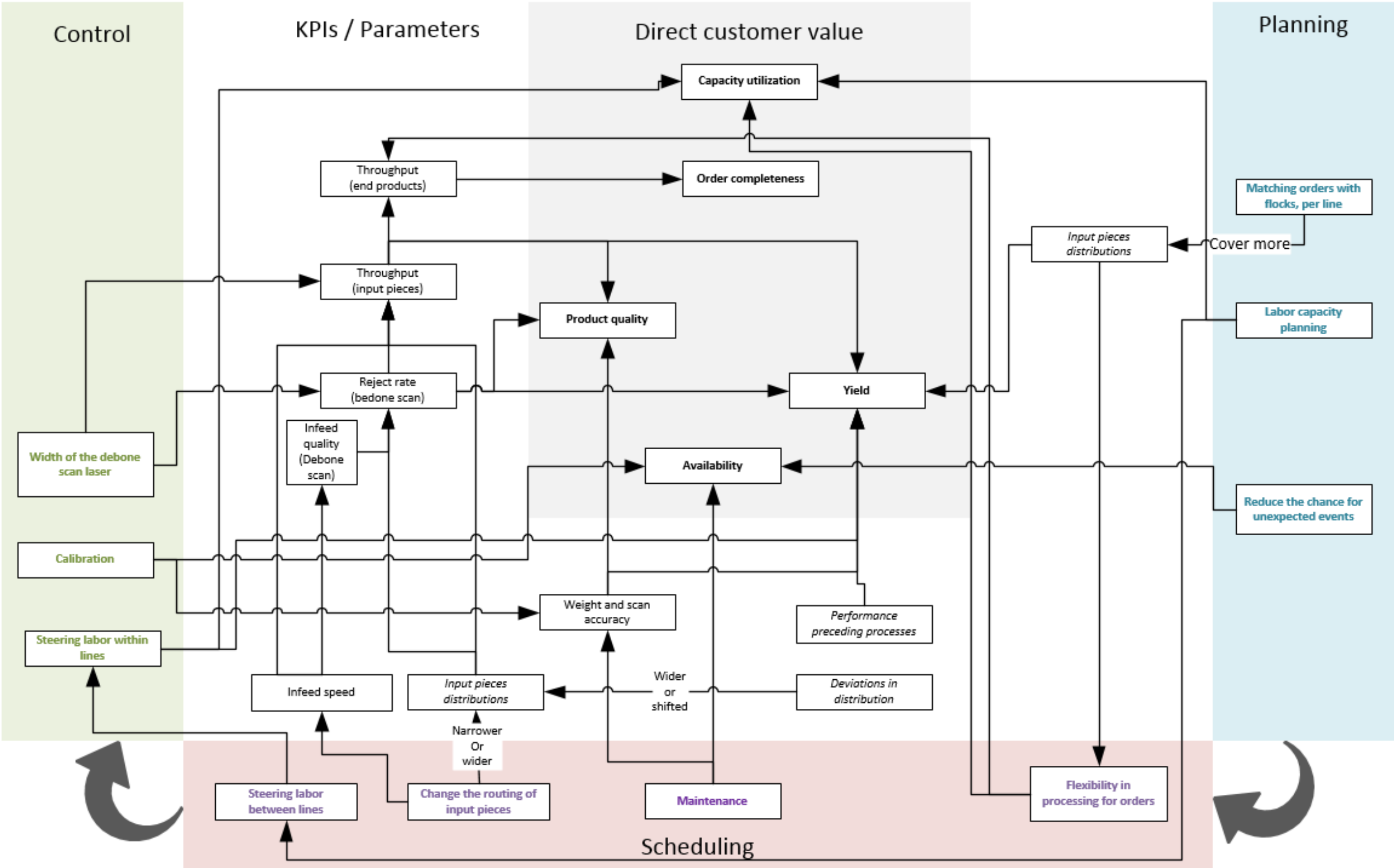


Figure C.2 Relations scheme for process area: Trimming & deboning

Batching

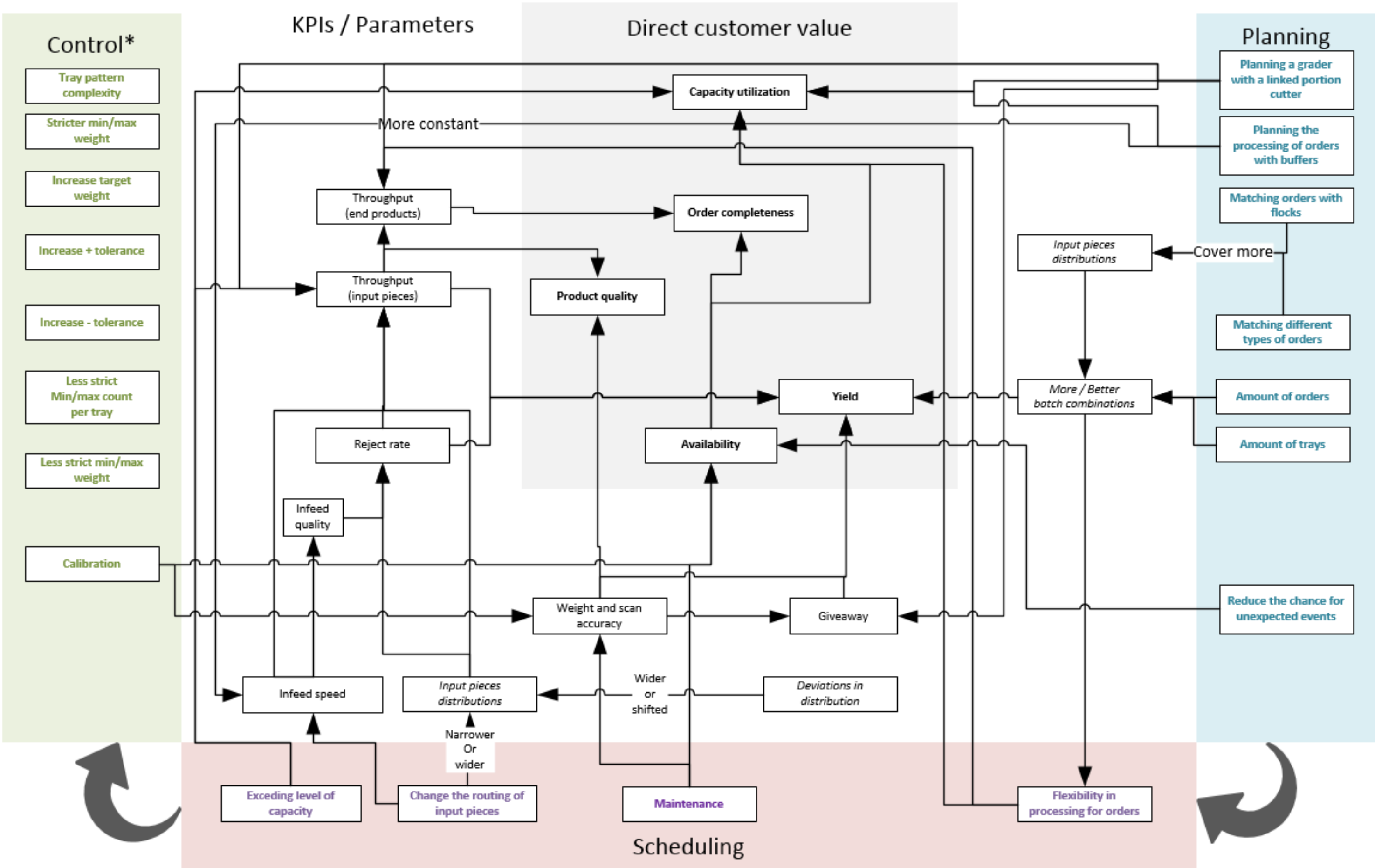


Figure C.3 Relations scheme for process area: Batching

Portioning

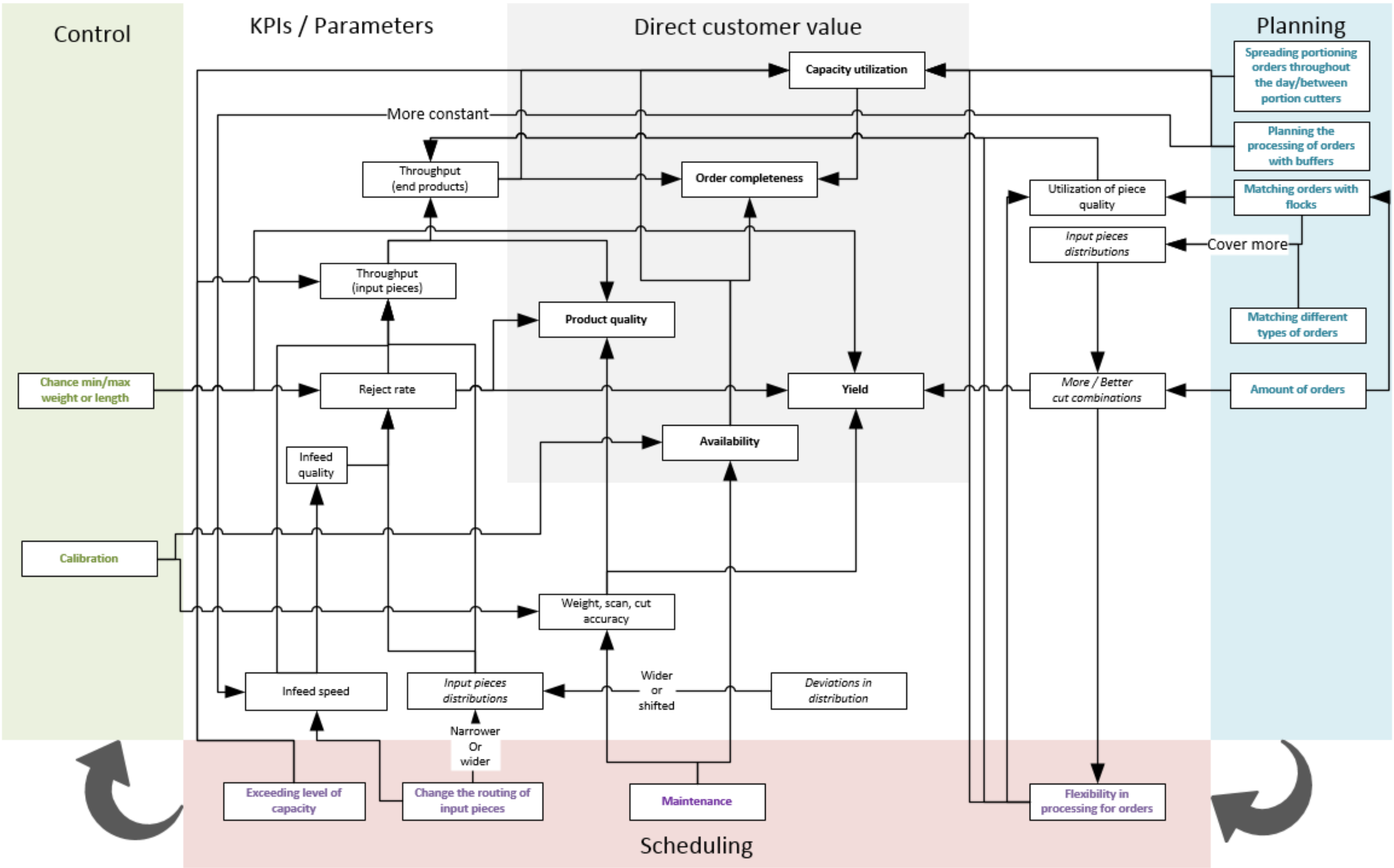


Figure C.4 Relations scheme for process area: Portioning

Appendix D: Measures, KPIs and variables relations

Cut-up schedule

The available measures on planning and scheduling level for the cut-up department (fillet department) were also analyzed. It is good to take note that retail customers are more important than industrial customers to the client. Customer friendliness and other factors are covered by a non-existing KPI now named ‘Costs’. Some orders can be delayed, cancelled or be discussed with customers. Sometimes flocks can also be delayed or postponed, affecting the ‘planning of upcoming days’. During the day, on rough level capacity can be adjusted, for instance by increasing line speeds or using more lines (or processes) than planned.

Planning level

Measures on planning level	Measure Nr.
Change industry order: (a) delay, (b)less quantity, (c) cancel	1
Discuss order with retail customer: less quantity	2
Adjust live bird plan by changing the delivery day of flocks	3
Collaborate planning of live bird plan between locations*	4
Match orders with flocks	5
Increase robustness of planning	6
reduce the chance for unexpected events, e.g., maintenance	7
Capacity planning	8
Build inventory for next day	9

*Available measure for this plant.

Insufficient raw material to fulfill expected orders							
Measure Nr.	**Order completeness**	**Yield**	**Capacity utilization**	**Availability**	**Process stability**	**Planning upcoming days**	**Costs***
event	---		-		-		
1a	+					-	-
1b	+						-
1c	++						--
2	+						-
3	+	-				-	
4	+	+				+	
Insufficient capacity available							
event	--		-		--		
1a	+		++				-
1b	+		+				-
1c	+		+				--
2	+		+				--
8	+++		- or +				---
Industry order is cancelled							
event	+		--				
3			+			++	
4			=				

5	+	+					
8	-		+				
9			++			++	
Too much raw material							
event							
1a	+		-				-
1b	+		-				-
1c	++		--				--
2	+						--
3	+					+	
4	+					++	
9			+				
Create flexibility on scheduling level, prevent adjusting of planning							
event							
6	++		-	+	++		
7	++			- and +	+		

*the KPI 'Costs' refers to some form of loss, like missing out on income or slightly damaging the customer relationship.

Schedule level

<u>Measures on schedule level</u>	Measure Nr.
Change slaughter sequence of flocks	1
Change routing of input pieces	2
Change sequence or priority of orders	3
Discuss order with customer: less quantity	4
Discuss order with customer: allowed delay	5
Speed of whole production line: (a) increase, (b) decrease	6
Purchase products from Cellerland*	7
Delivery of a flock by a day: (a) advance, (b) delay	8
Delivery of a flock by minutes/hours: (a) advance, (b) delay	9
Change industry order: (a) delay, (b)less quantity, (c) cancel	10
Delay DC retail order: (a) delay, (b)less quantity, (c) cancel	11
Adjusting capacity	12

*Available measure for this plant.

Insufficient raw material to fulfill all orders of the day										
Measure Nr.	**Order completeness**	**Yield**	**Capacity utilization**	**Product quality**	**Through put**	**Availa bility**	**Process stability**	**Utilization of piece quality**	**Planning upcoming days**	**Costs***
event	---		-		-					
4	++									--
7	+		= or +		+					-
8	++		+		+				--	
10b	+		-				-			-
10c	++		-							--
11a	+								--	
11b, c	++									- or --

Momentarily insufficient raw material causing line restraints									
event	-		-		-	--	--		
6b		+		+	=		+		
8a	+		+		+	+			
12	+		++		+		-		
Too much raw material									
event	+		-						
8a	-		+					+	
9b	=		+						
Insufficient capacity available									
event	-				-		-		
2	++	-	- or +		- or +		-		
3	- or +		+		+		-		
4	+								-
5	+								-
6a	-	+		+	-				
9b									
12	+		++				-		
Order is cancelled									
event	+		--						
1	+		+						
2	+	+	+				-		
3	+	+	+				-		
8b	-							+	
12			+				-		
Order is expected to not be completed on time									
event									
2	+	-	- or +		- or +		-		
3	+	-			+		-		
4	++						+		-
5	++						-		-
6a	+	-	= or +	-	+				
7	++								-
8	+	-			+			---	
9a	+								
10	++							-	-
11	++							--	--

*the KPI ‘Costs’ refers to some form of loss, like missing out on income or slightly damaging the customer relationship.

Fillet system and harvesting

Planning level

<u>**Measures on planning level**</u>	**Measure Nr.**
Planning the processing of orders with buffers	1
Matching orders with flocks, per line	2
Labor capacity planning	3
reduce the chance for unexpected events, e.g., maintenance	4

Improve the planning on capacity utilization								
Measure Nr.	**Order completeness**	**Yield**	**Capacity utilization**	**Capacity utilization**	**Reject rate**	**Throughput**	**Availability**	**Process stability**
1	- or +		- and ++	- and ++		+		-
2	- or +	-	++	++		+		
3	-	--	+	+	+	-		
Improve the planning on yield								
2	-	+	+	+	-	=		
Reduce expected adjusting of planning								
4	+						- and +	+

Scheduling level

<u>**All measures on schedule level**</u>	**Measure Nr.**
Flexibility in order processing, e.g., increase throughput for urgent order	1
Maintenance	2
Change the routing of input pieces	3
Adjusting labor between lines	4

Order is expected to not be completed on time							
Measure Nr.	**Order completeness**	**Yield**	**Capacity utilization**	**Reject rate**	**Throughput**	**Availability**	**Process stability**
1	= or +	-		-	+		-
3	+	-	- or +	-	+		-
4	++	-	-		+		--
The level of capacity is required to be exceeded							
4	+		-		+		
Threshold of reject rate or yield loss is passed							
2	-	+	-	-		-- and +	
4	+	+	+	-	+		

Control level

All measures on control level	**Measure Nr.**
Calibration	1
Adjusting labor within lines	2

Measure Nr.	Order completeness	Yield	Capacity utilization	Product quality	Reject rate	Throughput	Availability	Weight, scan, cut accuracy	Process stability
Order is expected to not be completed on time									
2	+	+	-		-	+			-
Threshold of yield loss is passed									
1	-	++		+			--	++	
2	+	+			-	+			-

Trimming & Deboning

Planning level

<u>All measures on planning level</u>	**Measure Nr.**
Matching orders with flocks, per line	1
Labor capacity planning	2
reduce the chance for unexpected events, e.g., maintenance	3

Improve the planning on capacity utilization							
Measure Nr.	**Order completeness**	**Yield**	**Capacity utilization**	**Reject rate**	**Throughput**	**Availability**	**Process stability**
1	- or +	-	++		+		
2	-	--	+		-		
Improve the planning on yield							
1	-	+	+	-	=		
2	+	+	++		+		
Create flexibility on scheduling level (robustness of planning)							
-							
2	+	+	--		+		- and +
Reduce expected adjusting of planning							
-							
3	+					- and +	+

Scheduling level

<u>All measures on schedule level</u>	**Measure Nr.**
Maintenance	1
Change the routing of input pieces	2
Adjusting labor between lines	3

Order is expected to not be completed on time								
Measure Nr.	**Order completeness**	**Yield**	**Capacity utilization**	**Product quality**	**Reject rate**	**Throughput**	**Availability**	**Process stability**
2	+		+		+			
Capacity utilization is tried to be increased								
3		-	+++					--
Threshold of yield loss is passed								
3	+	+						--

Control level

All measures on control level	**Measure Nr.**
Width of the debone scan laser: (a) increased, (b) decreased	1
Calibration	2
Adjusting labor within lines	3

Measure Nr.	**Order completeness**	**Yield**	**Capacity utilization**	**Product quality**	**Reject rate**	**Throughput**	**Availability**	**scan accuracy**	**Process stability**
Order is expected to not be completed on time									
1a	+	-	+	-	++	+		--	
Threshold of reject rate or yield loss is passed									
1a/1b	-/+	+		+	-				
2	-	++		+	-		--	++	
3	+	+			-	+			-

Portioning

Planning level

<u>**All measures on planning level**</u>	**Measure Nr.**
Spreading portioning orders throughout the day	1
Spreading portioning orders between portion cutters	2
Planning the processing of orders with buffers	3
Matching orders with flocks	4
Matching different types of orders	5
Amount of orders	6
reduce the chance for unexpected events, e.g., maintenance	7

Create flexibility on scheduling level for order processing							
Measure Nr.	**Order completeness**	**Yield**	**Capacity utilization**	**Reject rate**	**Throughput**	**Availability**	**Process stability**
4	+	+++		--	++		
5	+	++	+	-	+		
6	+	+	+	-	+		
Improve the planning on capacity utilization							
1	+		++				++
2	- or +	-	-		- or +		+
3	- and +		- and ++		+		-
Reduce expected adjusting of planning							
7	+					- and +	+

Scheduling level

<u>**All measures on schedule level**</u>	**Measure Nr.**
Flexibility in order processing, e.g., increase throughput for urgent order	1
Maintenance	2
Change the routing of input pieces	3
Exceeding level of capacity	4

Order is expected to not be completed on time							
Measure Nr.	**Order completeness**	**Yield**	**Capacity utilization**	**Reject rate**	**Throughput**	**Process stability**	**Utilization of piece quality**
1	++	-			+	-	-
3	++	-	-- and +	+	+		-
The level of capacity is required to be exceeded							
4	+		--		+		
Threshold of yield/giveaway is passed							
3	-	+	-- and +	-	-	-	- or +

Control level

All measures on planning level	**Measure Nr.**
Chance min/max weight or length: (a) increase, (b) decrease	1
Calibration	2

Order is expected to not be completed on time							
Measure Nr.	**Order completeness**	**Yield**	**Product quality**	**Reject rate**	**Throughput**	**Availability**	**Weight, scan, cut accuracy**
1a	++	--		--	++		
Threshold of yield/giveaway is passed							
2		++	+			---	++

Batching

Planning level

<u>All measures on planning level</u>	**Measure Nr.**
Planning a grader with a linked portion cutter	1
Planning the processing of orders with buffers	2
Matching orders with flocks	3
Matching different types of orders	4
Amount of orders	5
Amount of trays	6
reduce the chance for unexpected events, e.g., maintenance	7

Create flexibility on scheduling level for order processing									
Measure Nr.	**Order completeness**	**Yield**	**Giveaway**	**Capacity utilization**	**Product quality**	**Reject rate**	**Throughput**	**Availability**	**Process stability**
3	+	+++	--			--	++		
4	+	++	-			-	+		
5	+	+	-	+		-	+		
6	+	+	-	+		-	+		
Improve the planning on capacity utilization									
1	+	- and +	--	--		-	+		
2	- and +			- and ++			+		-
Reduce expected adjusting of planning									
7	+							- and +	+

Scheduling level

<u>All measures on schedule level</u>	**Measure Nr.**
Flexibility in order processing, e.g., increase throughput for urgent order	1
Maintenance	2
Change the routing of input pieces	3
Exceeding level of capacity	4

Order is expected to not be completed on time								
Measure Nr.	**Order completeness**	**Yield**	**Giveaway**	**Capacity utilization**	**Product quality**	**Reject rate**	**Throughput**	**Process stability**
1	++	-	+				+	-
3	++	-	+	-- and +		+	+	
The level of capacity is required to be exceeded								
4	+			--	-		+	
Threshold of yield/giveaway is passed								
3	-	+	-	-- and +		-	-	-

Control level

All measures on control level	Measure Nr.
Tray pattern complexity	1
Chance min/max weight or length: (a) increase, (b) decrease	2
Increase target weight	3
Increase + tolerance	4
Increase - tolerance	5
Less strict min/max count per tray	6
Less strict min/max weight limit	7
Calibration	8

Order is expected to not be completed on time									
Measure Nr.	**Order completeness**	**Yield**	**Giveaway**	**Capacity utilization**	**Product quality**	**Reject rate**	**Throughput**	**Availability**	**Weight, scan, accuracy**
1	+			-	-		+		
2a	++	--	++			--	+		
3	+	-	+			-	+		
4	++	-	++			--	++		
5	++	-	++			--	++		
6	+	+	-		-	-	+		
7	**++**	**+**	**-**		**-**	**-**	**+**		
Threshold of yield/giveaway is passed									
8	--	++	-		+			--	++

Appendix E. Clarification of KPIs, measures, variables and relations

This appendix will discuss, per process (area), the measures, KPIs and variables that are relevant to the process on the level of Planning, Scheduling and Control. In control the discussion of most mutual relations between KPIs are located, while under planning and scheduling most of the measures are discussed. If the clarification of a relation is searched for, then first find the right process (area) and then the right level (planning, scheduling or control). Every KPI that is part of an important relation is written in **bold**.

Portioning:

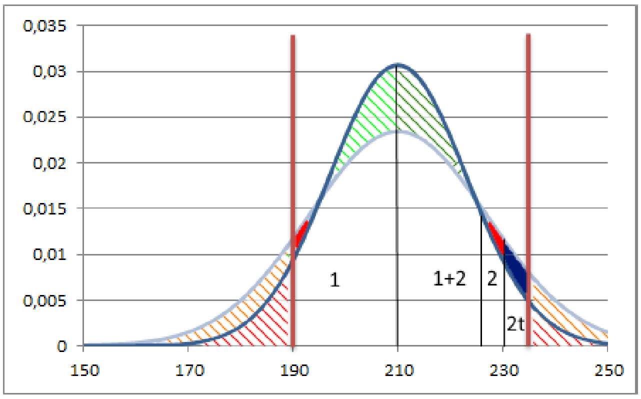
Planning

Measures 4-6: Amount of orders, matching orders with flocks, matching different types of orders
The cut-up schedule is made in the planning, based on the rough plan where the expected flocks and orders are already roughly matched. Only a few product types that require portioning can be combined and processed at a portion cutter. End products can only be produced by a specific portion cutter (I-Cut, SmartSplitter), limiting the combinations of orders that can be combined.

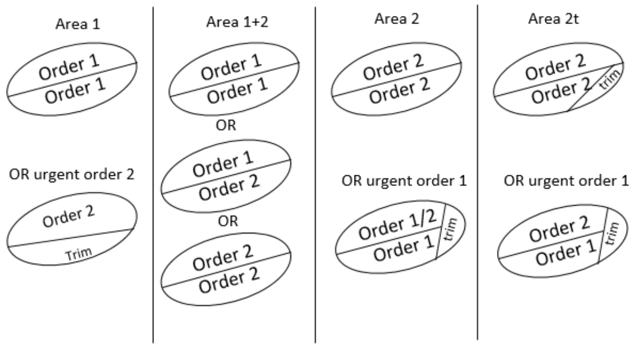
In the portion cutter it is possible to produce for several orders at the same time. Producing for different orders will increase the possible cutting combinations for input pieces. Orders can differ in many ways: *Product type, product weight, weight tolerance, product shape, product size, product quality and more.*

First, an illustrative example will show the benefits of producing more orders at the same time.
Example 1
Order 1: schnitzels, 95 – 110 gram
Order 2: schnitzels, 105 – 115 gram
Input pieces (weight): Normal distributed, mean 210, st. dev. 17 and 13 (narrowed distribution).
Min/max weight: 190 – 235 gram

In the graph figure below, the scenario is visualized. Here, the red vertical lines are the min/max weight boundaries. Outside these boundaries, there is red plus orange striped area that represents the rejected pieces.
The white area (with the '1') represents the pieces that are being processed for order 1. This area can be used to produce for order 2 if the order is very urgent, but the piece will be trimmed into a primary product and secondary product. The secondary product will be a piece or several pieces of fillet roughly weighting between 85 and 105 gram.
The white area (with the '1+2') represents the pieces that can be processed for both orders. The next white area (with the '2') is the area with pieces that are being processed for order 2 without requiring a trim. The white area plus the blue area on the most right (with 2t) represents the pieces that are processed for order 2, but the piece must be trimmed to reduce the weight. Narrowing down the distribution will decrease the pieces between 230 and 235 gram by the blue area. Fewer pieces must be trimmed for order 2 and more pieces can be processed for both orders (dark green area). In addition, more pieces can be processed for order 1 (light green area).



If average weight would increase, the distribution will move slightly to the right as a whole. The orange/red area that represents the rejected pieces will change too. First, the reject rate will decrease on the lower side (left) and then increase again on the upper side (right). The amount of pieces that must be trimmed for order 2 (230 to 235 gram) will increase. However, more pieces can be cut for both orders (dark green area), instead of being trimmed or processed for only one order only.



It can be concluded that producing for more different orders at the same time is a beneficial practice, since it increases the combinations and options for pieces to be cut up into. Some orders fit better with other orders (more, optimal cut combinations). Noticeable is how specific urgent orders can be combined with less urgent orders to increase the throughput for such urgent orders without losing a lot of yield (e.g., the white area 1+2 in the previous image, and in case of extreme urgency pieces from area 1 can be trimmed to fulfill order 2).

Combining the right orders with each other and flocks will:
- Increase **(+) Order completeness**, since more flexibility measures on scheduling level are available to increase the throughput of specific products for specific orders and less secondary and trimmed products will be created.
- Increase **(++) Yield**, since more combinations are possible and more of the weight, quality and size distributions are covered. This results in less rejects, less trimming and secondary products.
- Decreases **(-) reject rate**, since more input pieces fit orders.
- Increases **(+) throughput,** because flexibility is created to increase throughput for a specific order if needed.

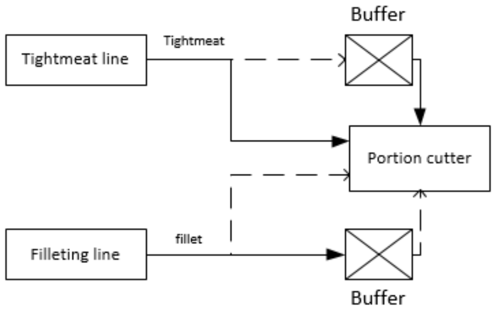
In fitting flocks with portion cutters and their orders, some aspects are important to take into account. Some of which are also further clarified in the next section 'scheduling'.
- Order requirements (weight and size) that cover most of the area of the weight and size distributions will reduce the amount of rejects.
- Order requirements with high quality standards will require high quality pieces to reduce the reject rate. Combining orders that are in need of different product qualities will reduce the reject rate.
- Orders can be combined in different ways. For instance, retail orders can be combined with bulk orders to provide more flexibility in completing the retail order.
- Specific characteristics of input pieces matter more to some product types over others. Length is more important in producing strips, while thickness is more important for schnitzels. Weight and yield is more important in producing schnitzels than medallions or strips, since a piece can be cut up into fewer products. The product type could be taken into account when matching input pieces and their characteristics' distributions with orders and thus portion cutters. Both on scheduling and planning level.

Measure 1-2: Spreading portion orders throughout the day/between portion cutters
The capacity of portion cutter is limited. Spreading the orders that require portioning over the day will reduce the idle time of available portion cutters. If the orders are spread, the required throughput is more stable and lower throughout the day. A good spread will reduce the required portion cutters, but should try to utilize most of the portion cutter's available capacity.

Measure 3: Spreading portion orders with buffers

Buffers can be used to create some flexibility in portioning. In the image below a thigh meat and fillet line are both assigned to the same portion cutter. In the current situation, an order with thigh meat that requires portioning is planned and processed by the portion cutter. In the meantime, the fillet line will produce fillets that are stored in a buffer (e.g., a container). After a while, the portion cutter switches from order and the feed of input pieces will become fillets. Both the buffer and fillet line will feed fillets at an infeed speed that equal to throughput which the portion cutter can handle. After this switch, the thigh meat from the thigh meat line will be stored in the buffer.

The usage of buffers will increase the **(+) capacity utilization** capacity-wise. It also increases the overall **(+) throughput** of the portion cutter, since the **(+) infeed speed** is constant high. However, some orders will be put on hold by using the buffer system, reducing their **(-) order completeness**. Combining the system with a bulk order, will cause less problems for the order completeness.



The capacity of processes and lines are taken into account in making the rough plan. By, in example, rejecting or planning industry orders on another production day, the capacity is not exceeded. During a production day, processes and lines are planned to be available on certain times. After planning the rough plan, the required labor is calculated.

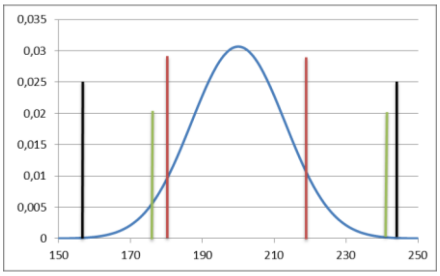
Measure 7: reduce the chance for unexpected events
On planning level, maintenance is used to prevent chance for machine failure but costs time. On the day itself, it increases the **(+) availability**. Aside from maintenance, the cut-up schedules can be checked on mistakes or other measures can be made to reduce the chance for unexpected events. This is at the cost of **(-) availability**, but provides extra **(+) process stability** on the day itself.

Scheduling

The cut-up schedule is known for the portion cutters. During the production the flocks are weighted, counted and scanned for their quality and size. The actual distributions of these characteristics can differ from the previously expected distributions. The effects of different distributions (other mean and standard deviation values) are, among other things, discussed in this section.

Parameter: weight distribution affecting KPIs: Yield, reject rate, throughput

A wider **(+) weight distribution** will decrease the **(-) yield,** since more secondary and trimmed cuts will be made and less primary products. Depending on the order that is fulfilled with the portion cutter and the portion cutter program that is followed to make these products, the weight distribution of incoming pieces affects the yield loss in different ways. If the **weight distribution** fits the program well, less trimmed, secondary and other/uncut products are produced.

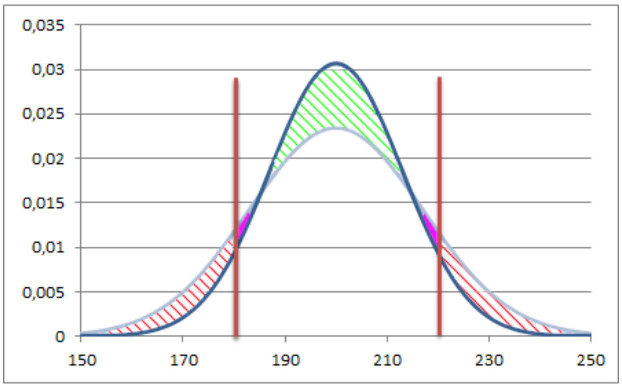


In portioning and grading input pieces must fit a min/max weight to be allowed to be processed into a product. If an input piece's weight lies outside the allowed min/max weight, it is rejected.
The weight distribution can fit the **min/max weight** boundaries in three ways. The weight distribution…

1. … Is situated **within** the weight boundaries (**black**).
2. … Is situated also **outside** the weight boundaries (**red**).
3. … Is situated **partly within** the weight boundaries. (**Green**).

The weight distribution can become wider (higher standard deviation) or narrower (smaller standard deviation). For case 1, both changes in the distribution will not affect the amount of rejected pieces if the distribution is still within the weight boundaries. In case 2, the total rejects at both sides of the distribution will increase if the weight distribution widens. In case 3, only the amount of rejects will increase at the lower side of the weight distribution. Smaller distributions will decrease rejects.

In general, a narrower **(-) weight distribution** will decrease the **(-) reject rate** and, as a result, increase the **(+) throughput** of input pieces and end products**.** In the image on the right, the weight distribution is narrowed. Here, the red striped area represents the pieces that are not rejected anymore with the new distribution. The green area represents the increased amount of pieces that can be processed. The pink area represents some pieces that are now distributed closer to the mean value and lie inside the green area.



A narrower weight distribution also has negative effects. As is displayed in the graph figure on the right, with the narrowed distribution the input pieces lie closer to the mean value of 200 gram. Depending on the order that is being processed, fewer or more combinations can be made with a narrower weight distribution. If, for instance, an order requires most of the products to be around 180-185 gram to provide the best and allowed combinations, then the narrowed weight distribution in the image on the right will decrease the throughput for this order. The pink area is moved towards the green area, while the pink area provides the best input pieces.

Parameter: Length distribution
Weight and size are mutual correlated with each other. A wider weight distribution means a wider length distribution of incoming pieces. The same relations of the weight distribution count for the length distribution.

Parameter: Quality distribution
The quality of input pieces and the required quality of ordered products are important to each other. Orders with high quality standards are in need of an average high quality of input pieces. Routing high quality input pieces to portion cutters which process for high quality products will result in better **(+) order completeness** and more **(+) Yield** (less trimmed, other/uncut and secondary pieces). If there is a lack of input pieces with the right quality, input pieces with an even higher quality can be used to fulfill the order. This will increase the **(+) throughput, (+) order completeness** and **(+) yield.** But at the cost of **(-) utilization of piece quality** since high quality pieces are processed for orders that require lower quality input pieces.

Variables: Average weight, length and quality, shifting of distribution
An increased **(+) average weight** or **(+) average length** fits the minimum and maximum weight and length boundaries better or worse, depending on their values. The **(-) reject rate** decreases if the gap between the average weight and length closes in on the center of the allowed weight and length ranges, assuming pieces are normally distributed. In short, more pieces fit within the ranges and fewer pieces are rejected, resulting in **(+) yield** and **(+) throughput**.

The path of input pieces, whose weight and length is known, could be more optimally routed to the portion cutter with the best fitting order characteristics (reflected by the portion cutter's program and other things). Furthermore, by knowing the estimated width of the weight, length and quality distributions of pieces per flock, pieces can be matched more optimal with portion cutters.

The section is summarized:

- Expected distributions can differ from the actual distributions. To react on these deviations, pieces can be routed to portioning with the best matching orders. By doing this properly, this will decrease the **(-) reject rate** and increase **(+) throughput, (+) order completeness, (+) yield.**
- A wider distribution than expected will impact the KPIs, depending on the orders that are being produced and the current values of control variables. Thus, the current processed orders at a portioning cutter must be one of the reference points in rerouting pieces.

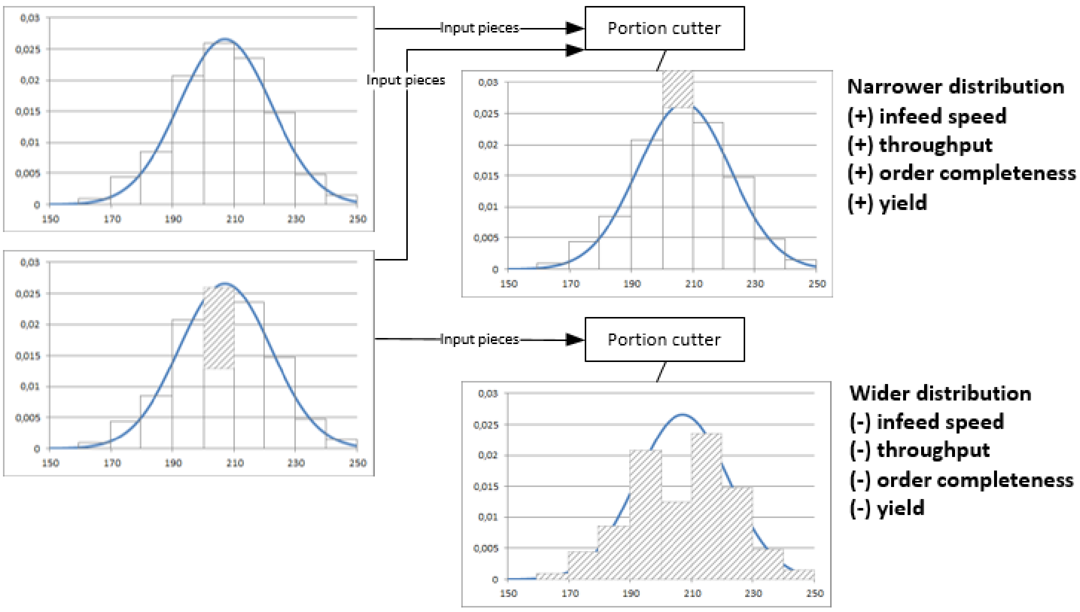
Measure 1: Flexibility in order processing
From measure 4-6 from the planning section it became clear that orders can be matched to increase the **(+) throughput** for one specific order. Nevertheless, this is bad for the **(-) yield** since more trims and cuts must be made.

Measure 2: Maintenance
Scheduling maintenance during the production is needed if a machine has problems. Commonly, this is a forced measure to solve problems related to bad performance on yield or throughput. The measure affects the **(--/+) availability, (-/+) order completeness, (+) yield, (-/+) throughput** differently.

Measure 3: Change the routing of input pieces
The infeed speed describes the total input pieces per minute that arrives at a portion cutter. Increasing the **(+) infeed speed** may increase the **(+) throughput** of end products at the portion cutter and can be done by:

1. Routing more pieces to a portion cutter which otherwise would be routed to and processed by another portion cutter or process.
2. Or increasing the overall speed of the production line.

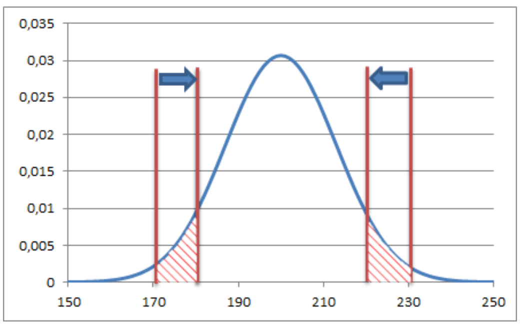
Option 2 is limited. With option 1, the pieces distributions (weight, quality, size etc.) might become wider or narrower.
Certainly, for the other process the infeed speed will decrease and the input pieces distributions will change. A scenario is illustrated in the image below. Well-fitting input pieces from a weight distribution are routed to another portion cutter instead. This is the gray striped area in the bottom-left diagram.



Measure 4: Exceeding levels of capacity
Aside from chancing the routing of input pieces to optimize the match between input pieces and orders, it can also be used in order to reduce the line-restrained time of processes or increase the resource utilization both labor and capacity-wise.
Reducing the **(-) throughput** of input pieces will reduce the throughput of products. Processes have different levels of capacity that, if exceeded, require more and more labor. There is a trade-off between **(-) throughput, (-) capacity utilization** labor and capacity-wise. Lowering the throughput could be a wise measure if the infeed speed is lower than the current capacity of the process.

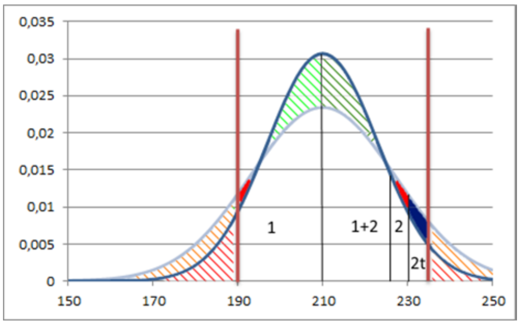
Control

Measure 1: Chance min/max weight
In a portion cutter, the input pieces can be rejected if their weight is not complying with the maximum and minimum weight.
Decreasing the range of min/max weight will result in an increased **(+) reject rate** (red striped area in the image). However, depending on the order that is produced for, the new weight boundaries will either decrease or increase the trimmed and secondary products.
To illustrate this, example 1 is used again:



Again, we have two orders. If the max weight increases, the right red line will shift further to the right allowing more input pieces to be processed for order 2 (with requiring trimming). There is an increased throughput, but at the cost of trimming excessively resulting in less yield. If the max weight is decreased, the opposite effect occurs.

If we decrease the min weight limit, very light input pieces are allowed which can only be processed for order 1. Half of a fillet can be cut into a schnitzel, while the other half is too light. It is probably not worth reducing the min weight limit if the throughput for order 1 must be increased. Instead increase the max weight limit and do more significant smaller trimmings to increase the throughput of order 1.



At control level, the throughput can only be increased if, in example, the **max cuts/min** is increased too. As a consequence, less precise cuts are made at the cost of **(-) Yield** and **(-) product quality.** Furthermore, a higher infeed speed will result in a lower **(-) infeed quality** due more errors in scanning products.

The **product aesthetic** might suffer by changing the **min/max weight**. More trimming activities will result in more different shaped and sized products.

Measure 1: Chance min/max length

The same option for the minimum and maximum weight is available for the length of incoming pieces. Increasing the range of **(+) min/max length** will decrease the **(-) reject rate** and increase **(+) throughput**. Depending on the order(s) that is being produced for, more or less secondary products of the total input pieces will be created. For instance, if the allowed maximum length for input pieces is increased but this length is still situated within the required length of the ordered products there will not (necessarily) be an increased rate of trimmed and secondary products.

Orders can have strict requirements for their product shape, weight and sizes. The portion cutter's program must comply with the requirements. At the cost of **(-) Yield**, the portion cutters can deliver orders on time by increasing the range of **(+) min/max weight** and **(+) min/max length** for a higher **(+) throughput.** Note that the **(-) reject rate** is decreased, thus **(+) Yield** will also increase.

Measure 2: Calibration

Frequent **(+) calibration** may increase the **(+) weight accuracy, (+) scan accuracy** of the length and shape of incoming pieces, and the **(+) cut accuracy** (knife positioning). As a result, the (+) Yield and **(+) Product quality**, but the **(-) Availability** decreases.

Other variables

Knife cutting angle, distance between knifes, knife cutting height (dependent on the type of portion cutter).

Batching:

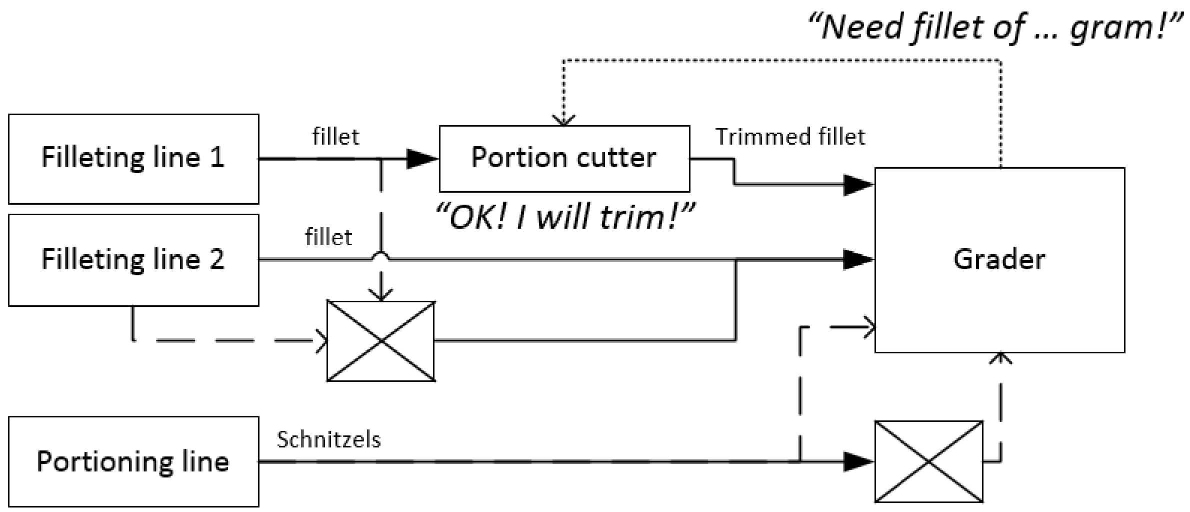
Planning

For the batching of products, most of the information covered by portioning is applicable here. However, making combinations in the batching process consist of matching different products to fill a tray, while portioning will cut a piece in order to fulfill one or several orders.
The batching process can receive input pieces from one of two different preceding processes; portioning or the trimming line.

Important planning restrictions are:

- There can be batched for up to 3 different trays at the robobatcher. A robobatcher can only batch 3 different trays at the same time, but produce for more than 3 orders.
- Graders connected with portion cutters will be limited in what orders can be batched for. The flexibility in chancing the routing of input pieces for such graders is limited too. In planning, the routing of input pieces from portion cutters to graders should take into account the effects on and created limitations for the batching process.
- Spreading orders throughout the day is less important because almost any input piece has to be batched, in contrary to portioning. Spreading the orders between graders is of course beneficial.

Measure 1-2: Planning a grader with linked portion cutter, planning the processing of orders with buffers
A buffer system can be used in batching too.
More importantly, a portion cutter can be linked with a grader to trim input pieces into specific required weights. The grader will request input pieces with specific weights from the portion cutter that are needed to fill specific trays. This will increase the **(+) throughput,** reduce the **(-) giveaway** resulting in more **(+) yield,** but both at the cost of some yield that is lost with the trimming tasks. Also, an extra portion cutter is required which will only need to make a few trims. This is poor **(-) capacity utilization,** if the batched order is not by origin a portioning order.



The capacity of graders is limited. If a robobatcher's capacity is exceeded, excessive input pieces will be rejected. For a multihead weighter, pieces cannot be batched properly with overcapacity.

Measure 3-4: Matching orders with flocks, Matching different types of orders
Combining orders so that they cover as much of the weight distribution and fit the quality distributions well, will decrease the giveaway and increase order completeness.

If the same two orders of 400 and 600 gram trays are processed together and an order with 700 gram is added, it will help in covering more of the input pieces distribution since this order will use heavier and lighter fillets to fill up a tray.

Selecting and matching orders that cover more of the input pieces weight and size distributions will result in a lower **(-) reject rate, (-) giveaway,** and a higher **(+) throughput** and **(+) order completeness.**

Orders of high quantities which require similar input pieces and orders with early order deadlines can cause difficulties when they are combined.

Measure 5-6: Amount of orders, Amount of trays
Combining more orders is beneficial in the same way it is for the portioning process. Urgent orders can be prioritized in the batching process. Combining less and more urgent orders will create flexibility to increase the throughput for specific urgent orders.
If two orders of 400 and 600 gram trays will be processed together, it created the flexibility to increase the throughput for one of the two orders since both orders use the same input pieces. This, of course, negatively affects the throughput of the other order. Batching for more different orders (thus tray types) at the same time will increase the possible batch combinations, reducing the **(-) reject rate**, **(-) giveaway** and increasing the **(+) throughput** and **(+) order completeness.**

Measure 7: reduce the chance for unexpected events
See measure 7 in the process *portioning* in planning section.

Scheduling

Variables: Weight distribution and Average weight
Comparable to portioning, the weight distribution of input pieces is matched with specific orders to reduce the **(-) giveaway, (-) reject rate** and **(-) yield,** and increase the **(+) throughput** and **(+) order completeness.** The weight distribution's width can change if other input pieces are routed to the grader than before. This can happen when an order is urgent and the throughput for this order must be increased. Commonly, the distribution will widen since flocks are processed for less suitable orders than before. A weight distribution's width can also change if different input pieces are directed to the grader, in example if input pieces from a different (new) flock arrive.
Depending on the current orders, weight distribution and grader settings, a change in the weight distribution will affect the KPIs differently. In a normal situation, a wider **(+) weight distribution** will result in an increased **(+) reject rate** since more input pieces are outside the allowed weight ranges. A higher reject rate will result in decreased **(-) yield, (-) throughput** and **(-) order completeness.** Furthermore, a wider distribution will affect the different kind of combinations that can be made, and how frequent these combinations can be made. For instance, if a wider distribution will result in fewer quantities of 190 to 210 gram fillets but more fillets of other weights while 400 and 600 gram trays are being batched, less suitable combinations can be made. This effect will also play on the **(-) reject rate, (-) throughput, (-) order completeness** and **(+) giveaway.**

Measures 1-4
The same measures are available in the batching process as in the portioning process. See measures 1-4 in *portioning* in scheduling section.

Measure 1: Change the routing of input pieces, infeed speed
Increasing the **(+) infeed speed** by making changes in the routing scheme might increase the **(+) throughput**, but at the cost of a hastier batching process with more mistakes. In case of the robobatcher, it might happen that the robobatcher is too busy to process all incoming pieces. As a result, the **(+) reject rate** will increase and **(-) Yield** is lost. Also, the robobatcher might more

frequently position a product in a tray wrongly. This will have consequences for the **(-) product quality** and **(-) resource utilization** that is used in manually fixing more trays.

Measure 2: Maintenance
More and better **(+) maintenance** increases the **(+) weight accuracy** and **(+) availability** of the process. But also decreases **(-) availability** for the planned maintenance.

Measure 3: Change the routing of input pieces
This option is limited since a grader is connected to a limit set of portion cutters or fillet lines.

Measure 4: Exceeding level of capacity
Increasing the throughput of the process which exceeds a level of capacity will form a trade-off with **(-) resource utilization.**

Control

Measure 1: Tray pattern complexity
A better, more simplistic tray pattern will result in less dispositioning of pieces and increase the **(+) product quality** aesthetic-wise. This is, with the help of employees fixing the aesthetic of batched trays, probably an insignificant gain on product quality. In addition, more complex tray patterns might be more attractive. In case of the robobatcher complex tray patterns will decrease its capacity and might end up too busy to batch all incoming pieces.
Batching trays becomes more difficult and complex when sizes of input pieces deviate more.

Measure 2: chance min/max weight
See measure 1 in *portioning*'s control section.

Measure 3: increase target weight
The target weight in graders is the desired weight for a batched tray. Target weights can be set for every order that is processed. Increasing the **(+) target weight** will increase the **(+) giveaway**, and is for this reason only handy if catch weight batches are produced. Here, the weight distribution can be matched as optimal as possible with the tray weights using the target weight. For fixed weight batches, the target weight is responsible to ensure a sufficient throughput of trays to fulfill orders on time, but limit the giveaway. In combination with controlling the **Tolerance**, the balance between the throughput of trays and giveaway can be made optimal.
The target weight will also affect the making of combinations, depending on the weight distribution. To illustrate this, a simplistic example is given:

Product type: 400 gram trays
Target weight: 401 gram
Tolerance: -2 to +4 gram
Weight distribution: normal distributed with 202 mean and a deviation of 13.

Increasing the target weight from 401 to 404 will increase the throughput, since more combinations can be made that end up close to 404 gram with a weight average of 202 gram for input pieces. However, the giveaway is higher since heavier batches will be made. Decreasing the tolerance to -5 and +1 will allow all the batched trays between 399 and 405 gram. This will decrease the throughput. Both 'settings' have the same allowed weight range for trays, but the second setting will have a higher throughput and more giveaway.

Measure 4-5: Increase – or + tolerance

By increasing the allowed **(+) overweight** with the target weight as starting-point, the total **(+) giveaway** will increase too. However, the batcher can make faster matches and fewer pieces will be rejected (e.g., for 'job not found'). This will increase the **(+) throughput** of trays and thus orders can be completed quicker (**(+) order completeness**).
Increasing the allowed **(+) underweight** will also increase the throughput of trays and order completeness. Also, it reduces **(-) giveaway** but the underweight must be compensated and allowed.

A tray of 400 gram and 600 gram fillets require resp. 2 and 3 fillets to be batched. It is handy to set a narrower tolerance and a target weight with lower giveaway for the smaller trays than the bigger trays. Only a few combinations with low giveaway can be batched into 400 gram trays, while many more combinations can be batched into 600 gram trays with also a low giveaway.

Measure 6: less strict min/max count per tray
The minimum and maximum pieces per package are normally order defined and restricted and thus cannot be played with. The same counts for the **tolerance** and **tray patterns.** Nonetheless, if there can be played with any of these, it certainly affects the throughput and giveaway.
If the min/max pieces per package has a wider range, more allowed batch combinations can be made quicker. More combinations and flexibility in making combinations will reduce the **(-) giveaway** and increase the **(+) throughput.**

Measure 7: Less strict min/max weight limit
Some orders specify the weight range of an individual piece in a tray, to reduce weight variances between pieces. More strict limits will increase the **(+) reject rate** and reduce the **(-) throughput**, **(-) order completeness** and **(-) giveaway.**
The other way around the min/max weight limit can be made less strict (wider range) with opposite effects. This is a flexible measure to increase the throughput for orders at the cost of more **(+) giveaway.**

Measure 8: Calibration
Monitoring the **Weighting accuracy** and improving it by recalibration is important. However, recalibration might decrease the **(-) availability** of the process.
Increased **(+) weight accuracy** will result in less **(-) giveaway** and lower **(-) reject rate** of batched trays with too much underweight.

Parameter: Weight accuracy
All graders weight input pieces differently. A robobatcher weights before pieces enter the grader. Thus, the weight of some input pieces (which still have to be batched) is known. While the multihead weighter weights one input piece and batches it immediately into one of the batch bins.
The accuracy of weighing input pieces is not completely precise. Minor but consistent errors and fluctuating errors occur. Since trays are batched and the weight must comply with the **Estimated sign rules**, even minor errors can cause the rejection of trays due under- or overweight.
A better **(+) weight accuracy** will cause less cases of under- or overweighed trays that are rejected after batching, but also reduce the **(-) giveaway** since trays can be batched more precisely and closer to the target weight.

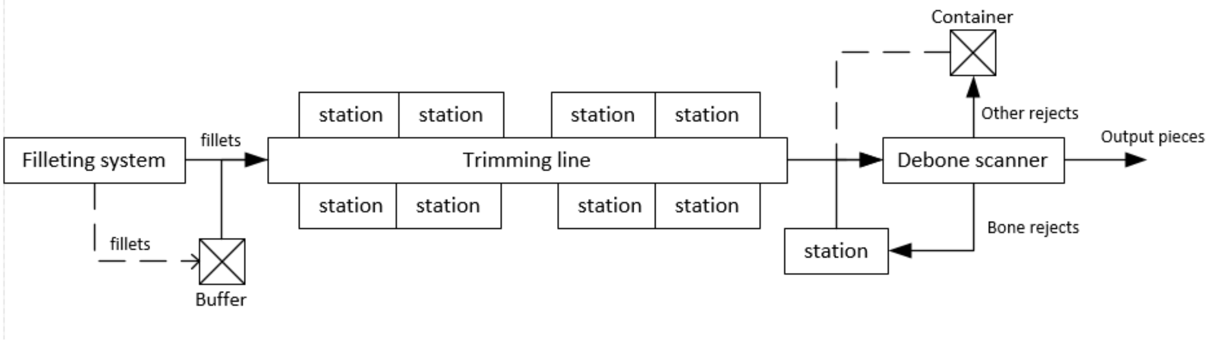
Information: Monitoring
During a day, batchers are monitored on different KPIs.
For every pack type, the overweight (%) and target weight versus actual weight is monitored.
For every batcher, the Throughput (pcs/min and kg/h), reject rate (%), input history (per bin range) is monitored.
Commonly, if thresholds on reject rate (%), overweight (%) and giveaway (%) are not exceeded the operators do not adjust the control process to improve the performance on these KPIs.

Trimming and deboning:

Planning

The trimming line consists of several trimming stations. Every station has one employee. Input pieces are routed to the station and trimmed. Since trimming is a labor intensive process and manually done, **resource utilization** (labor), **yield** and **throughput** are the important KPIs.

To give an idea how a trimming and deboning set-up looks like, a rough example is given.



Measure 1: Matching orders with flocks, per line
Trimming lines are highly dependent on the quality of flocks and performance of preceding processes. Fillets from FHF lines require in general more and heavier trims and encounter more defects.

Measure 2: Labor capacity planning
The capacity of the trimming line is dependent on the available labor. More **(+) labor** is more capacity**.** There is a maximum of trimming stations available per trimming line which, combined with the throughput of employees, define the maximum capacity.
The required capacity at the trimming line is dependent on the infeed speed of input pieces.

Measure 3: Reduce chance for unexpected events
See measure 7 in *portioning* in planning section.

Scheduling

Measure 1-3
See measures 1-3 in *portioning* in scheduling section.

Measure 4: Adjusting labor between lines
On scheduling level, labor can be adjusted between trimming lines to increase their capacity and throughput. Labor can also be adjusted from other processes to the trimming line.

The trimming lines are labor-intensive processes, therefore it is important to utilize their capacity efficiently.

Variables: Deviations in distributions of input pieces
A wider **(+) distribution** of input piece's weight and size will result in worse performance of preceding processes. This will result in more and longer trimming tasks, thus lower **(-) throughput** and lower **(-) yield**. If the decreased throughput will cause other processes to be line restrained, the **(-) order completeness** is also negatively affected.

Control:

Measure 1: Width of the debone scan laser

After the trimming line, the debone scanner (SensorX 502) is used to check for any bones left in input pieces. A scanned piece can receive one of the three categories:

- *Bones*
- *Other rejects*
- *No bones*

The **reject rate** at the debone scanner is a rough indicator for the performance of the trimming lines and wishbone removing process. However, the occurrence of 'other rejects' have to do with the **infeed quality** of input pieces. If a piece cannot be scanned, it is flagged with:

- *Too long,* for pieces which are too long.
- *Gap too short*, for pieces could not be scanned because the gap between other pieces was too short.
- *Out of bounds***,** for pieces that were flagged as out-of-bounds.
- *Unhandled,* for pieces that could not be handled for some other reason.

A lower **(-) infeed speed** will result in a less 'other rejects', since the employee that has to repositioning input pieces can do a better job.

The **(+) throughput** of the debone scanner can be increased if the scan width is increased, at the cost of the scanner's **(-) accuracy**. The accuracy is also worse if the input piece's thickness increases. Thus, a wider distribution of input pieces (thickness-wise) will decrease the throughput. The scanner can have a perfect accuracy and this is aimed for.

Measure 2: Calibration

If there is a high reject rate or yield loss at the trimming or deboning, it might need recalibration. Improving the weight accuracy of trimming stations and scan accuracy of the deboner scan may result in **(+) yield** and **(-) reject rate.**

Measure 3: Adjusting labor within lines

On the level of control, the throughput for specific orders can be adjusted by managing the labor. If an order becomes urgent, more trimming stations can be assigned to trim for this order. The **(+) throughput** for the urgent order is increased, but this can be at the cost of **(-) yield**.

The **throughput** at a trimming line is dependent on the performance in preceding processes:

- Wishbone removing
- Tenderloin harvesting
- Fillet harvesting

Poor performance of these processes will result in more and longer trimming tasks, which decreases the throughput and capacity that is produced at and cause yield loss.
Every employee is monitored on yield and throughput. There is a live system to switch and assign employees to different trimming stations and between lines. This creates a lot of flexibility on scheduling and control level and must be taken into account when planning the capacity of trimming lines.

Filleting system and harvesting

Variables

There is not a lot of flexibility available to adjust the planning. The capacity at which can be produced is restrained by the infeed speed defined by preceding processes. A higher **(+) throughput** will not affect the performance of the wishbone removing process and other automated parts of the filleting system, according to marel's information manual of the wishbone module and filleting system. There is no reject rate monitored in the filleting system, with an exception on the breast cap deskinning module. In this module, the breast cap is deskinned. The succession of removing the breast cap skin is affected by the performance of the leaf fat removing module. If the skin is not properly removed (thus as a result of poor **(-) infeed quality**), it is done manually at the cost of **(-) yield**, **(-) product quality** and **(-) throughput** of the process. Decreased yield and product quality is the result of breast cap meat that is accidently pulled off with the skin in the deskinning process.

In the filleting system, cuts are made in the breast cap in order to manually pull off its fillets and tenderloin. A better **(+) accuracy** of the cuts will result in more **(+) yield** in the fillet and tenderloin harvesting modules. The yield loss at the harvesting modules is not monitored per employee. However, the **(+) performance of employees** might affect the **(+) yield**.
Harvesting the tenderloins and fillets is done by hand. A too high **(+) infeed speed** will give employees less time to carefully pull of the pieces. The **(+) throughput** might increase but at the cost of **(-) yield.**
A wider **(+) weight and size distribution** of incoming pieces affects the **(-) accuracy** of the cutting modules.

Furthermore, by increasing the throughput more **(+) labor** is required to keep up with capacity at the fillet and tenderloin harvesting modules. Adjusting the required labor between lines is a scheduling activity where **capacity allocation** is a KPI. The resource allocation is both related to labor- and capacity utilization.

Planning

Measures 1-2: Planning the processing of orders with buffers, matching orders with flocks
Measures 1 and 2 are discussed in *portioning* in planning section with resp. measures 3 and 4.

Measures 3: Labor capacity planning
See measure 2 of *trimming and deboning* in planning section.

Measure 4: reduce the chance for unexpected events
See measure 7 of *portioning* in planning section.

Scheduling

Measure 1-3: Flexibility in order processing, maintenance, change routing of input pieces
Measure 1-3 can be found in *portioning* in the scheduling section at measures 1-3 respectively.

Measure 4: adjusting labor between lines
Within the lines, labor can be adjusted around between the tenderloin and fillet harvesting modules for better **(+) resource utilization**. This might improve the **(+) throughput** for otherwise restrained lines due a lack of labor.

Control

Measure 1: calibration
The filleting system has weight, scan and cut modules. Calibration will increase **(+) weight, scan and cut accuracy** of these modules. In particular a better scan and cut accuracy for the filleting system is

important for the harvesting process. Here, better accuracy will lead to more the **(+) yield** since the fillets are pulled off better.

Measure 2: Adjusting labor within lines

The harvesting stations require several employees. Adjusting employees between the fillet harvesting and tenderloin harvesting modules may increase **(+) capacity utilization.** Currently the yield and throughput of individual employees is not recorded making the proper adjusting of employees difficult. Some employees perform better than others if the process is in a hasty state, having the right employees at the right line will therefore increase **(+) yield.**

Appendix F. Overview of decisions in secondary process with flow charts

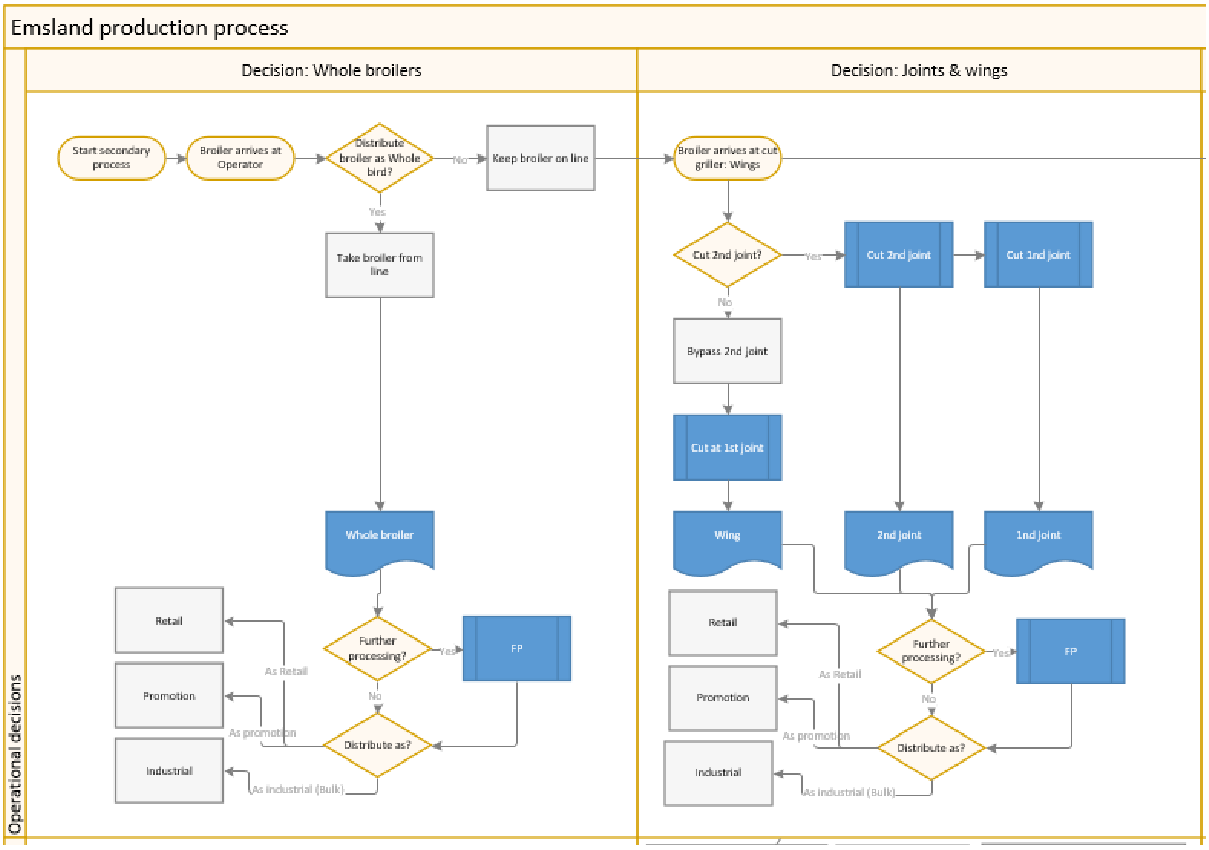


Figure F.1A Flow chart with the decisions made in the secondary process that defines a products path.

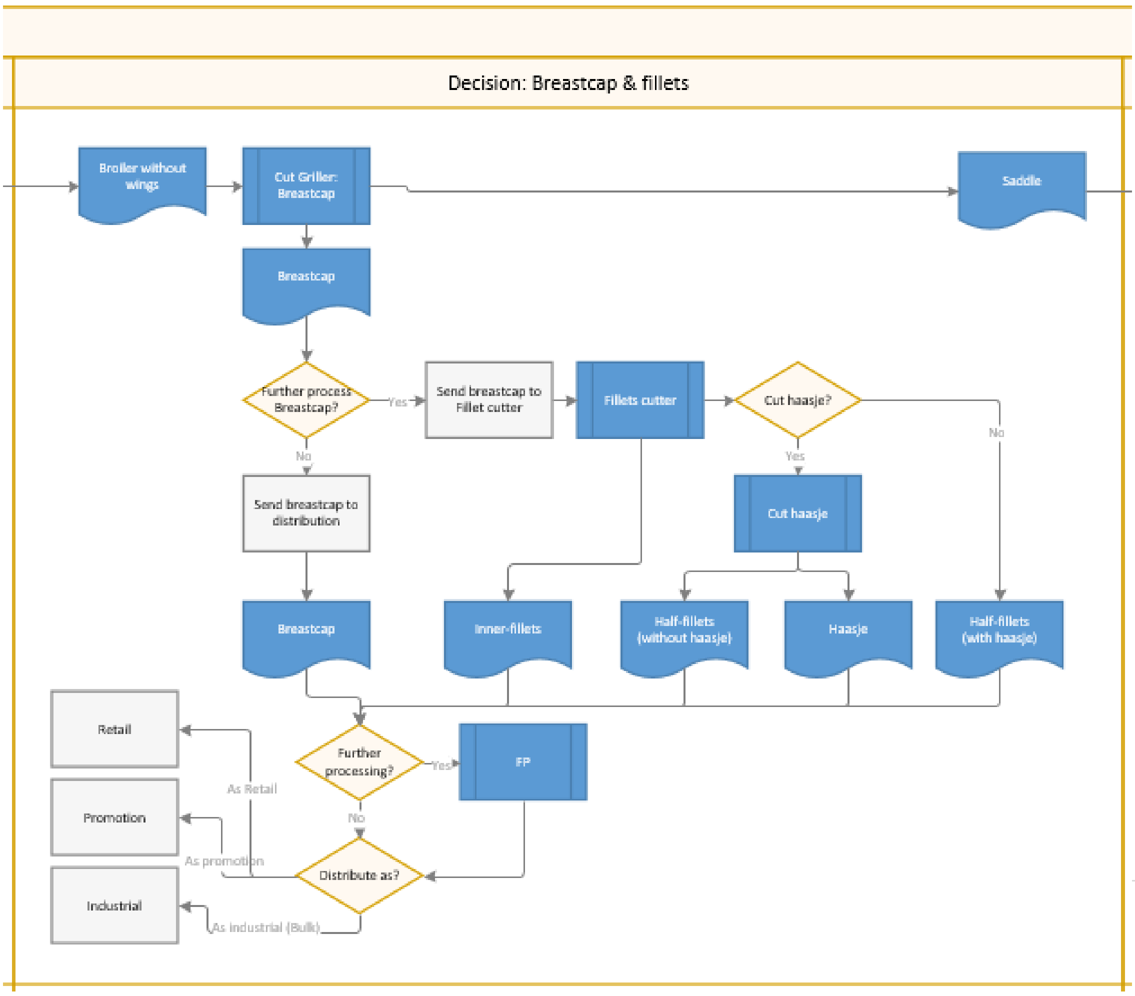


Figure F.1B

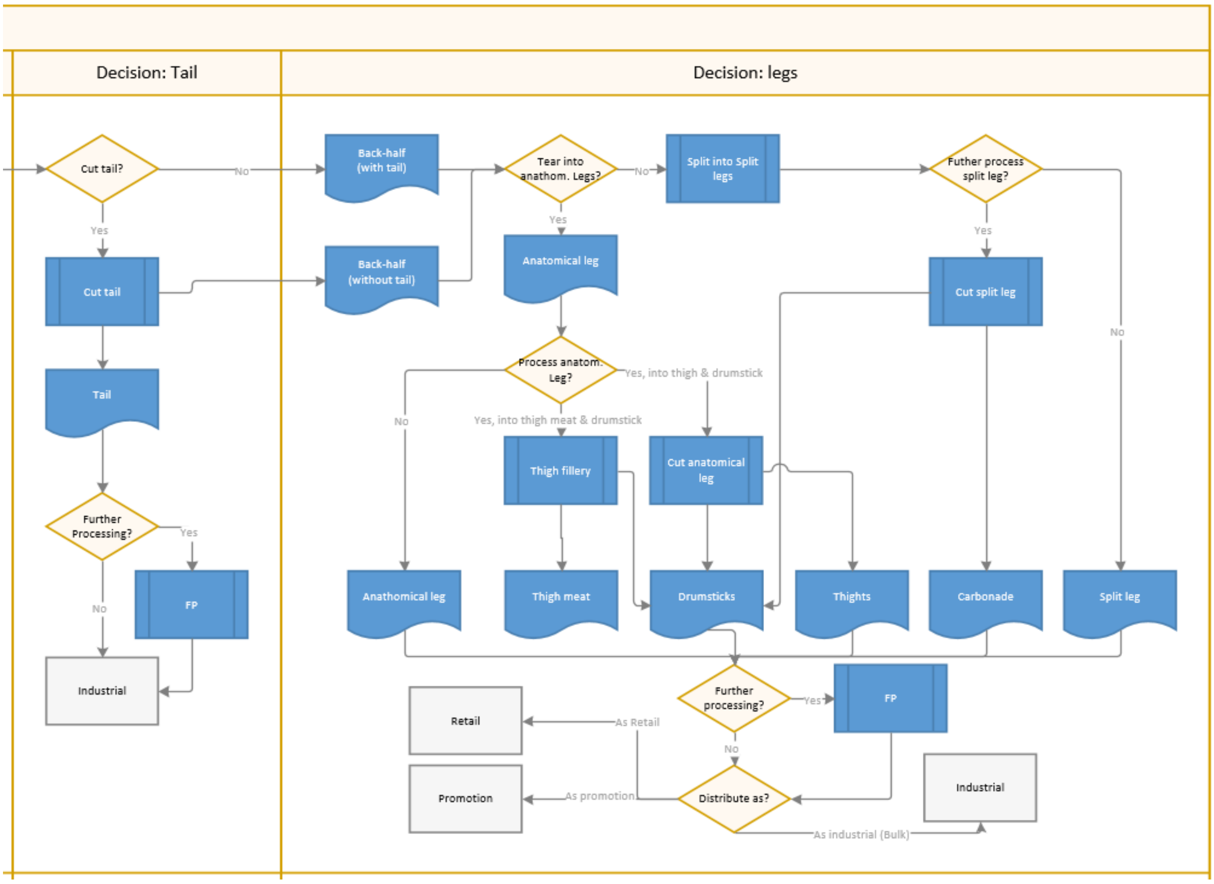

Decision: Tail
Decision: legs
Cut tail?
No
Yes
Cut tail
Tail
Further Processing?
Yes
No
FP
Industrial
Back-half (with tail)
Back-half (without tail)
Tear into anathom. Legs?
No
Yes
Split into Split legs
Futher process split leg?
Yes
No
Anatomical leg
Cut split leg
Process anatom. Leg?
Yes, into thigh & drumstick
No
Yes, into thigh meat & drumstick
Thigh fillery
Cut anatomical leg
Anathomical leg
Thigh meat
Drumsticks
Thights
Carbonade
Split leg
Further processing?
Yes
No
FP
Retail
As Retail
Promotion
As promotion
Distribute as?
As industrial (Bulk)
Industrial

Figure F.1C