OPERATIONS STRATEGY
Orange Climate Waterloo

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OC WATERLOO

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Orange Climate Waterloo

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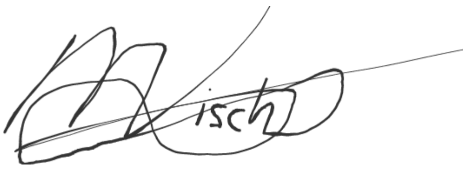
PREFACE

This research is the completion of the Master Business Administration programme with a specialisation in Digital Business at the University of Twente. The thesis focuses on the development of an operations strategy for OC Waterloo. I have worked on this thesis from January till the start of July 2021.

Firstly, I would like to thank Petra Hoffmann for her excellent and thorough feedback on my thesis. This feedback not only helped me to write the operations strategy, but I also learned from it and enjoyed it a lot. Second, I would like to thank CEO Paul Lustig for making this research possible and providing the resources for executing the research. In addition, I am also grateful that I was allowed to be present at OC Waterloo, especially in a year where all the studying took place at home. Thereby, I would like to thank OC Waterloo's employees for their willingness to help, the valuable data and the great time I had.

Lastly, I would like to thank my family and friends for their tremendous support during this study.

Enjoy reading,



Maurits Visch

Holten, June 30, 2021

MANAGEMENT SUMMARY

Situation: The demand for OC Waterloo's products have risen. Hence, OC Waterloo's turnover over the last five years has increased from 4,5 million euros to 8,5 million euros. As a result, the demand for OC Waterloo's operations has risen. Therefore, OC Waterloo has invested heavily in its operations. In total, these investments were 1,2 million euros. Although OC Waterloo has made investments in its operations, there are still several problems in the production facility. The most important problems are: exceeding delivery dates, a high lead time, over utilization of machines and personnel, digitisation issues with planning and data, a lack of support for changes and the personnel does not have the same focus, in terms of growth, towards the future of the operations facility.

Complication: Although OC Waterloo is working on these problems, a clear strategic operations plan is lacking for the future. For this reason, OC Waterloo has made investments that did not contribute to the improvement of the operations. Thereby, OC Waterloo is not making the best of its current resources and questions whether they have the right focus in the operations facility. Considering OC Waterloo is growing, an operations strategy is needed to be able to cope with the adaptions and or/upscaling of the operations. An operations strategy provides a well-thought-out plan for that.

Question: Therefore, the goal of this research is to develop a strategic plan for the operations facility which is in line with the strengths of the current production facility, business strategy and market's needs. Therefore, the following central research question has been answered:

What should the Operations Strategy of OC Waterloo become and how could it be implemented for the following 5 years, so that it is in line with the strengths of the current production facility, business strategy and market's needs?

The question has been answered using a literature review, data analyses and semi-structured interviews.

Answer: OC Waterloo's desired competitive priorities are not in line with the competitive priorities OC Waterloo currently focuses on. OC Waterloo and the external environment desire flexibility and time/delivery. However, OC Waterloo focuses on flexibility and costs. Therefore, OC Waterloo needs to shift its focus from costs to time/delivery. OC Waterloo should do this by implementing Quick Response Manufacturing in the organisation. The main focus should be reducing the Manufacturing Critical Path Time to 30% of the current Manufacturing Critical Path Time. OC Waterloo should do this using a three-way strategy (variability, utilization and batch size). The batch size should be reduced to 20% of the current batch size, the machine's and personnel's utilization needs to be reduced to a maximum of 75% (except for the bottleneck) and the variability needs to be measured and reduced in the process. This should be done to improve OC Waterloo's competitive priority time/delivery. Furthermore, OC Waterloo should insource the powder coating, select a new ERP system based on QRM's, Industry 4.0's and the company's requirements and train its employees to get sufficient knowledge of QRM. Thereby, OC Waterloo should expand the QRM strategy across the entire organisation.

To implement the strategy, OC Waterloo should appoint a QRM facilitator, a QRM steering group, a QRM cross-functional scheduling team and a QRM implementation team. The strategy should be deployed and monitored using the Hoshin Kanri model/X-matrix.

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UNIVERSITY OF TWENTE.

1 INTRODUCTION

This report is the master thesis about the operations strategy of OC Waterloo. In this section OC Waterloo, the product range, the production department, the situation and complication, the focus of the central research question and the contribution will be described.

1.1 OC Waterloo

OC Waterloo B.V. is a company specialised in air distribution equipment (such as air grills and roof hoods) based in Holten, province Overijssel. OC Waterloo is part of the Orange Climate Group and has around 65 FTE employees. The Orange Climate (OC) Group is a group of producers specialised in air handling units, air terminal devices and ducting (Orange Climate, n.d.-a). The slogan of Orange Climate is, therefore: “We care about healthy air” (Orange Climate, n.d.-b). Orange Climate consists of OC Autarkis, OC Verhulst, OC Waterloo, OC Agri, OC Filtration Solutions (which is part of OC Verhulst), the just acquired OC IMP Klima based in Slovenia and two firms in Dubai (Orange Climate, n.d.-b). The Orange Climate group has a total of 400 employees.

OC Waterloo was founded in 1971 (Orange Climate, n.d.-c). However, it was founded as a European factory for Waterloo Air Products plc. from the United Kingdom (Orange Climate, n.d.-c). The shares of Waterloo have been sold in 2011, since then, Waterloo became part of the Orange Climate group (Orange Climate, n.d.-c). Figure 1-1 shows an organisational chart of OC Waterloo.

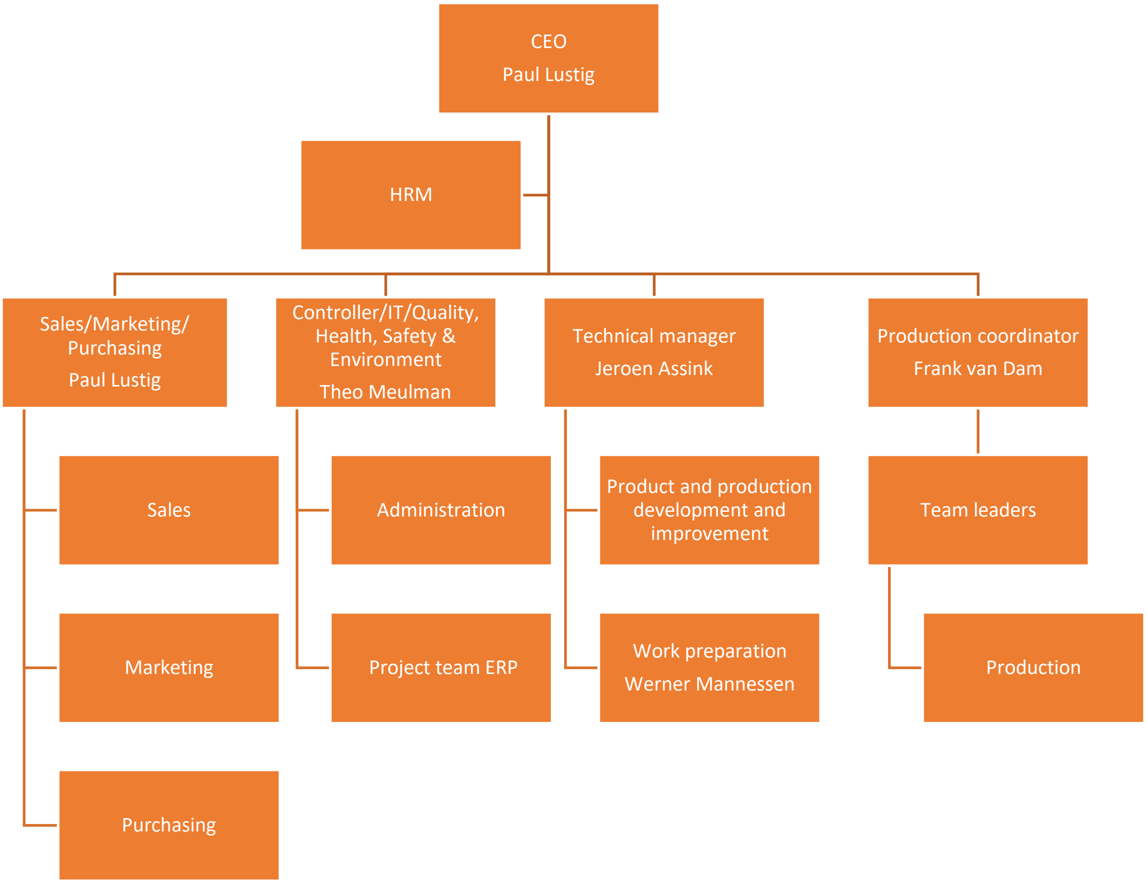

Figure 1-1 Organisational chart OC Waterloo

1.2 Product range

OC Waterloo produces/delivers ceiling grills, wall and duct grills, fire dampers, outside air grills/roof hoods, door and wall grills (transit), induction units, volume control dampers, floor grills, fan coils, industrial grills, appendages, air handling units and innovative sustainability with PCM (Phase Change Material (Orange Climate Waterloo, n.d.). Figure 1-2 shows an example of an outside air grill/roof hood and Figure 1-3 shows an example of a ceiling grill.

Figure 1-2 Outside air grill/roof hood

Figure 1-3 Ceiling grill

1.3 Production department

The production department of OC Waterloo is divided into four departments: sheet metal department, outside air department, air vents department and end-assembly/transport. The departments are led by the production coordinator. Figure 1-4 shows the organisation of the production department of OC Waterloo.

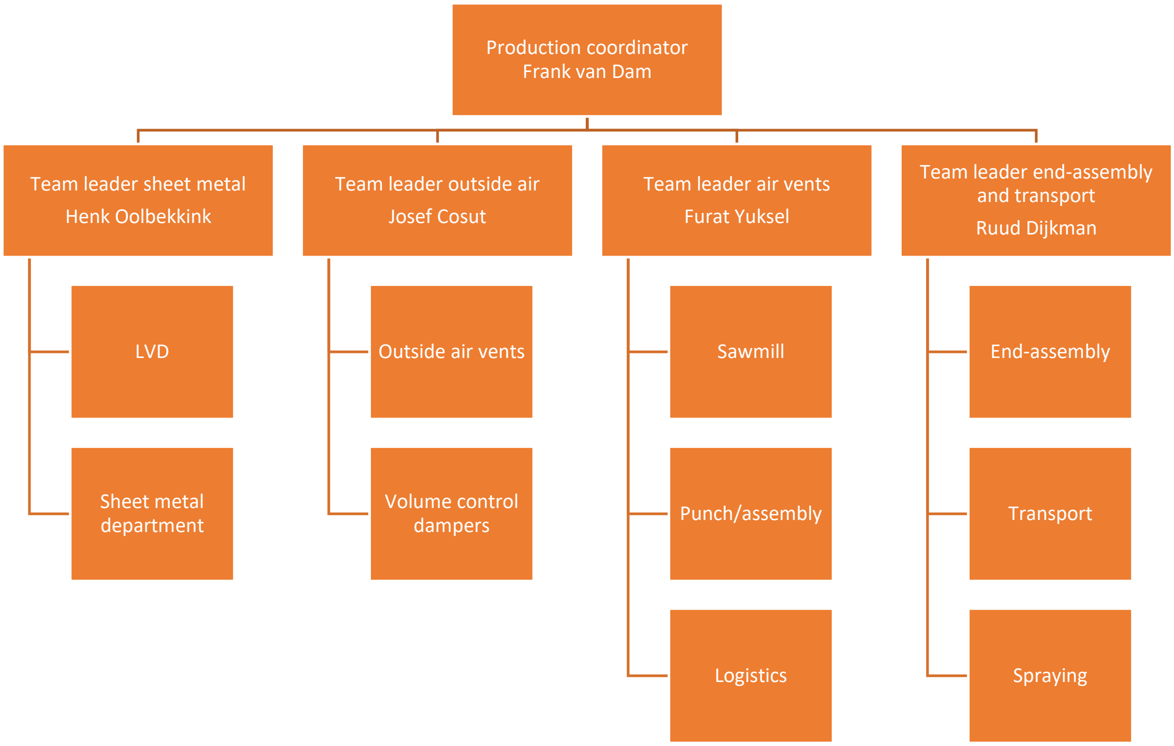

Figure 1-4 Production department

The production layout is shown in Appendix 1: Production map. The saw mill and the LVD punch nibbling machine are located on the right side of the production facility. The punching and assembly of the air vents are done in the middle of the facility. The sheet metal working is also done in the centre of the facility. The left side of the production consists of a test chamber, end assembly, volume control dampers and the welding and assembly of outside air vents. The flow in the factory is from right to left, so the production process starts at the saw mill and LVD punch nibbling machine.

1.4 Situation and complication

OC Waterloo's turnover has increased significantly over the past few years. The goal of the Orange Climate Group is to double its revenue every five years. The current turnover of OC Waterloo is 8.5 million euros. OC Waterloo's goal of the last five years was to increase their turnover from 4.5 million euros to a turnover of 9 million euros, so the firm almost reached its goal. As a result of the increasing turnover of the last five years, the demand for the production facility has risen too. To meet the higher demand, OC Waterloo has taken several steps. Firstly, OC Waterloo hired more production employees. Second, the company invested in advanced machineries, such as a:

- **LVD punch nibbling machine**. This machine can punch, nibble bend tap and form sheet metal. The end products are used in the further process.
- **Ciampalini fully automatic profile storage**. This machine stores profiles which are used in the sawing department. The machine automatically takes the necessary container for the products to be cut.
- **Safan press brake update**. After this update, the press brake programs can be loaded into the machines from the work preparation.
- **Several punch machines**. These machines are used to punch holes in the material to assembly the air vents.
- **Automatic saw measurement system.** The measurement system saves time in the sawing department because the employee does not have to measure the length of the product by him-/herself.

These investments were done in 1,5 years and the total costs of these investments were 1.2 million euros. Third, OC Waterloo and the Orange Climate Group are researching a possible new ERP system to further digitalise and optimise the firm(s) using this data from the ERP system.

Even though OC Waterloo is investing in machinery, IT and hiring employees. There are still several problems in their facility. According to the management team of OC Waterloo, the most important problems in the production facility are:

- Exceeding delivery dates. OC Waterloo has an average on-time delivery of 74%. Customers who order their product(s) early (earlier than the average lead time for that product) often get their products too late.
- Lead time too high. The lead time of the production is high, on average 8,2 days for a product which takes on average 265 minutes to make.
- Over-utilization of machines and personnel. The machines and personnel are often overutilized which leads to a higher lead time and disturbances in the process. Currently, the machines are planned and filled to 100% of the capacity.
- Digitisation of the factory is not working properly. The digitisation is not working properly because not every employee understands the digital boards and the data is hard to retrieve for the production leaders.
- Lack of support for changes by production personnel, because the personnel is working like this for years, so it is hard to change their way of working.
- Personnel does not have the same focus on the future of the operating facility. Mainly because there is no goal for the future. This also concerns a failed implementation of QRM.

OC Waterloo is currently working on these problems by conducting several improvement projects inside the company. Despite these improvement projects, a clear strategic goal and vision are missing for the production facility. As a consequence, the new CEO of mentions that OC Waterloo has made investments that did not contribute to improving the production facility. For example, an automatic saw was bought and sold after it turned out that the machine had to be changed over too many times. OC Waterloo is currently not making the best of its resources, therefore a strategic plan is needed. In addition, OC Waterloo questions whether they have the right focus in the operations. Furthermore, as explained earlier, OC Waterloo is growing. Therefore, a strategy is needed, because growth leads to adaptions and/or upscaling of the operations. A lack of strategy or problem-solving could lead to a reduced market share, due to unsatisfied customers. As a result this leads to a lower revenue and profit.

Moreover, OC Waterloo has changed its management. The previous Commercial Director became CEO in September 2020. Beforehand, the firm was managed by the owner of the group. The Orange Climate group has developed a strategy for the group. The Orange Climate group wants to double its turnover to 100 million euros in five years. Thereby, the holding group wants to have a stable EBITDA of 8% of the turnover in five years. The new CEO of OC Waterloo has applied this strategy to OC Waterloo. To be in line with the holding group, the goal for OC Waterloo is to double their revenue and increase their EBITDA to 8% in the coming five years too. Furthermore, the CEO developed a strategic sales plan for the sales department of OC Waterloo. The goal of this plan is to achieve the turnover increment.

Despite that OC Waterloo has developed a strategic sales plan for the coming five years, there is no strategic plan for the operations of OC Waterloo yet. OC Waterloo is a manufacturing company, so the operations of the company play an important role in the performance of the company.

In conclusion, OC Waterloo has invested 1.2 million euros in its production facility. Thereby, the most important problems are exceeding delivery dates, the high lead time and the malfunctioning digitisation. The improvement projects are pointed at solving these problems, but there is no long term strategic vision. The company's projected growth and a general strategic plan further provide the need for a strategic operations plan.

1.5 Focus of central research question

The goal of this research is to develop a strategic plan for the operations which is in line with the strengths of the current production facility, business strategy and market's needs. Furthermore, the advice about the operations strategy will be given to the management team of OC Waterloo. To fulfil the goal of this research, a central research question has been formed. The central research question sounds as follows:

What should the Operations Strategy of OC Waterloo become and how could it be implemented for the following 5 years, so that it is in line with the strengths of the current production facility, business strategy and market's needs?

To answer the research question, the question has been divided into sub-questions:

- What theories could be used to develop an operations strategy suitable for OC Waterloo?
- What is the business strategy of the Orange Climate group and OC Waterloo?
- What are the market demands regarding the operations of OC Waterloo?
- What are the strengths and weaknesses of OC Waterloo's operations?
- What should the operations strategy of OC Waterloo become?
- What improvements in operations are needed to achieve this strategy?
- How could OC Waterloo implement the operations strategy?

1.5.1 Scope of the study

The scope of the study is as follows:

- This study develops an operations strategy for OC Waterloo, not for the entire OC Group. Nevertheless, this research can contribute to an overall operations strategy by applying this operations strategy at other firms inside the OC Group. For example, OC IMP Klima produces similar products as OC Waterloo, therefore this strategy may apply to OC IMP Klima.
- The data for this research has been collected in the second and mainly fourth quartile of the study program Business Administration (MSc.).
- The study has been conducted at OC Waterloo and partly at home.
- The study has been conducted in the second and fourth quartile of the study program Business Administration (MSc.).

1.5.2 Deliverables

The deliverables of this study are an advice and implementation plan about the operations strategy of OC Waterloo to the management of OC Waterloo and the Orange Group. Thereby, this study delivers practical improvements which will reduce the lead time and thereby costs of the production facility. These practical improvements are developed using the analysis used for determination the operations strategy.

1.6 Contribution

Contribution to theory

The theoretical framework has shown that research in operations strategy and its competitive priorities are far developed. However, the theory on Quick Response Manufacturing is limited. Thereby, ERP systems have been pushed aside by QRM, even though most organisations use ERP systems (Suri, 2011). The reason for this is that ERP systems do not consider the effects of system dynamics (the understanding of behaviour of complex systems over time (Suri, 2011)) in operations. Therefore, ERP systems focus more on costs, which leads to higher utilization and higher batch size. However, OC Waterloo is currently selecting a new ERP system that can be configured to take system dynamics into account. For this reason, requirements for the new ERP system have been set up based on the three-way strategy (variability, utilization and batch size) mentioned by Suri (2011). The requirements are described in section 6.2.5. So, this research contributes to theory by developing ERP requirements based on Quick Response Manufacturing. The requirements contradict Suri's view by drawing up ERP requirements so that ERP systems can be used with QRM. Thus, the effect of considering system dynamics in ERP systems on operations' time/delivery needs to be examined in the future.

Contribution to practise

This research contributes to practice by advising on the operations strategy of OC Waterloo. Firstly, the aspects of an operations strategy are brought clear for the management of OC Waterloo. The operations strategy is essential for OC Waterloo's competitiveness and performance. Thereby, the operations strategy describes how OC Waterloo could reach its desired competitive position. The operations strategy aligns OC Waterloo's external environment with its business strategy and current resources/operations. In addition, the analysis of the external environment, business strategy and current resources/operations brings misalignments to light. The analysis of the four main competitive priorities of the current operations leads to practical recommendations to improve operations and thereby better match the desired market position. Lastly, the research delivers insight into the operations strategy of OC Waterloo for the holding firm Orange Climate. Orange Climate could use this strategy (if applicable) or this approach across multiple organisations inside the group.

2 THEORETICAL FRAMEWORK

This theoretical framework examines the literature of Operations Strategy. Furthermore, the theoretical framework leads to the development of the methodology section and could be used during the data collection and analysis. Section 2.1 covers the method for the literature review. Section 2.2 mentions the definition of an operations strategy. Section 2.3 gives the development of an operations strategy. Thereby, it gives insights into the business/sales strategy analysis and the external environment. Section 2.4 covers the competitive priorities of an operations strategy. In addition, it discusses KPIs and measurement methodologies to measure the competitive priorities. Section 2.5 discusses a maturity model for analysing digitalisation. Section 2.6 gives the most used manufacturing methodologies to build the operations strategy upon. Last, Section 2.7 gives a summary and conclusion of the theoretical framework.

2.1 Literature review method

This section provides the methodology for the literature review. According to Snyder (2019), a literature review has four phases:

- Phase 1: design;
- Phase 2: conduct;
- Phase 3: analysis;
- Phase 4: structuring and writing.

These four phases are used for this literature review. First, the design has been set up. The goal of this theoretical framework is to define (operations) strategy and subsequently dig into the development and measurement of the strengths and weaknesses of the operations of a company. Therefore, an integrative approach has been used. Firstly, a more narrow approach is used to define operations strategy. Thereafter, the approach became broader to analyse the criteria of a good operations strategy and how these could be measured.

Conducting the literature review has been done via Scopus and Google Scholar. Google Scholar has been included because it generally contains more books. Books are useful because these give a broad view on the topic, as starting point for the research. The articles were selected on impact factor (>2), relevance (based on the topic of this research and the content of the article) and recency (depends on the type of sub-topic). The topic operations strategy and the main competitive priorities are less assessed on recency because these topics include more seminal works. This also partly applies to the measurement methodologies of a manufacturing facility. Logically, this does not apply to literature about the fourth industrial revolution: Industry 4.0/Smart Industry. The keywords for this literature review are:

- Operations strategy;
- Manufacturing strategy;
- Business strategy;
- Sales/Market strategy;
- Sales/Market analysis;
- Operations strategy development;
- Competitive priorities;
- Production/manufacturing analysis;
- Industry 4.0/Smart Industry.

Articles about Industry 4.0/Smart Industry are included in the search because the industries and therefore operation strategies are becoming more digitally oriented. Industry 4.0 and Smart Industry are the main terms in this topic. Sales/market strategy and analysis articles are searched because the sales/market strategy and analysis has an impact on the operations strategy. For example, if the market desires products to be delivered in short term, but customers comply with a higher price, then this has an impact on the operations and therefore operations strategy of a company.

The analysis of the papers is done via the application to the research question. The papers should have cohesion with the central research question and the goal of this research/literature review.

The structure of the literature review is in response to the stages of development of an operations strategy. So, first the business strategy and market environment. Thereafter, the competitive priorities and at the end the measurement of these competitive priorities.

2.2 Defining operations strategy

This section provides insights into the definition of operations strategy, the development of a (operations) strategy, the market analysis and the analysis of the four main competitive priorities.

To develop a theoretical framework for this research about the operations strategy of OC Waterloo, operations strategy needs to be defined first. Operations strategy is defined as follows: "... the development of specific competitive strengths based on the operations function that is aimed at helping an organization achieve its long-term competitive goals" (Amoako-Gyampah & Boye, 2001, p. 59). The term Operations strategy is often referred to as manufacturing strategy (Slack & Lewis, 2008). However, both terms have different meanings. Manufacturing strategy also focuses on purchasing, customer support, supply chain management and service strategy (Slack & Lewis, 2008). On the other hand, Slack and Lewis (2008) describe Operations Strategy as a plan to correspond to the requirements of the market with the resource capabilities of the operations. Therefore, competitive strengths are of importance to this research. Slack and Lewis (2002), divide Operations Strategy into three themes: market influence, resource influence and vision. Firstly, the operations of the company should represent the desired or current market position of the firm (Slack & Lewis, 2002). Secondly, to work towards this market and business strategy goal, the company has to investigate the current resources and processes (Slack & Lewis, 2002). Thirdly, the operations strategy has to consist of a certain vision or goal towards the future (Slack & Lewis, 2002). In addition, the vision can be pragmatic as well as philosophical (Slack & Lewis, 2002). As mentioned before business strategy partly determines the operations strategy. Anand and Gray (2017), mention the following topics under strategy and organisation/business strategy:

- Alignment: between the business strategy and the market.
- Formulation Process: the development of a strategy and the implementation of it.
- Configuration: performance measures cost, quality delivery and flexibility.
- Trade-offs and Combinations: combining different operational performance dimensions.
- Learning and Knowledge Management: transfer the knowledge inside and across organisations.
- Incentives: incentives in all organisational levels.
- Team Dynamics: creating structure in the teams across the entire organisation.
- Design of Operations: the location and structure of the operations.
- Technologies: selecting the right technologies throughout the firm.

Operations strategy is often defined in categories. Boyer and Lewis (2002) framework operations strategy in three categories: the competitive priorities which lead to a structure and infrastructure. The structure consists of capacity, facilities and technology, and the infrastructure consists of workforce quality, production planning and organisation (Boyer & Lewis, 2002). However, Corbett (2008) divides operations strategy into two decision categories, namely 1) structural decisions which consist of capacity, sourcing and vertical integration, facilities and information and process technology and 2) Infrastructural policies and systems which consists of resource allocation and capital budgeting systems, human resource systems, work planning and control systems, quality systems, measurement and reward systems, product and process development systems and organisation structure. Both studies mention the importance of capacity, facility, technology planning and organisation and its impact on the four main competitive priorities.

On the other hand, digitisation plays a role in the manufacturing industry. According to more recent studies, the level of digitisation is of importance to operations management/strategy (Caiado et al., 2020). Digitisation of production systems is often called Industry 4.0 or Smart Industry (Frank et al., 2019). The goal of Industry 4.0 is to increase the productivity and efficiency of factories using smart approaches, also called Smart Manufacturing (Frank et al., 2019). Digitisation is becoming increasingly important for an organisation. Ghobakhloo and Fathi (2020) mention the following: "… the digitization of certain operations and processes, when aligned with the firm's core strategies, capabilities and procedures, can offer superior competitiveness even in Industry 4.0 era." (p. 22). So, digitisation can lead to high competitiveness. As mentioned before, improving competitiveness is part of the operations strategy. For OC Waterloo it is of importance because the organisation has difficulties with digitisation. Therefore, it is of importance to assess the level of digitisation at OC Waterloo.

For this study, it is of importance to develop an operations strategy that builds upon the business strategy (business influence) and market strategy (market influence). Furthermore, the study should consist of a resource analysis in the form of a study of the current production by measuring the competitive strengths and digitisation. After that, it must be investigated how OC Waterloo can continue to grow on the competitive demands the business/market desires. Lastly, this study should provide a vision for the future for OC Waterloo.

2.3 Developing an operations strategy

The development of an operations strategy is important for this research. Ward and Duray (2000) developed a conceptual model with four factors, which are the environment, the competitive strategy, the manufacturing strategy and the performance. This model suggests that the environment affects competitive strategy as well as the manufacturing strategy. Competitive strategy affects the manufacturing strategy and performance and the manufacturing strategy affects the performance too. Furthermore, Chakravarthy and White (2006) developed a holistic framework for the strategy process. Strategy development is both emergent and planned (Chakravarthy & White, 2006). The strategic framework is shown in Figure 2-1. The framework shows that the strategy has three main elements, namely: the organizational context, the business context and the firm performance. Thereby, the business context consists of the external environment (comparable with the market influence of Slack and Lewis (2002) and core competencies. The key to strategy development is that it never stops, so there is feed-forward learning and feedback learning. Therefore, Chakravarthy and White (2006), mention the importance of time and the actions and decisions that lead to the strategy over time.

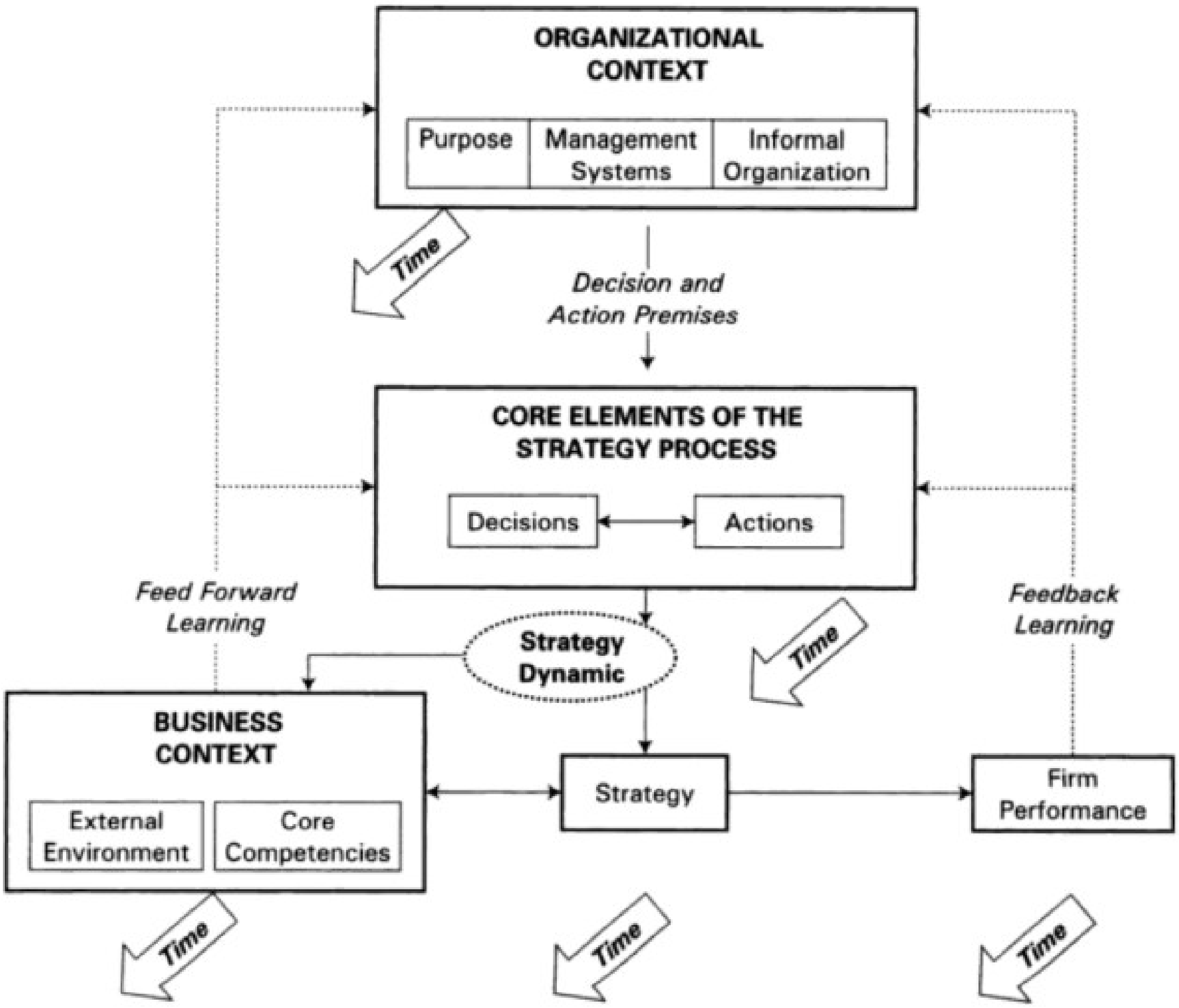

Figure 2-1 Strategic Framework (Chakravarthy & White, 2006)

On the other hand, Kaplan and Norton (2008) developed a closed-loop management system for the link between strategy and operations. The management system is shown in Figure 2-2. This closed-loop management system shows the stages in the development of an overall strategy and the links between the operations plan and the overall strategy. Thereby, this framework shows the feedback learning just as Chakravarthy and White (2006). The research of Kaplan and Norton (2008) further elaborates the elements of the operations of a company. The closed-loop system implies that developing a strategy is a continuous process, this is of importance because the environment of businesses is changing (Kaplan & Norton, 2008). Therefore, a strategy is not fixed and has to adapt to the learning of the organisation (Kaplan & Norton, 2008).

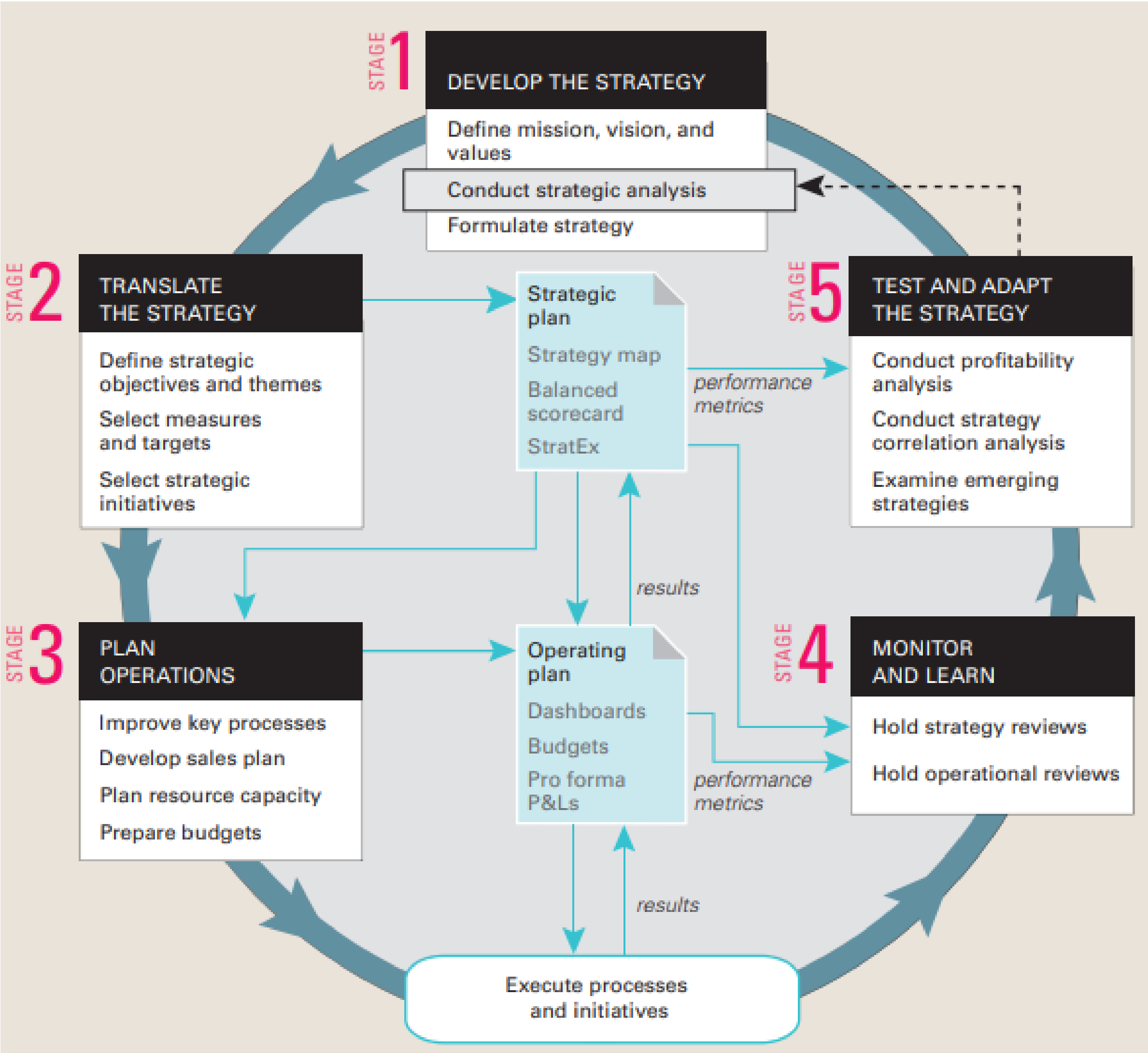

Figure 2-2 Closed-Loop Management System (Kaplan & Norton, 2008)

In conclusion, the frameworks show the importance of closed-loop strategy development, this means that learning and improving is a continuous process. Thereby, all studies mention the business strategy, the operations and the external environment of a company as the main factors for developing a strategy. However, Kaplan and Norton (2008) also mention a sales plan, where Chakravarthy and White (2006) only mention the external environment. For this study, the overall strategy, the external environment and the sales strategy of OC Waterloo will be used to develop the operations strategy of OC Waterloo.

Business strategy

As mentioned before, operations strategy builds upon the business strategy. A business strategy sets up the mission and objectives of a company (Slack & Lewis, 2002). Thereby, the business strategy defines how the company wants to compete in the market (Slack & Lewis, 2002). One of the ways to deploy the business strategy is using a Hoshin Kanri model with an X-matrix. Orange Climate uses the X-matrix for deploying its strategy. Hoshin Kanri is seen as a policy deployment method and is an "organizational learning method and competitive resource development system" (Jackson, 2006, p. 12). The X-matrix is used by companies to build and deploy the strategy and annual goals (Jackson, 2006). An example of an X-matrix is shown in Figure 2-3. The X-matrix consist of four categories: 3-5 year breakthrough objectives, annual objectives, top-level improvement priorities and targets to improve/KPIs. This framework will also be used for OC Waterloo's operations strategy, because the X-matrix is an often used framework for setting up business strategy (Jackson, 2006).

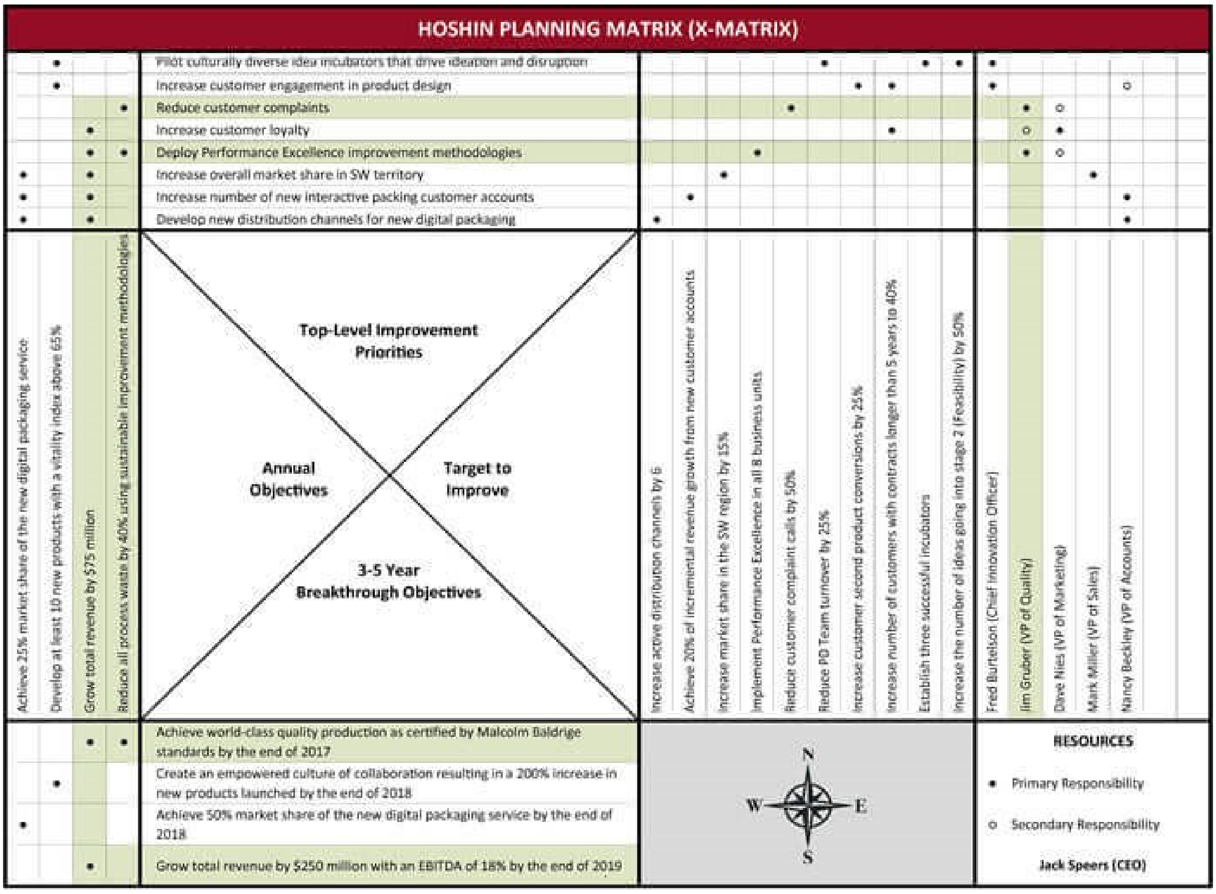

Figure 2-3 Hoshin Kanri/X-matrix [1]

[1] https://kanbanize.com/lean-management/hoshin-kanri/what-is-hoshin-kanri-x-matrix

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External environment/Sales strategy

External environment and sales strategy are of importance to analyse the desired market position of a company to work towards to with the operations strategy. The external environment and sales strategy relate to each other, because the sales strategy is (partly) based on the external environment. The external environment and sales strategy determine which competitive priorities should be focused on in the operations strategy. Therefore, the external environment and the sales strategy have to be defined.

There are typical steps to analyse an industry. Porter (2008), developed a framework for the analysis of an industry. Porter (2008) divides this into three steps. First, the industry has to be defined, so what products are in it and who are the customers of that product (Porter, 2008). Second, the products and customers have to be segmented into groups (Porter, 2008). Groups useful for this research are the product and customer groups. Third, the overall industry structure should be determined (Porter, 2008).

According to Kaplan & Norton (2008), a sales plan has to be analysed to develop a strategic operations plan. The sales plan need to be deconstructed in the quantity of the products, mix of the products, mix of the customers, nature of individual sales orders, production runs and transactions volumes per customer (Kaplan & Norton, 2008). These values could be obtained via the ERP system. If these variables are analysed the expected resources of the production facility can be analysed.

For this research, it is of importance to analyse the competitive priorities per product/customer group using the sales strategy of the company, the external environment and the interviews with employees.

2.4 Competitive priorities

Competitive strengths are the basis for an operations strategy. There are four main competitive priorities included in the operations strategy: Quality, Cost, Time/Delivery, and Flexibility (Liu & Liang, 2014). These four main competitive priorities have been included by various researchers (Boyer & Lewis, 2002; Ward & Duray, 2000). However, Corbett (2008) makes these four competitive priorities depend on the manufacturing strategy. There are four manufacturing strategy configurations, namely: market-based strategy, product-based strategy, capability-based strategy and price based strategy (Corbett, 2008). Market-based organisations differentiate themselves by focussing on product quality with excellent customer service and flexibility (also in product variety)(Cagliano et al., 2005). A product-based organisation focus on the development of their product, this includes high product quality with a high variety of products (Cagliano et al., 2005). The capability-based strategy focuses on the improvement of the capabilities which leads to high product quality with flexibility, service and low prices (Cagliano et al., 2005). The price-based strategy focuses on the price-quality ratio, with sometimes the flexibility to adapt the product to customer needs (Cagliano et al., 2005). Table 2-1 shows the competitive priorities per manufacturing strategy configuration edited by Corbett (2008). This table shows more competitive priorities than mentioned before, however, the first competitive priorities are the four main competitive priorities. For this research, it is important to determine which competitive priorities are of importance to OC Waterloo. Thereby, the current status of the competitive priorities should be analysed.

Table 2-1 Manufacturing strategy configurations and competitive priorities (Cagliano et al., 2005; Corbett, 2008)

Manufacturing strategy configurations	Competitive priorities
Market-based strategy	Quality
	Service
	Flexibility
	Product variety
Product-based strategy	Product variety
	Quality
	(Price)
Capability-based strategy	Quality
	Flexibility
	Service
	Price
Price-based strategy	Price
	Quality
	(Flexibility)

2.4.1 Performance criteria/KPIs

The main competitive priorities can be further divided into performance criteria. Researchers have different opinions on these performance criteria. Therefore, this section discusses, links and compares the competitive priorities with KPIs. According to Kathuria (2000), the main competitive priorities; cost, delivery, quality and flexibility could be measured in seven variables. These seven variables are accuracy, quality, productivity, customer satisfaction, efficiency, quantity of work and timeliness (Kathuria, 2000).

Quality measures

Uyar (2009), evaluated the performance of quality measures inside 500 manufacturing companies using a survey. There were eleven quality measures measured. These measures were divided into two groups: 1) financial measures of quality and 2) non-financial measures of quality. The following measures were evaluated:

(1) Financial measures:

- itemized quality cost reporting;
- analysis of quality cost components;
- quality cost budgeting and variance analysis;
- comparison of quality costs to industrial standards; and
- multi-period trend analysis of quality costs (Uyar, 2009).

(2) Non-financial measures:

- percentage of product reworks;
- rate of material spoilage;
- rate of defects in production output;
- percentage of returned goods to total sales;
- on-time delivery of goods or services to customers; and
- total number of customer complaints (Uyar, 2009).

The result of this study was that non-financial measures gave short-run feedback in comparison to financial measures (Uyar, 2009). Thereby, non-financial measures were easier to understand (Uyar, 2009).

However, Neely et al. (1995) mention different performance measures to quality. These quality costs are prevention costs, appraisal costs and failure costs. Prevention costs are costs incurred to prevent quality problems (Campanella & Corcoran in Neely et al., 1995). Examples include training of personnel, supplier assessments and quality planning. Appraisal costs are costs that prevent wrong or rejected products from being delivered (Campanella & Corcoran in Neely et al., 1995). This is prevented by inspections and random samples. Failure costs happen when a product for example has been falsely produced (Campanella & Corcoran in Neely et al., 1995). Failure costs are divided into two categories: Internal failure costs and external failure costs (Campanella & Corcoran in Neely et al., 1995). Internal costs are costs made before the delivery of the product, this could be rework and external failure costs are costs made after the delivery (Campanella & Corcoran in Neely et al., 1995). An example of this are unsatisfied customers and customer complaints. Furthermore, Neely et al. (1995) mention: performance, features, reliability, conformance, technical durability, serviceability, aesthetics, perceived quality, humanity and value. On the other hand, Liu and Liang (2014), mention the following key criteria: defect rate, product performance, reliability, environmental impacts and certification. These measures are used to assess the quality of OC Waterloo's operations.

Table 2-2 Overview of quality measures

Liu and Liang (2014)	Neely et al. (1995)	Uyar (2009)
Defect rate	Performance	Product reworks
Product performance	Features	Material spoilage;
Reliability	Reliability	Defects in production output
Environmental impacts	Conformance	Returned goods to total sales;
Certification	Technical durability	On-time delivery of goods or services to customers
	Serviceability	Number of customer complaints
	Aesthetics	
	Perceived quality	
	Humanity	
	Value	

Cost

Neely et al. (1995) mentioned the following key criteria to measure cost: manufacturing cost, value-added, selling price, running cost and service cost. However, Liu and Liang (2014) mention the following key criteria: production costs, value-added costs, quality costs, activity-based costs and continuous improvement costs. In addition, one of the most important measures of a factory is reducing operations expenses (Goldratt & Fox in Muthiah & Huang, 2006). Operations expenses have a lot to do with efficiency, effectiveness/performance and productivity. Another KPI is the production part cost. The production part cost is calculated by dividing the total utilization cost by the total approved products (Andersson & Bellgran, 2015). The goal of this measurement is to analyse the costs and reduce these. There are nine costs described:

- Operator cost;
- Material supply cost;
- Maintenance cost;
- Rework cost;
- Scrap cost;
- Material cost;
- Equipment and operating cost;
- Tool cost;
- Other cost (Andersson & Bellgran, 2015).

Table 2-3 Overview of cost measures

Liu and Liang (2014)	Neely et al. (1995)	Andersson and Bellgran (2015)
Production costs	Manufacturing cost	Operator costs
Value-added costs	Value-added cost	Material supply costs
Quality costs	Selling price	Maintenance cost
Activity-based costs	Running cost	Rework cost
Continuous improvement costs	Service cost	Scrap cost
		Material cost
		Equipment and operating cost
		Tool cost
		Other cost

Time/Delivery

Time/Delivery is the third main competitive strength. Neely et al. (1995) mention the following key criteria: manufacturing lead time, rate of product introduction, delivery lead time, due-date performance and frequency of delivery. However, Liu and Liang (2014) mention the following key criteria: lead time, on agreed time, on agreed quality, on agreed quantity and dependable promises. When these two sources are compared, it appears that Liu and Liang (2014) focus more on the delivery itself, so the quality and completeness of the delivery and Neely et al. (1995) more on the lead time and partly on the due-date performance. Both perspectives are of importance for this research, to investigate the lead time and due-date performance. The due-date performance is also partly measured in the quality section.

Moreover, four factors are influencing waiting time. These factors are variability, location of variability, occupation rate and the movement of batches (Hopp & Spearman, 2011). Variability always lowers the performance of a production system (Hopp & Spearman, 2011). The location of variability is of influence because the earlier the variability in the routing the more variability in the remaining process (Hopp & Spearman, 2011).

Table 2-4 Overview of time/delivery measures

Liu and Liang (2014)	Neely et al. (1995)	Hopp and Spearman (2011)
Lead time	Manufacturing lead time	Variability
On agreed time	Rate of production introduction	Location of variability
On agreed quality	Delivery lead time	Occupation rate
On agreed quantity	Due-date performance	Movement of batches
Dependable promises	Frequency of delivery	

Flexibility

Flexibility is the fourth main competitive strength. Neely et al. (1995) mention the following key criteria to flexibility: material quality, output quality, new product, modify product, deliverability, volume, mix and resource mix. In addition, Liu and Liang (2014) mention the following key criteria: design adjustments, changes in product volume, changes in product mix, changes in product lifecycle and broad product line. Furthermore, Gerwin (1993) partly mentioned other flexibility dimensions. These dimensions are product mix, changeover (product innovation), modification (to customers wishes), volume (market share), rerouting (customers' delivery dates), material (product quality) and responsiveness (strategic adaptability) (Gerwin, 1993).

Table 2-5 Overview of flexibility measures

Neely et al. (1995)	Liu and Liang (2014)	Gerwin (1993)
Material quality	Design adjustments	Product mix
Output quality	Changes in product volume	Changeover
New product	Changes in product mix	Modification
Modify product	Changes in product lifecycle	Volume
Deliverability	Broad product line	Rerouting
Volume		Material
Mix		Responsiveness
Resource mix		

Summary

The KPIs/performance criteria are of importance to assess the current status of the main competitive priorities of OC Waterloo. The KPIs/performance criteria are summarized and compared per researcher in Table 2-6. The used KPIs are described in the methodology section.

Table 2-6 Key criteria per competitive priority per researcher

Competitive priority	**Key criteria**					
	Liu and Liang (2014)	Neely et al. (1995)	Uyar (2009)	Andersson and Bellgran (2015)	Hopp and Spearman (2011)	Gerwin (1993)
Quality	Defect rate	Performance	Product reworks			
	Product performance	Features	Material spoilage;			
	Reliability	Reliability	Defects in production output			
	Environmental impacts	Conformance	Returned goods to total sales;			
	Certification	Technical durability	On-time delivery of goods or services to customers			
		Serviceability	Number of customer complaints			
		Aesthetics				
		Perceived quality				
		Humanity				
		Value				

Cost	Production costs	Manufacturing cost	Operator costs		
	Value-added costs	Value-added cost	Material supply costs		
	Quality costs	Selling price	Maintenance cost		
	Activity-based costs	Running cost	Rework cost		
	Continuous improvement costs	Service cost	Scrap cost		
			Material cost		
			Equipment and operating cost		
			Tool cost		
			Other cost		
Time/delivery	Lead time	Manufacturing lead time		Variability	
	On agreed time	Rate of production introduction		Location of variability	
	On agreed quality	Delivery lead time		Occupation rate	
	On agreed quantity	Due-date performance		Movement of batches	
	Dependable promises	Frequency of delivery			
Flexibility	Design adjustments	Material quality			Product mix

Changes in product volume	Output quality	Changeover
Changes in product mix	New product	Modification
Changes in product lifecycle	Modify product	Volume
Broad product line	Deliverability	Rerouting
	Volume	Material
	Mix	Responsiveness
	Resource mix	

2.4.2 Measurement methodologies

This section provides possible measurement methodologies for analysing the main competitive priorities and the KPIs in the previous subchapter. Thereby, this section couples measurement methodologies with the main competitive priorities and the KPIs, so a decision can be made which measurement methodology is most applicable to OC Waterloo.

Value Stream Mapping (VSM)

Value Stream Mapping (VSM) is an often-used method for visualising and analysing manufacturing systems. A value stream map is a method that collects all actions done in the process to bring similar product(s) from the suppliers to the customer (Rother & Shook, 1999). The actions include both the flow of products as well as the flow of information (Abdulmaleka & Rajgopal, 2007). Figure 2-4 gives an example of a VSM. The boxes represent the process and the triangles the inventory. The VSM measures cycle time (CT), machine reliability (MR) and the number of operators, defect rate, transport time/type and shifts and working time (Abdulmaleka & Rajgopal, 2007; Huang & Tomizuka, 2017). In the end, the total waiting time and the processing time is counted. The goal is to improve the value-added time and reduce the processing time. Value Stream Mapping is often done with a current state and future state overview. The goal is to improve the current state VSM so that it becomes the future state. Due to the fact that VSM focuses on defects, value-added time, and cycle time it relates with the main competitive priorities quality, costs and time/delivery. Flexibility is excluded because the VSM focuses on similar products. Furthermore, the VSM measures the following KPIs:

- Quality: defect rate, performance, defects in production output, reliability, value.
- Cost: value-added costs, manufacturing/production costs, operator costs, rework costs, equipment and operating costs.
- Time/delivery: lead time, manufacturing lead time, delivery lead time, frequency of delivery, and movement of batches.

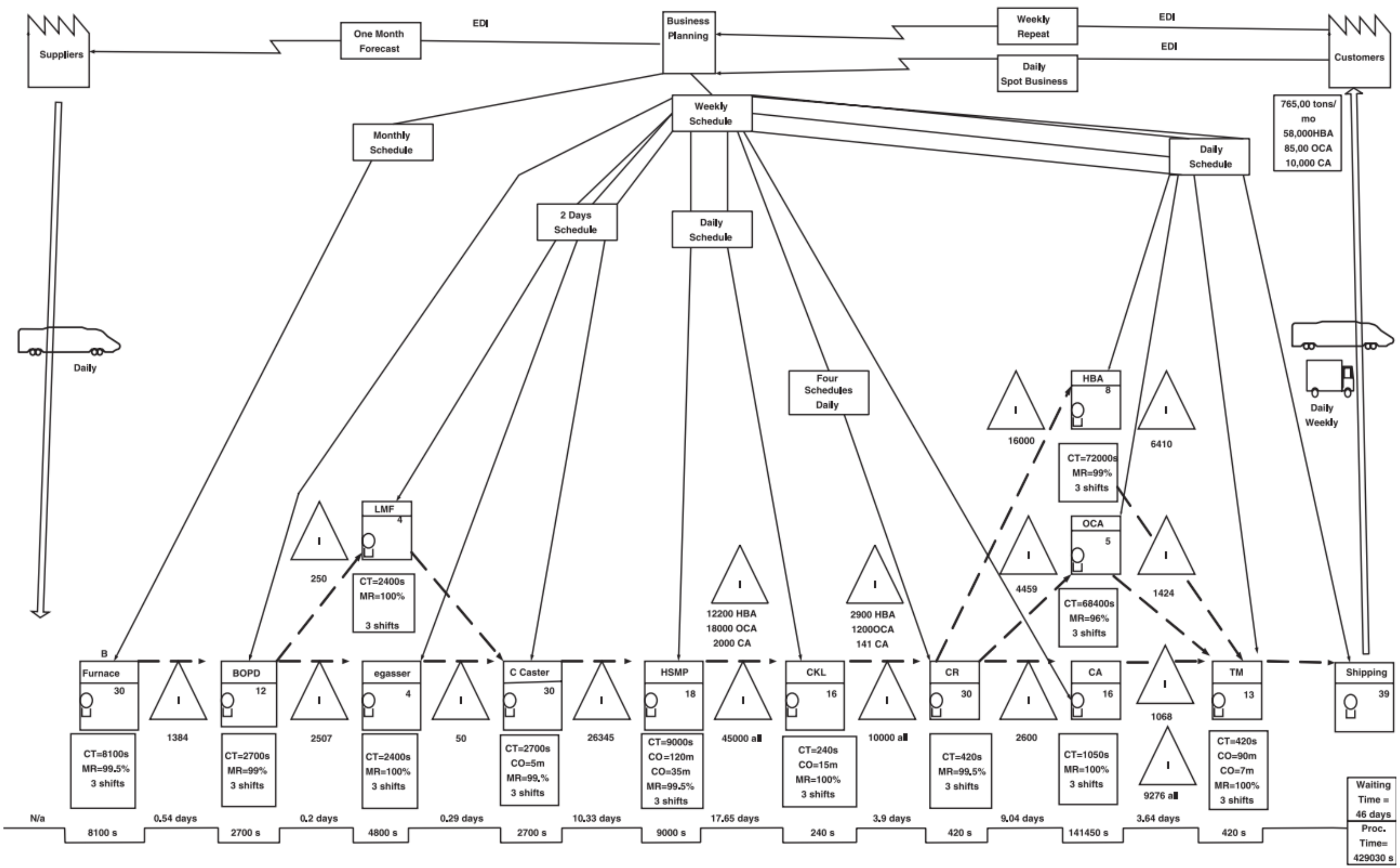


Figure 2-4 Current state Value Stream Map (Abdulmaleka & Rajgopal, 2007)

Spaghetti Diagram

Value Stream Mapping does not cover the flow through the factory in terms of distance. Measuring the flow of a product through the factory is done with the spaghetti diagram (Gort, 2016). Figure 2-5 gives an example of a Spaghetti Diagram. The lines are the distance the product or operator has travelled. The Spaghetti Diagram gives a clear insight into the flow and movements inside a factory. Thereby, it can trigger improvement, especially the improvement of flow. Therefore, the Spaghetti Diagram focuses on the main competitive priorities time/delivery and flexibility. It focuses on costs because improving the flow leads to more value-added time, which relates to costs. The Spaghetti Diagram does not influence the quality. Furthermore, the Spaghetti Diagram measures the following KPIs:

- Cost: value-added cost and other costs
- Time/delivery: variability, location of variability and movement of batches
- Flexibility: changes in product mix, mix, resource mix, product mix, rerouting and responsiveness.

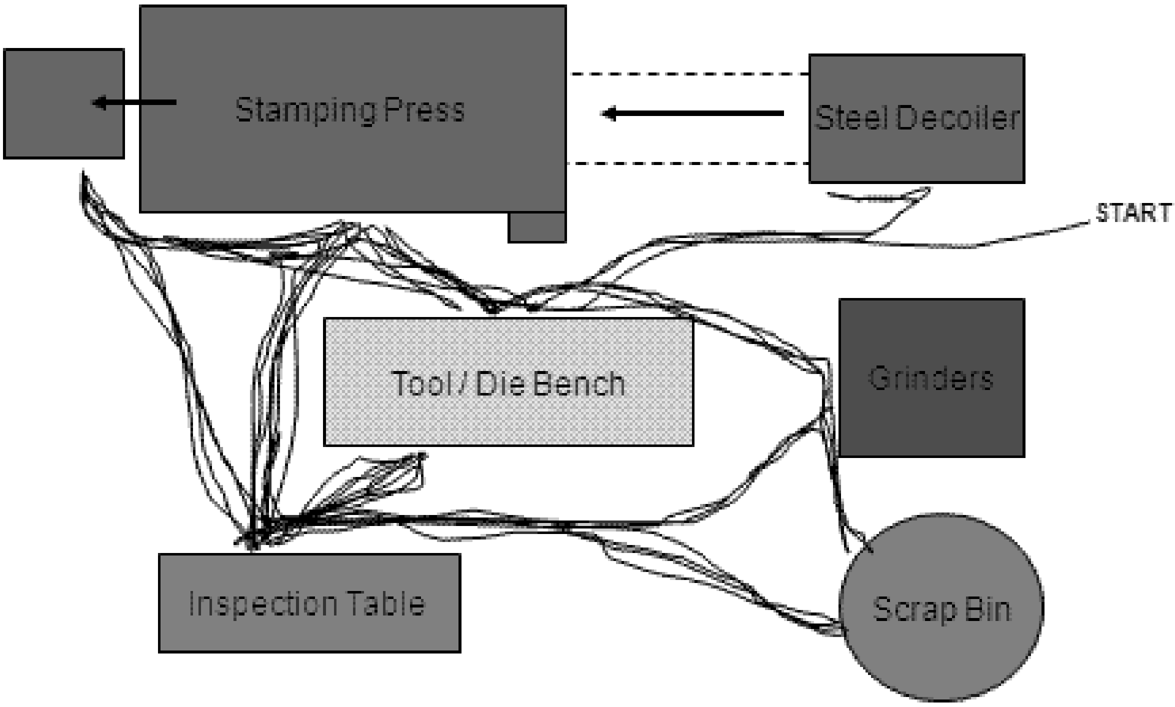


Figure 2-5 Spaghetti Diagram Plot [2]

[2] Retrieved from https://www.six-sigma-material.com/Spaghetti-Diagram.html

Manufacturing Critical Path

Manufacturing Critical Path (MCT) is defined as the amount of calendar time of the moment when a customer gives the other, following the critical path, till the first delivery of the order to the customer (Suri, 2011). Figure 2-6 shows the difference in disciplines between time measurement and the traditional cost-based method. The choice between cost-based or time-based depends on the environment the organisation is in. MCT focuses on the total time, cost-based strategies mainly focus on the touch time (Suri, 2011). The grey areas cover only five per cent of the total manufacturing critical path time (Suri, 2011). There are three important rules for the calculation of the MCT:

1. The MCT is calculated assuming that all activities are being fully executed from scratch;
2. All normal waiting times and delays should be calculated, not the values that orders undergo that apply to a rush order;
3. While in the manufacturing industry stocks are used to reduce lead time, at QRM time spent at all stages must be added to the MCT value (Suri, 2011).

The MCT is comparable with the Value Stream Map. However, MCT measures less information than VSM (Suri, 2011). The MCT does not focus on the processing time, so it does not cover, machine reliability, change overtime etc. Furthermore, the MCT is easier to use, because you need less data for this method. Due to the fact that the MCT focuses on time and reducing this, it focuses on the main competitive priorities time/delivery and flexibility. Costs are excluded in this measurement because this measure explicitly shifts from the cost-based focus to the time-based focus. Thereby, the quality is not mentioned in this measure. Furthermore, the MCT measures the following KPIs:

- Time/delivery: lead time, manufacturing lead time, delivery lead time and movement of batches.
- Flexibility: responsiveness.

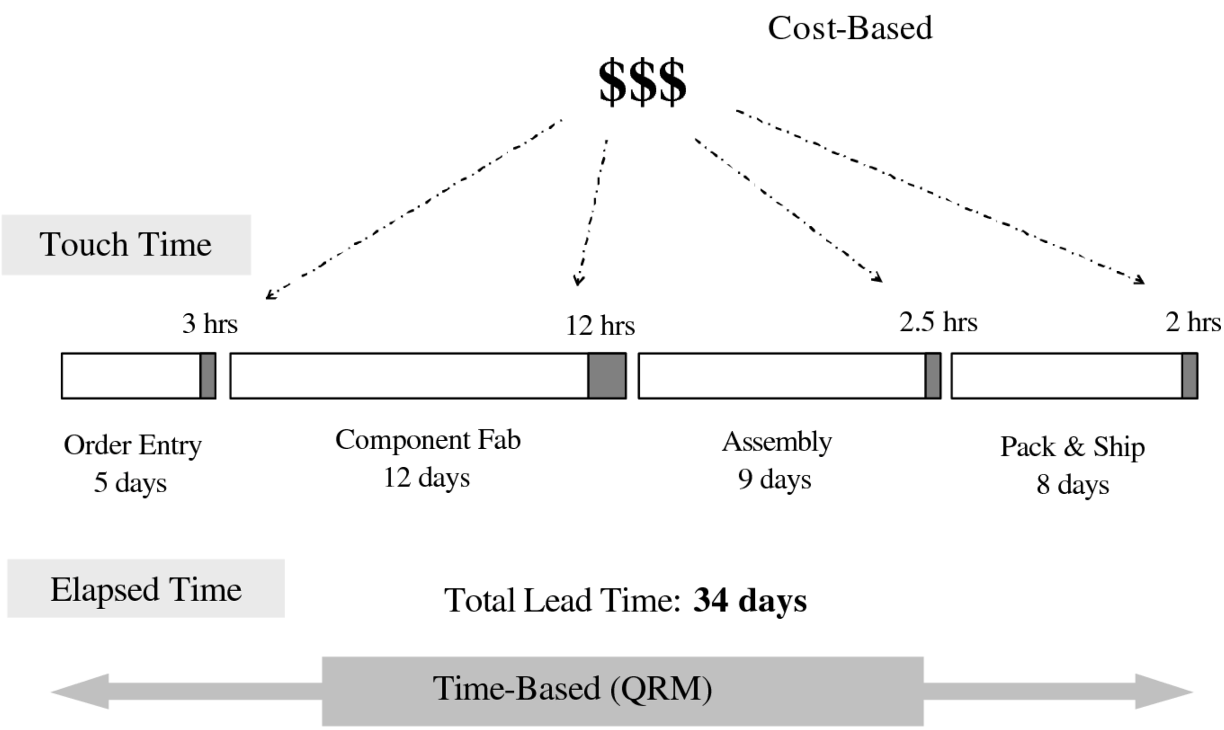


Figure 2-6 Cost based vs time-based (MCT) (Suri, 2011)

Utilization graph

An increasing occupation rate causes an exponential growth to the mean cycle time (Suri, 2011). The cycle time is proportional to the moving batch size (amount at a time) used in the routing (Hopp & Spearman, 2011). The last factor is comparable with the work in progress which leads to less focus in the factory. The exponential growth of the lead time due to the occupation rate is shown in Figure 2-7. Because the utilization rate relates with the WIP, batch size and influences the lead time it relates with the main competitive priorities time/delivery and flexibility. Costs and quality are excluded because this measure mainly focuses on time and quality is not mentioned. Furthermore, the utilization graph measures the following KPIs:

- Time/delivery: lead time, manufacturing lead time and occupation rate.
- Flexibility: deliverability and responsiveness.

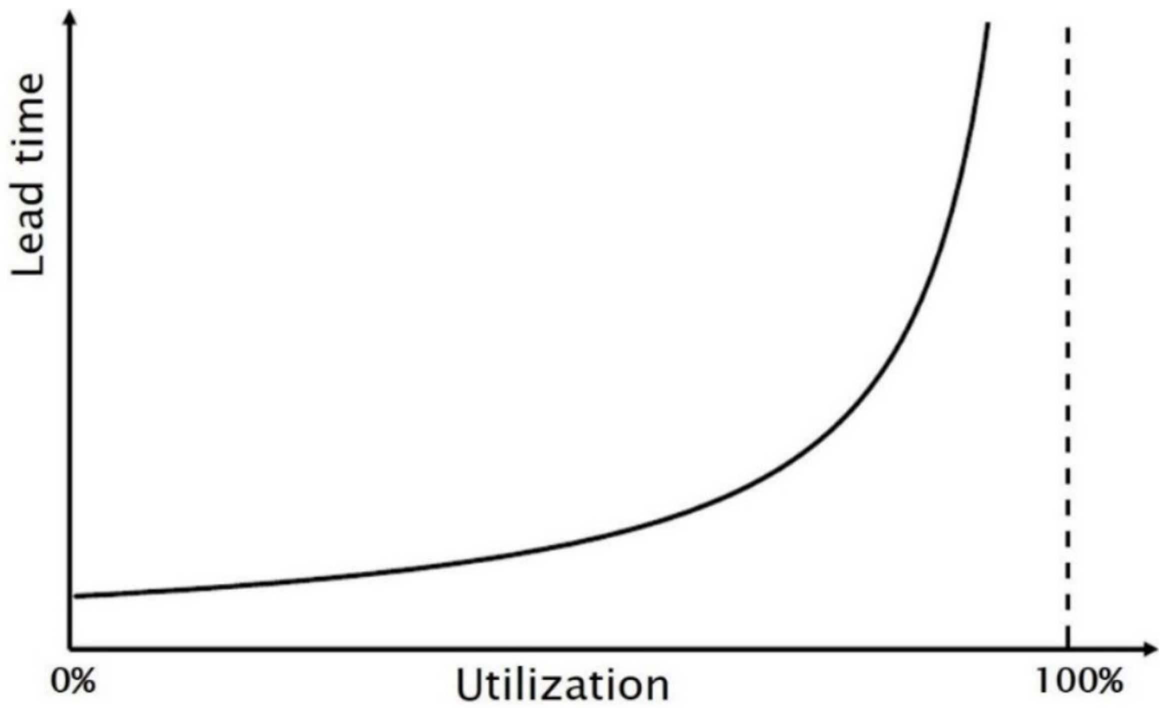


Figure 2-7 Relationship between utilization (occupation) rate and lead time (Suri, 2011)

Overall Equipment Effectiveness (OEE)

Overall Equipment Effectiveness (OEE) is a productivity measure that measures production wastes and leads the way for process improvement (Muchiri & Pintelon, 2008). The OEE measures the value-added time. The OEE has been applied to various industries. Therefore, has the methodology been changed to fit the industry requirements. According to Muchiri and Pintelon (2008), other measures are Overall Factor Effectiveness, Overall Plant Effectiveness, Overall Throughput Effectiveness, Production Equipment Effectiveness, Overall Asset Effectiveness and Total Equipment Effectiveness Performance. The previously mentioned factors: equipment utilisation, production line efficiency, machine capacity, parts per hour and performance rates are elements of the OEE or Overall Plant Effectiveness (OPE).
The OEE defines six major losses namely: equipment failure, setup & adjustment, idling & minor stoppage, reduced speed, defects in the process and reduced yield (Muchiri & Pintelon, 2008). The OEE can be calculated by multiplying the availability against the performance and the quality.

$$OEE = A \, x \, P \, x \, Q$$

Where:

$$Availability\ rate\ (A) = \frac{Operating\ time\ (h)}{Loading\ time\ (h)}\ x\ 100$$

$$Operating\ time = Loading\ time - Down\ time$$

$$Performance\ efficiency\ (P) = \frac{Theoretical\ cycle\ time\ (h)\ x\ Actual\ ouptut\ (units)}{Operating\ time}\ x\ 100$$

$$Quality\ rate\ (Q) = \frac{Total\ production - Defect\ amount}{Total\ production\ units}\ x\ 100$$

Figure 2-8 gives a graphical presentation of the calculation of the OEE. The Overall Plant Effectiveness also includes external reasons, for example, low demand or supplier failure (Muchiri & Pintelon, 2008). However, Andersson and Bellgran (2015) mention that the OEE does not measure the improvement of the ideal cycle time. As a result, by analysing the OEE, a reduction in ideal cycle time cannot be measured. In conclusion, OEE is an interesting method for analysing the performance of machines or factories. However, this method cannot be the only analysis method, because it does not measure the cycle time. Thereby, OEE is mainly used for automatic and semi-automatic processes (Jeong & Phillips, 2001). The processes of OC Waterloo are mainly non-/semi-automatic, so it will be hard to fully use the OEE methodology. However, elements of the OEE could be used to analysing parts of the facility.

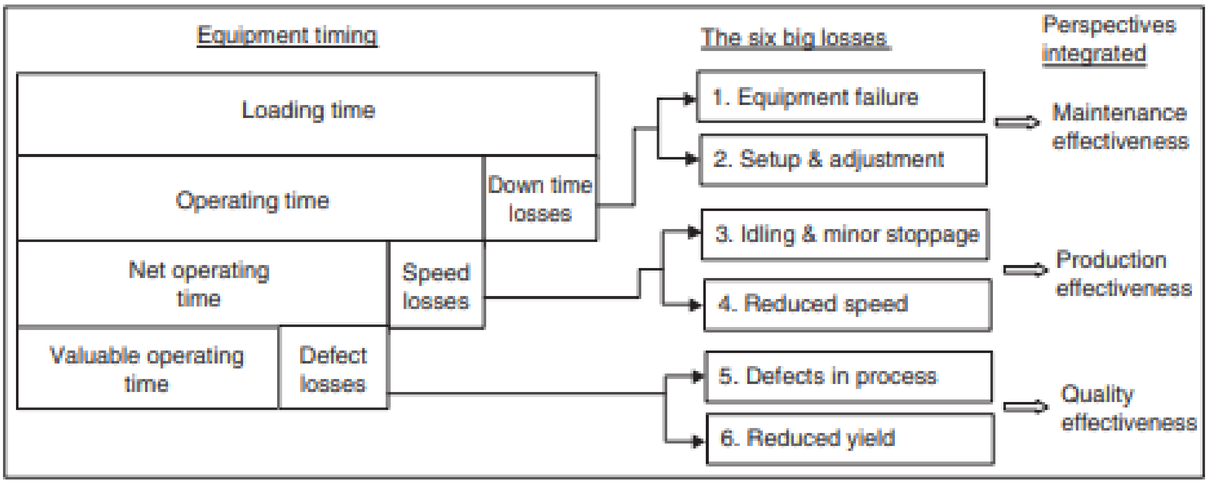


Figure 2-8 OEE measurement (Muchiri & Pintelon, 2008)

As mentioned before, OEE does not capture improvements in the ideal cycle time. Ideal cycle time is defined as follows: "The ideal speed in a production system, for example in a machining cell or an assembly line, is determined by the ideal cycle time (the lowest theoretical processing time without any disturbances) in the bottleneck process" (Andersson & Bellgran, 2015, p. 148). This means that the cycle time is the processing time of a product. The overall equipment effectiveness relates to the main competitive priorities quality, time/delivery and cost because it includes performance measures, quality measures and time measures. Flexibility is excluded because the OEE focuses on automatic production and performance. Furthermore, the OEE measures the following KPIs:

- Quality: defect rate, reliability, performance, product reworks and defects in production output.

- Cost: production/manufacturing cost, value-added cost, quality cost, running cost, maintenance cost, rework cost, equipment and operating cost.
- Time/delivery: Lead time, manufacturing lead time and occupation rate.

Product families

Unfortunately, most measurement methodologies cover only one product/process route. However, most companies produce several product types. Therefore, product families have to be created. Product families are described as "… a group of products that passes through similar downstream processing. By downstream processing, we mean the flow of product to the customer after the shared resources" (Duggan, 2013, p. 31). A product family matrix is used to identify product families by comparing them on the necessary processing steps (Duggan, 2013). The product families have no focus on the main competitive priorities. However, the product families are needed to cluster the several product groups of OC Waterloo.

Conclusion

The measurement methods are of importance to assess the current status of the main competitive priorities. The measurement methods are summarized and compared with the competitive priorities and the KPIs of the measurement methods in Table 2-7. For this research, the Manufacturing Critical Path and the Utilization Graph are used, because OC Waterloo mainly focuses on the main competitive priorities time/delivery and flexibility.

Table 2-7 Measurement methods per competitive priority's KPIs

Measurement method	**Competitive priority's KPIs**			
	Quality	Cost	Time/Delivery	Flexibility
Value stream mapping	Defect rate Performance Defects in production output Reliability Value	Value-added costs Manufacturing/production costs Operator costs Rework costs Equipment and operating costs	Lead time Manufacturing lead time Delivery lead time Frequency of delivery Movement of batches	-
Spaghetti diagram	-	Value-added cost Other costs	Variability Location of variability Movement of batches	Changes in product mix Mix Resource mix Product mix Rerouting

				Responsiveness
Manufacturing critical path	-	-	Lead time Manufacturing lead time Delivery lead time Movement of batches	Responsiveness
Utilization graph	-	-	Lead time Manufacturing lead time Occupation rate	Deliverability Responsiveness
Overall Equipment Effectiveness	Defect rate Reliability Performance Product reworks Defects in production output	Production/manufacturing cost Value-added cost Quality cost Running cost Maintenance cost Rework cost Equipment and operating cost	Lead time Manufacturing lead time Occupation rate	-

2.5 Digitalisation

Digitalisation is defined as follows: "digitalization refers to usage of any digital assets organizations can use to improve their performance" (Kuusisto, 2017, p. 342). As mentioned before, digitisation affects the competitiveness of an organisation (Ghobakhloo & Fathi, 2020). Therefore, it also has an impact on the operations strategy. According to Frank et al. (2019), digitisation leads to productivity and efficiency increment. Therefore, Caiado et al. (2020) developed maturity models to assess the progress of a company on its Industry 4.0 development. The model is presented in Table 2-8. The maturity model has five levels. Level zero shows no implementation of Industry 4.0. This means that the process has not been implemented in the IT system(s) (Caiado et al., 2020). Level one shows the conceptual deployment of Industry 4.0. This means that the company has started with the deployment of the process in the IT system(s), but the data exchange is not yet automated (Caiado et al., 2020). Level two shows a managed level of Industry 4.0 implementation. This level shows that the company can collect and share structured data, but lacks the integration between applications (Caiado et al., 2020). Level three shows an advanced level of deployment of Industry 4.0. The advanced level shows standardisation in the company and Industry 4.0 reach beyond the boundaries of the company (Caiado et al., 2020). Lastly, the fourth level shows a self-optimized level of Industry 4.0. The self-optimised level shows that the company can integrate Artificial Intelligence inside the company's information system(s) (Caiado et al., 2020). For this research, it is of interest to assess the Industry 4.0 maturity level of OC Waterloo, because digitisation affects the competitiveness of an organisation by having effect on the processes. (Ghobakhloo & Fathi, 2020). The maturity levels could be assessed by analysing OC Waterloo's current ERP system and its possibilities.

Table 2-8 Operations Supply Chain Management 4.0 Maturity levels (Caiado et al., 2020)

Level name	Description
0 Non-Existent	The process has not been implemented, it is based on experience and generated without standards, being implemented informally, and with little control. Process management is reactive and does not have the appropriate technologies to build an infrastructure that supports the digital revolution. The organization does not address I4.0 and the available enterprise IT-system supports only its field of application, generating data islands along the process.
1 Conceptual	A formal deployment process has been initiated and there is more exclusive knowledge about the process advancement. Process management is weak due to a lack of organization and/or enabling technologies. A partial maturity in the management of infrastructure development. The organization begins to address the problems of I4.0 within departments and connects existing technology applications to create data flow, data is fully integrated into a single enterprise system, but data exchange is not automated.
2 Managed	Standardization can be achieved and I4.0 technologies and requirements can be implemented to detect improvement potentials as well as establish computer-assisted approaches and create automated data flows and processes. The process was formally documented and defined thanks to the planning and implementation of good management practices and procedures, but the planning and implementation of the process highlight some gaps/lack of integration and interoperability in the applications, despite the collection and sharing of structured data

3 Advanced	The process is built on integration and interoperability, based on a common and shared standardization within the company; this has been completely implemented in an area or several areas, with established indicators and optimized management, evaluating opportunities, and applying benchmarking. The principles and technologies of I4.0 are reached beyond corporate boundaries and actively followed by all business partners; there is planning and control forecasting, the service-oriented and cloud-based platform is available throughout the supply chain, appropriate encryption techniques and authentication are in place to ensure secure access to data and simulation systems are used for testing, prototyping and factory optimization. The use of data prediction is required since there is pragmatic interoperability and automatic actions are promoted before a problem or bottleneck appears.
4 Self-Optimized	The process is digital oriented, relying on solid technology infrastructure and an organization with high growth potential. Available data allow for real-time simulation, which can be used in collaborative diagnostics and decision-making. This level consists of the complete digitalization of internal and inter-company processes, together with strong collaboration, integration of AI and self-learning skills in information systems, and creation of proactive processes for forecasting and planning future production, integrating data visualization and systems external partners to enable supply chain predictability and intelligent manufacturing.

2.6 Manufacturing methodologies

The most renowned manufacturing methodologies for process measurement and improvement are described in this subchapter. These manufacturing methodologies are of interest to discuss because, as mentioned before, process technology is part of an operations strategy. Process technology is defined as: “the appliance of science to any operations process” (Slack & Lewis, 2002, p. 247). The process technology could be developed using manufacturing methodologies. Therefore, the competitive priorities are linked to each manufacturing methodology to get insight into what methodology aligns with what/which competitive priority/priorities. As explained later in this research, QRM is used for OC Waterloo’s operations strategy. Therefore, QRM is explained more thoroughly than other manufacturing methodologies.

Total Quality Management (TQM)

Total Quality Management is a renowned method for quality management. TQM is of interest because quality is one of the four main competitive priorities of an operations strategy. TQM is defined as follows:

> TQM is defined as the management approach of an organisation, centred on quality, based on the participation of all its members and aiming at long-term success through the customer satisfaction, and benefits to all members of the organisation and to society (Feigenbaum, 1956, 1991, as cited in Muthiah & Huang, 2006, p. 469).

Pinho (2008) researched the effect of Total Quality Management on performance. According to Pinho (2008), TQM or the organisation’s tendency for innovation has a positive effect on performance. According to Yusof and Aspinwall (2000), the eleven factors for implementing TQM are:

1. Leadership and support from top management
2. Providing effective and appropriate training for employees
3. Measuring results and performance
4. Conducting continuous improvement
5. Adopting a quality assurance system (e.g. ISO 9000)
6. Sufficient financial resources
7. Providing relevant training for senior management/staff level
8. Favourable work environment and culture
9. Selective application of tools and techniques
10. Involving suppliers in improvement activities
11. Desirable human resource practices

In connection with the four main competitive priorities, TQM mainly focuses on the main competitive priority quality, as it is a method for quality management. Thereby, TQM focuses on costs, because of the effect on performance.

Six Sigma

Six Sigma focuses on data-driven problem solving, so the focus of Six Sigma is on the problem (Pojasek, 2003). The goal of Six Sigma is to reduce variation in the process, which will lead to fewer business problems (Pojasek, 2003). Linderman et al. (2003), gives the following definition to Six Sigma: “Six Sigma is an organized and systematic method for strategic process improvement and new product and service development that relies on statistical methods and the scientific method to make dramatic reductions in customer defined defect rates.” (p. 195). According to Linderman et al. (2003), Six Sigma was the denomination for Motorola’s quality goal of 3.4 Defects per million opportunities (with 1.5 sigma shift in the mean, due to the standard deviation). A DPMO of 3.4 means a process yield of

99.99966%, which is extremely high (Linderman et al., 2003). Figure 2-9 gives the defect rate versus process sigma level.

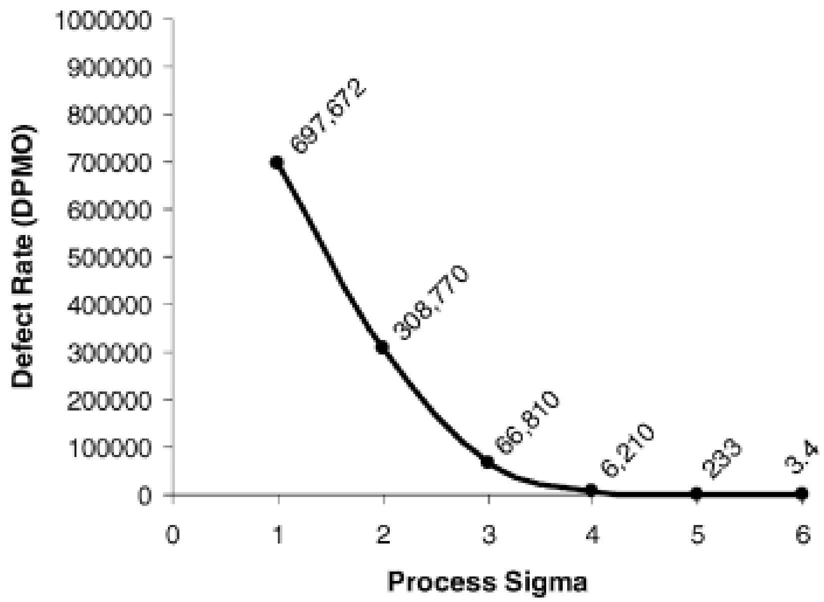


Figure 2-9 Defect rate (DPMO) versus Process Sigma level (Linderman et al., 2003)

Furthermore, Six Sigma uses a five-step approach to solve business problems to reach six sigma (Pojasek, 2003). This process is called DMAIC, which stands for Define, Measure, Analyse, Improve, Control (Pojasek, 2003). Because Six Sigma focuses on quality and business problem solving, it focuses on the main competitive priorities quality and costs.

Lean Manufacturing

Lean Manufacturing is a renowned methodology focussing on efficiency and effectiveness (performance)(Muthiah & Huang, 2006). Lean manufacturing divides the production activities into Value Added (VA) and Non-Value Added (NVA)(Rohimah, 2019). The goal is to reduce the non-value added activities/costs as much as possible. Eight types of waste are described:

- Overproduction;
- Waiting;
- Transport;
- Over-processing;
- Excessive stocks;
- Unnecessary movement;
- Defects;
- Unused creativity of employees (Gort, 2016).

Furthermore, the goal of Lean is the have pull production (Gort, 2016). The development pull production is done by calculating the takt time (Gort, 2016). This means that the customer decides the speed of the production process (Abdulmaleka & Rajgopal, 2007). For example, If a customer has a demand of 1000 units per day. The total lead time of thousand products should be a day. If you have an available time of eight hours a day, this means one unit has to be made in 28,8 seconds. So, takt time is the rate at which customers order products from the production facility (Abdulmaleka & Rajgopal, 2007). Due to the fact that lean focuses on efficiency, effectiveness, speed and reducing wastes, it relates to the main competitive priorities quality, costs and time/delivery.

Total Productive Maintenance (TPM)

Total Productive Maintenance is a method to improve the performance of maintenance activities (Ahuja & Khamba, 2008). TPM focusses on the following steps:

- Maximizing equipment effectiveness through optimization of equipment availability, performance, efficiency and product quality;
- Establishing a preventive maintenance strategy for the entire life cycle of equipment;
- Covering all departments such as planning, user and maintenance departments;
- Involving all staff members from top management to shop-floor workers; and
- Promoting improved maintenance through small-group autonomous activities (Ahuja & Khamba, 2008; Bamber et al., 1999).

The TPM implementation could be shown in an eight pillar 'house'. The pillars of TPM are shown in Figure 2-10 (Lamyaa & Sahib, 2017). Because TPM focuses on performance, effectiveness efficiency and product quality it relates with the main competitive priorities quality and costs.

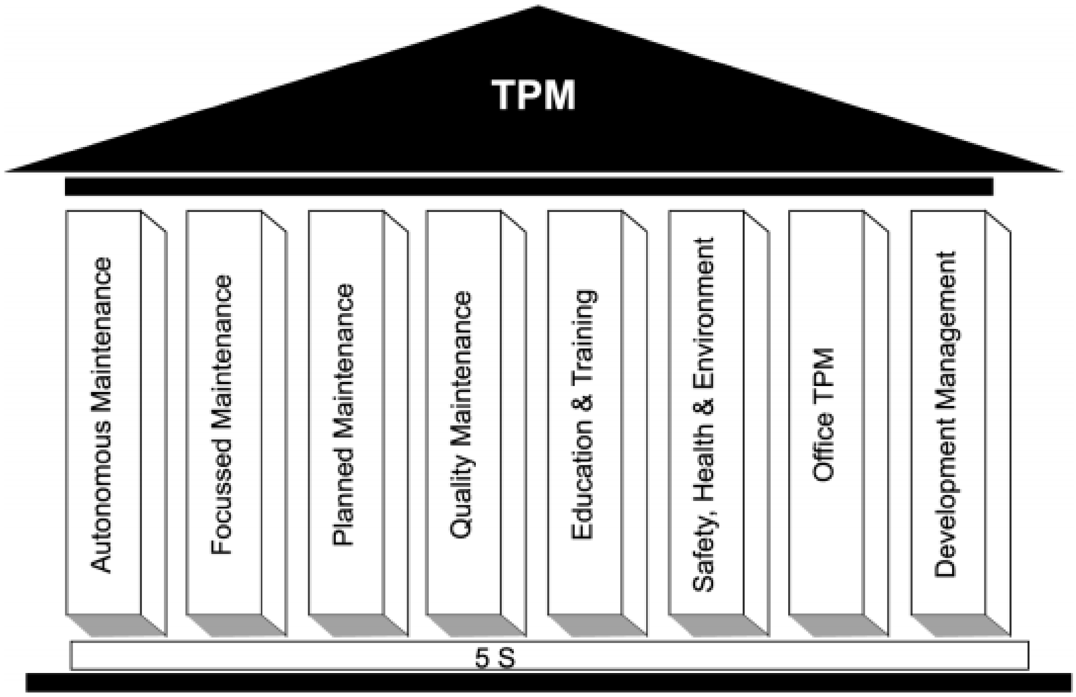


Figure 2-10 TPM pillars

Agile Manufacturing

Agile manufacturing is a methodology used by manufacturers who want to become or stay market leader in a competitive market with fast-changing customer requirements (Yusuf et al., 1999). The main points of agile manufacturing are summarized below:

- High quality, and highly customised products
- Products and services with high information and value-adding content
- Mobilisation of core competencies
- Responsiveness to social and environmental issues
- Synthesis of diverse technologies
- Response to change and uncertainty
- Intra-enterprise and inter-enterprise integration (Yusuf et al., 1999).

Since Agile Manufacturing focuses on high-quality products, fast-changing customer requirements and responsiveness to environmental issues, it relates with the main competitive priorities quality and flexibility.

Theory of Constraints (ToC)

Theory of Constraints is a methodology that aims at maximizing efficiency in systems. The principle of TOC is that there always is one constraint in the system, which leads to a limitation of the entire system (de Jesus Pacheco et al., 2020). If that constraint's utilization is maximized, the entire system is producing at its maximum (de Jesus Pacheco et al., 2020). Therefore, the output is only increased when the constraint is improved (Aryanezhad et al., 2010). Furthermore, TOC strives to cost reduction and financial/performance measures (de Jesus Pacheco et al., 2020). Because the TOC mainly focuses on efficiency and performance measures, it relates to the main competitive priority cost.

World Class Manufacturing (WCM)

World Class Manufacturing focuses on strategy and values to get superior operations (Chiarini & Vagnoni, 2015). The definition of WCM has been discussed a lot in the literature (Chiarini & Vagnoni, 2015). Word Class Manufacturing is shadowed by Lean production, however, WCM has been reinvented and has become an alternative to Lean production (Chiarini & Vagnoni, 2015). The goal of WCM is to achieve superior performance (Flynn et al., 1999 in Chiarini & Vagnoni, 2015) Nowadays, WCM is often seen as a combination of several manufacturing methodologies, especially a combination including Lean Manufacturing (Chiarini & Vagnoni, 2015). Because WCM is a combination of methodologies, it focuses on all main competitive priorities.

Quick Response Manufacturing (QRM)

QRM is a companywide strategy to reduce lead time in the entire organisation, as well as internally as externally (Suri, 2011). The QRM strategy is based on four main concepts:

- The power of time;
- Organisation structure;
- System dynamics; and
- Company-wide application (Suri, 2011).

These concepts are the basis for a company with lower lead times, higher quality, lower costs and a quicker response to the customer's demands (Suri, 2011).

The power of time

The goal of QRM is to reduce lead time. Suri (2011), defines five types of lead time:

- External lead time: the lead time that is experienced by the customer;
- Internal lead time: the time to let orders flow through the organization;
- Quoted lead time: the lead time that sales employees pass on to customers;
- Planned lead time: the time used for each routing step in the computer system;
- Supplier lead time: the time that is needed to get materials from suppliers.

According to Suri (2011), there are a lot more types of throughput time, however, the first two definitions are most important. The lead time is measured using Manufacturing Critical-path time diagrams. In contradiction to traditional manufacturing technologies, QRM focuses on the time between steps. Figure 2-11 shows how cost-based manufacturing technologies focus on the touch time and QRM focuses on the lead time, thus more on the time between the touch time.

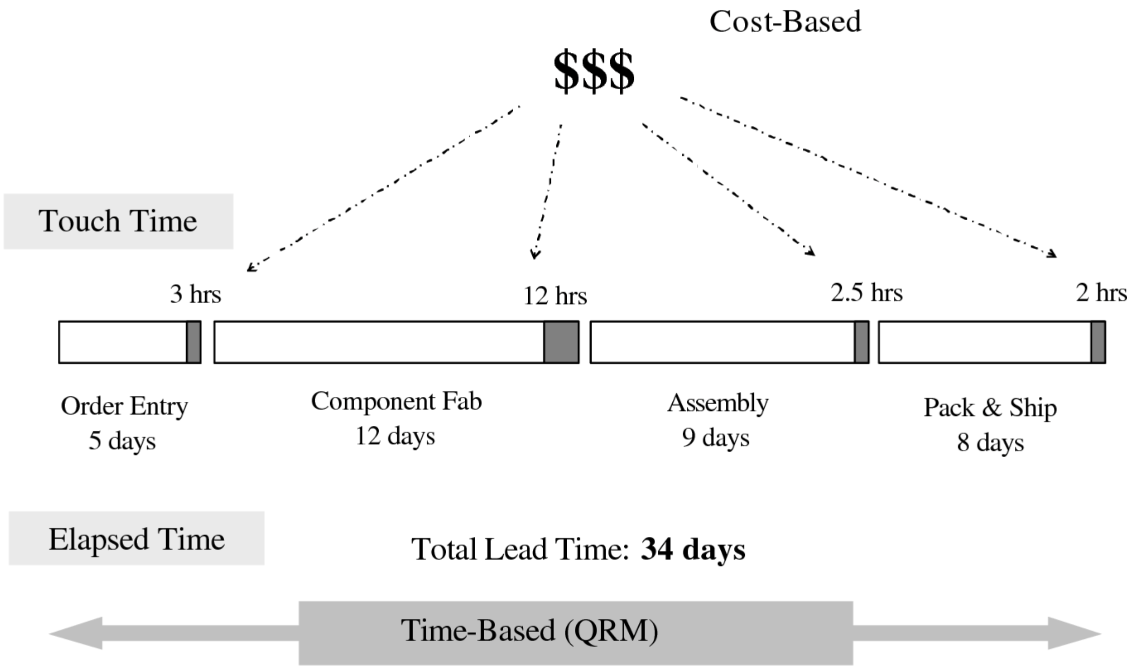


Figure 2-11 Cost based vs time-based (MCT) (Suri, 2011)

According to Suri (2011), focusing on delivery reliability leads to adverse effects. Instead of reducing the MCT, it leads to a long MCT. Therefore, QRM delivers another approach to measure delivery reliability. The KPI has to be the MCT, reducing the MCT leads to higher delivery reliability (Suri, 2011). Thereby, reducing the MCT leads to lower product costs (Suri, 2011).

Organisational structure

Firstly, Suri (2011) describes the unwished consequences of scale and costs thinking. These effects are called response time spirals. Response time spirals often occur at traditional organisations. Figure 2-12 gives an example of a response time spiral. The response time spiral starts at the long lead times, this makes it necessary to plan further away, which leads to inaccuracy of planning. Past performance problems provide for the insertion of a safety margin. The early start of jobs leads to a high WIP and inventory. The high WIP and inventory lead to unacceptable lead times and planning mistakes. For this reason, organisations initialise hot jobs. Hot jobs lead to a loss of focus on regular jobs which leads to delay. After that delay, the planning department decides to use long lead times, which maintains the vicious cycle.

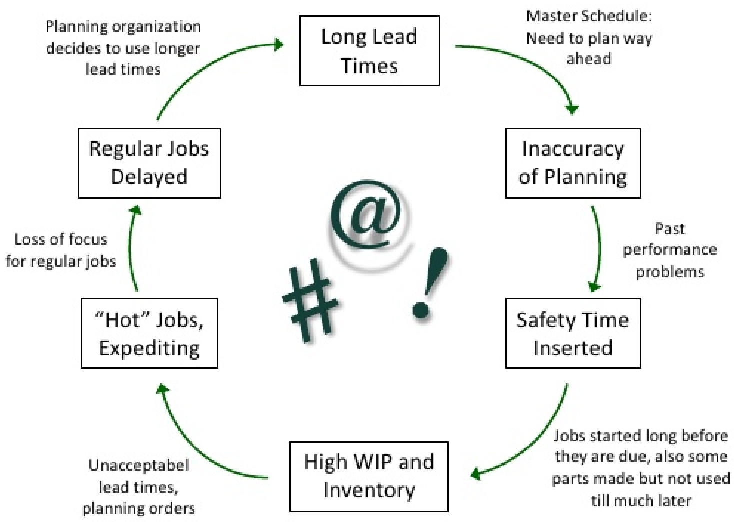


Figure 2-12 Response time spiral make to order products (Suri, 2011)

The response time spiral origins from the focus of reducing costs. This leads to the process being separated into various steps. The various steps lead to low skills and low hourly rates and functional departments. Managers focus on minimalizing costs in these departments which leads to the minimalization of sources and maximisation of efficiency and utilization. These focuses lead to a safety backlog and series, which lead to long feedback loops and searching. Lastly, this leads to bad quality long delivery times and high costs.

Suri (2011) provides four structural changes for a faster response. These key points are organisation, management, team members and thought on response. The goal of the organisation is to go from functional to cellular. The QRM cells do a continuous amount of steps in the department. As well as in the production as in the office. Management goes from the traditional top-down control to team ownership. The team is responsible for the entire delivery process based on the team's planning and their orders. The team members go from small and specialised to multi-functional. Team members need to get more skills to do multiple tasks in the cell. Traditional thoughts on efficiency, occupation goals have to be set aside and the focus must lie on MCT reduction/response.

The focus on MCT reduction can be measured by the QRM-number. The QRM-number measures the reduction of the MCT, which motivates the team to go through with the lead time reductions. The QRM-number is calculated by dividing the MCT base period by the MCT of the current period times 100. When lead time improvements are made the MCT number will become higher.

System Dynamics

System dynamics influence the MCT, the better system dynamics is being handled the lower the MCT will be. According to Suri (2011), the waiting times are increasing when the utilization rate increases. To reduce the waiting times, an organisation has to plan in a reserve capacity. This means that the planned utilization should be under 85% or even under 75%. The need for reserve capacity is due to variability in the process (Suri, 2011). QRM has another view of utilization than traditional manufacturing technologies. Traditional technologies see utilization as the time the machine is producing part (Suri, 2011). In QRM, utilization is the ratio the machine is occupied for any task, thus also planned maintenance and the total time the plant is operating (Suri, 2011). Flow time is the mean time an order has to wait till the previous order is done, plus the start of the process of the order and in the end, the time to finish the order (Suri, 2011). To investigate the impact of utilization on flow time, the oscillation effect of utilization is used. The formula is b divided by b-1 (Suri, 2011). For example, if a machine has a utilization of 75% (b=0,75), than the oscillation effect will be 0,75/0,25=3. However, if the utilization rises to 90% (b=0,90), the oscillation effect rises from three to nine, because O= 0,9/0,1= 9. So, there is an exponential growth in waiting times when the utilization increases (Suri, 2011). Thereby, Suri (2011) describes the miraculous effect of reserve capacity, which is calculated by 1-R divided by R, where R is the reserve capacity (so, 1- utilization). The magnifying effect of utilization and the traditional cost-based view are shown in Figure 2-13.

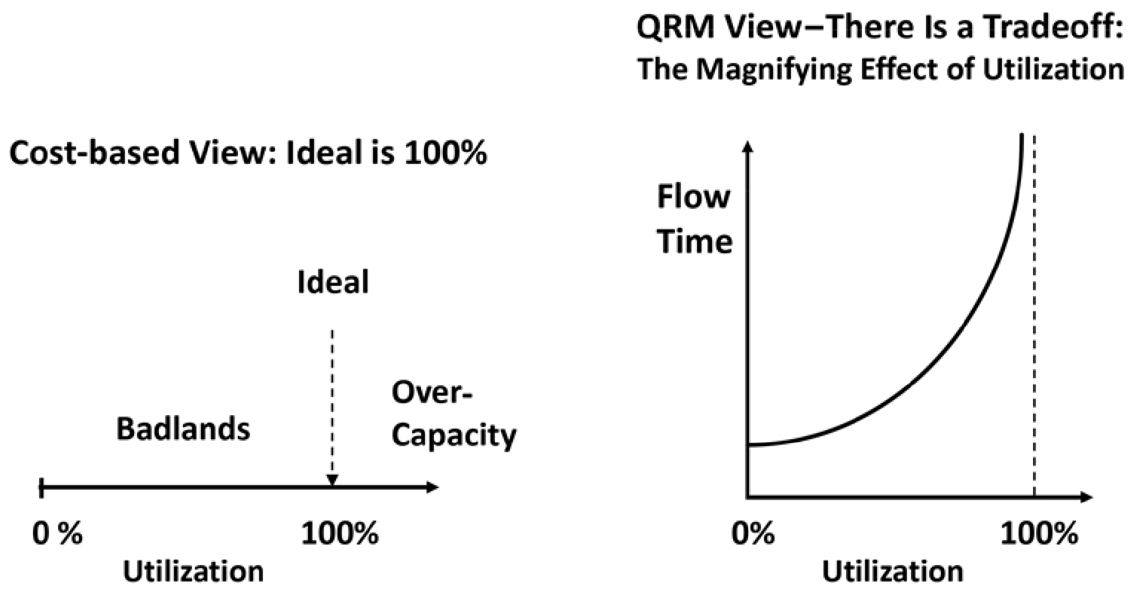


Figure 2-13 Utilization based on costs versus QRM (Suri, 2011)

Furthermore, variability has an impact on the flow time (Suri, 2011). In a manufacturing organisation, people typically describe variability as dimensional variations. However, in the QRM context, two types of variability influence flow time (Suri, 2011). The first is the variability in the arrival time of the orders at a source. Second, there is variability that influences the flow time by processing time (Suri, 2011).

Suri (2011), describes a three-way strategy to get insight into system dynamics and reduce the flow time and thus the MCT. In this formula, three items influence flow time, namely mean variability, miraculous effect of utilization and the order time. Figure 2-14 shows the combined impact of utilization and variability on flow time. Point A has a utilization of 90% and high variability. The flow time of the orders of this is nine days. When the utilization is reduced, de flow time will be six days. Lastly, if the variability is reduced too, it could reduce the flow time to three days. The combination of system dynamics improvements shows that it could reduce the flow time by 67%. The OT in the graphs is the mean time a source needs to process the order. When an organisation is in a market with high variability, the company has to invest more in low utilization rates.

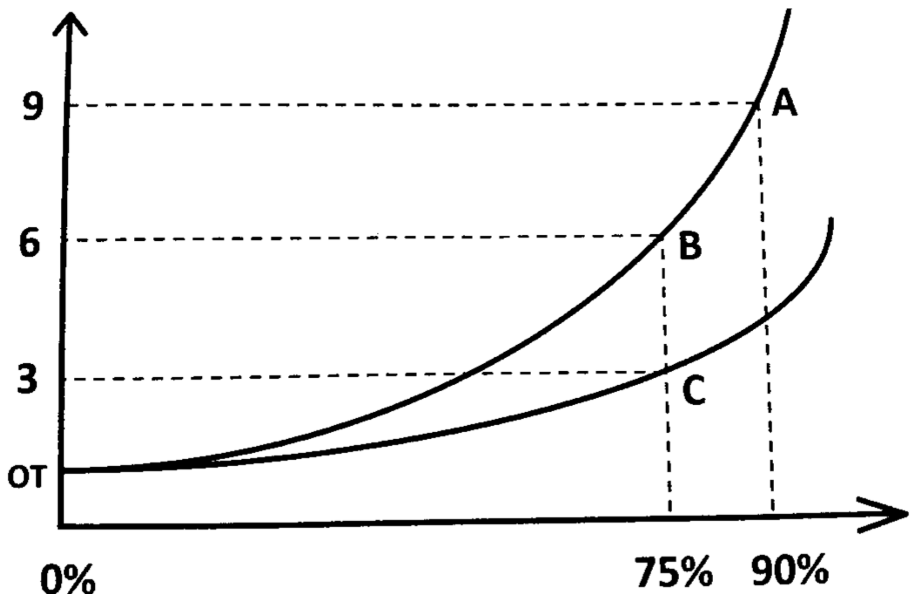


Figure 2-14 Combined impacts of utilization (x-axis) and variability on flow time (y-axis) (Suri, 2011)

Traditional efficiency measurements encourage big batches in production. However, big batches lead to a higher lead time. Therefore, QRM encourages batch production (Suri, 2011). According to Suri (2011), the flow time could be further reduced by reducing changeover time. Reducing changeover time makes it possible to handle smaller batches, which lead to a lower flow time. Figure 2-15 shows the combined influence of changeover time reduction and batch size on flow time. The upper line (SV) is the flow time before changeover time reduction and the second line (SN) shows the flow time after changeover time reduction. The x-axis shows the batch size and the y-axis the flow time.

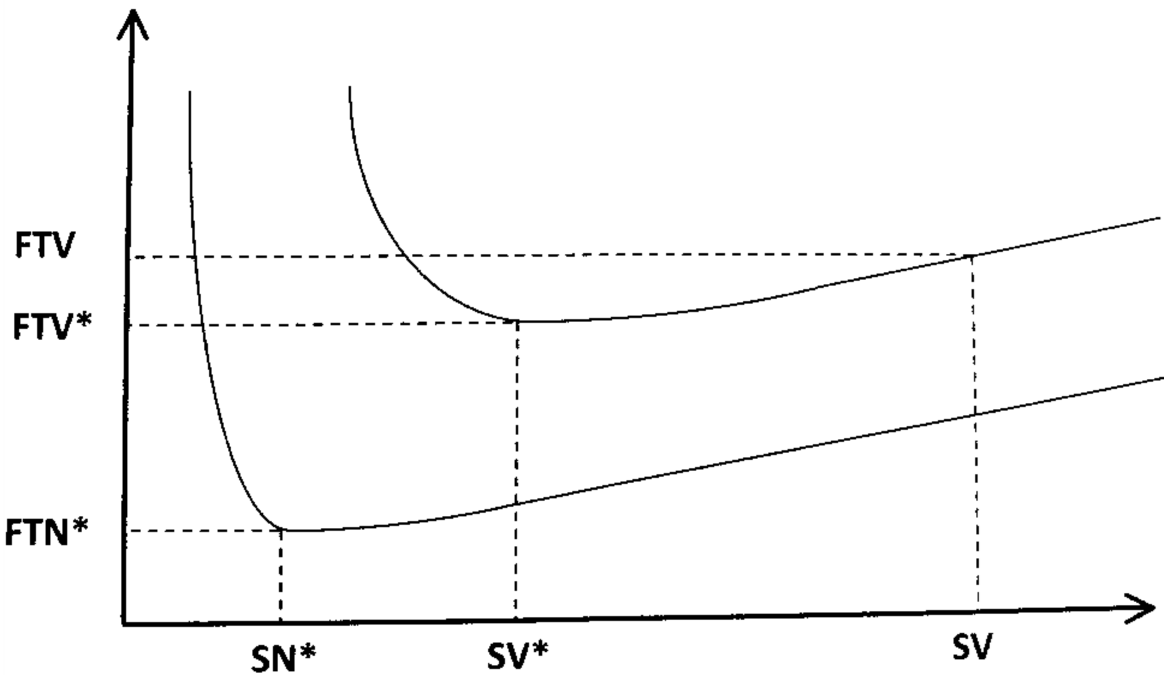


Figure 2-15 Combined influence of changeover time reduction and batch size (x-axis) on flow time (y-axis) (Suri, 2011)

Company-wide approach

The last core concept of QRM is the company-wide approach. QRM is not a strategy only for the workplace, but for the entire organisation. According to Suri (2011), office operations could:

- Take up half the calculated lead time;
- Take up more than 25% of the costs;
- Have a high influence on the order intake;
- Influence the overall market share.

The office operations encounter a similar response time spiral as the production department. Due to this response time spiral, lead time becomes gradually longer. The MCT is used for office departments too. Thereby, the office operations should shift from functional to cellular, these QRM cells are called Quick Response Office Cells, or Q-ROCs (Suri, 2011). The system dynamics from the previous core concept also apply to office operations.

Furthermore, the company should restructure the material resource planning to support QRM. According to Suri (2011), MRP or ERP systems have a negative impact on the MCT. To support reducing the MCT, it is essential to restructure the MRP in the following way. Firstly, MRP/ERP should be used to plan on a high level. The ideas behind high-level MRP are:

- Start with restructuring the organisation to QRM cells;
- Use the high-level MRP system to plan the flow of suppliers and between cells to meet the delivery date;
- Do not micromanage the QRM cells. The QRM cells should get ownership of the operations in that cell.
- Team members of the QRM cells will get more experience in planning and solving capacity issues.
- When products go to different cells, the POLCA system could provide guidance between the cells (Suri, 2011).

POLCA or Paired-cell Overlapping Loops of Cards with Authorization connects two cells by making use of a POLCA loop (Suri, 2011). This loop consists of several POLCA cards that operate in that loop. The number of loops depend on the number of cells and the diversity in the routing of the products. When cell A is finished with producing a product, it sends the product, including the POLCA card, to cell B. When cell B is done with producing, it sends back the POLCA card and sends the product to the next cell. When cell A receives the card back it can send the next product. The POLCA card indicates that the cell is done with the order which is sent by the cell before, so the next product can be sent (Suri, 2011).

The response time spiral also applies to supply chain management. The traditional measures of supply chain management, quality, costs and delivery reliability. These traditional measures lead to a longer lead time and higher costs (Suri, 2011). Therefore, Suri (2011) advises using the MCT as the primary measure of the supply chain, because it is a better indicator of effectiveness, it gives a clear insight into the possibilities of your supplier to adapt to change and it indicates the viability of the supplier on the long term.

Implementation

The 'Power of Six' rule is used for the impact on costs of QRM (Suri, 2011). Suri (2011), gives two measurements for the decision making of QRM implementation:

$$The\ MCT\ ratio = MV = \frac{Expected\ MCT\ after\ QRM\ implementation}{Current\ MCT}$$

and;

$$The\ Cost\ ratio = KV = \frac{Expected\ costs\ after\ QRM\ implementation}{Current\ costs}$$

From these calculations come ratios. These ratios could be used to calculate the other ratio (Suri, 2011).

$$MV = (KV)^6 \text{ and } KV = (MV)^{1/6}$$

These formulas can be used to decide on QRM implementation. For example, if the MCT will be reduced by 40%, the MV will become 0.6. To calculate the cost reduction 0.6 must be raised to the power of one-sixth, which will give 0,92. So the costs will then be reduced by 8%.

Furthermore, Suri (2011), describes four base principles to implement QRM:

1. Emphasise the power of time for your organisation;
2. Create the correct organisational structure;
3. Understand the importance of system dynamics and apply these;
4. Build a company-wide, combined strategy.

To emphasise the power of time in the organisation, the company should organise basic QRM training for managers and employees (Suri, 2011). Thereby, the organisation should make a list of wastes that lead to a long MCT (Suri, 2011). Furthermore, a QRM-facilitator has to be appointed with a steering group that monitor the projects (Suri, 2011).

To create the right organisational structure, the organisation has to create a cross-functional scheduling team. The cross-functional scheduling team/organisation must do the following:

- Train all members so that they have basic knowledge of QRM;
- The scheduling team gets better measurements of the MCT of the project area and uses this to capture the first FTMS (Focus target market segment) of this QRM project in accordance with the product volumes and strategical demands;
- The scheduling team comes up with plans for the FTMS;
- With the support and experience of the QRM facilitator, the scheduling team has to present the recommendations, along with a cost/benefits analysis, to the management (Suri, 2011).

Afterwards, the organisation should form an implementation team for the project (Suri, 2011). The implementation team/organisation should do the following:

- Train all members so that they have basic knowledge of QRM, bring experts for team building and team processes and form physical cells by relocations;
- Start working in cells, give teams ownership and encourage cross-training in cells;
- Ensure that the implementation team gets enough help from the facilitator and the steering group;
- Measure the MCT and implement the QRM number (Suri, 2011).

To apply and understand the importance of system dynamics the organisation has to plan the occupation of the cells with taking into account spare capacity (Suri, 2011). Thereby, the teams must be encouraged to use smaller series and solve bottlenecks occurring from these cases (Suri, 2011).

To build a company-wide, combined strategy the company has to discuss the results of the QRM projects (Suri, 2011). The teams have to receive acknowledgement and the results must be shown in the organisation (Suri, 2011). Furthermore, the company should do the following:

- Build the enthusiasm of the first teams;
- Encourage employees to find new FTMS's;
- Implement QRM in these fields;
- When more cells are formed, consider restructuring MRP and implement Polca;
- Implement QRM outside the production department, so in office and supply chain;
- Broaden the MCT measurement to the entire supply chain and publish the results to create support (Suri, 2011).

Due to the fact that QRM focuses on lead time reduction, high-quality products and providing customer-specific products, it relates with the competitive priorities quality, time/delivery and flexibility.

Summary

The manufacturing methodologies are summarized and compared based on the main competitive priorities in Table 2-9. All these manufacturing methodologies strive to achieve operational excellence. However, the manufacturing methodologies are made for different environments. For this research, QRM is used because QRM is the best fit with the competitive priorities OC Waterloo has/desires.

Table 2-9 Manufacturing methodology per competitive priority

Manufacturing methodology	**Competitive priority**			
	Quality	Cost	Time/Delivery	Flexibility
Total Quality Management (TQM)	X	X		
Six Sigma	X	X		
Lean Manufacturing	X	X	X	
Total Productive Maintenance (TPM)	X	X		
Agile Manufacturing	X			X
Quick Response Manufacturing (QRM)	X		X	X
Theory of Constrains (ToC)		X		
World Class Manufacturing	X	X	X	X

2.7 Conclusion

Operations strategy is divided into three sections, the business strategy (business influence), the external environment (market influence), and the current resources. Thereby, the goal of an operations strategy is to develop the competitive strengths of the operations to achieve the business and external environmental goals. Furthermore, the strategy should consist of a vision and long term goals. More recent studies elaborate on the importance of digitisation of a production facility, so digitisation should be assessed too.

The development of a strategy is continuous. Therefore, several closed-loop frameworks elaborate the relation between the sections of a strategy. These frameworks include business strategy, operations plan, external environment/sales plan, the execution of the plan and the monitoring, learning and adapting of the strategy. Despite that these studies focus on general strategy development, it includes the elements of an operations strategy. For this study the business strategy, external environment/sales plan are analysed. Thereby, the operations strategy consists of monitoring and learning.

Sales strategy/external environment is a driving factor for the operations strategy. A sales strategy could be analysed by analysing the sales plan of a company. Thereby, the external environment could be analysed by doing a brief market research. Furthermore, the product and customer groups are of importance to analyse to examine the difference between groups and/or products. The sales strategy and external environment determine the focus of the competitive priorities.

Out of the sales strategy, external environment and business strategy, competitive priorities arise. The main competitive priorities are quality, cost, time/delivery and flexibility. Depending on the focus of the sales strategy/external environment various (other) combinations of competitive priorities may occur.

The four main competitive priorities could be assessed using key criteria. Quality could be measured by financial and non-financial measures. These measures include the percentage of rework, percentage of defects, etc. The cost of a production facility could be measured by analysing the value-added and non-value added activities. Methods for analysing this are the Overall Equipment Effectiveness, Value Stream Mapping and the Spaghetti method. The time/delivery could be measured using a lead time analysis, utilisation analysis and due-date performance. Last, flexibility could be measured by the product families, size of the products, modification possibilities and volume of the products. Thereby, responsiveness and the development of new products are of importance too.

Digitisation is a more recent development that influences the operations strategy. Maturity models elaborate on the level of industry 4.0 of a company. These levels go from the 0 -non-existent level of industry 4.0 to level 4 self-optimised level of industry 4.0. The company can be assessed on the level of digitisation using these levels.

The desired manufacturing methodology for OC Waterloo should be selected based on the competitive priorities. A table has been made to summarize the competitive priorities per manufacturing methodology.

For this research, the main competitive priorities Time/delivery, quality and flexibility are most important, because these are the competitive priorities OC Waterloo has/desires. Therefore, mostly the KPIs of these main competitive priorities are used. To give further insights into the strengths and weaknesses of OC Waterloo, KPIs of the competitive priority cost are also included. Thereby, the measurement methods MCT and utilization graph are used. Concerning the methodology, QRM is used, because this method applies best to OC Waterloo's situation. The operations strategy is developed using components of structure and infrastructure.

3 METHODOLOGY

The methodology chapter describes the way how the research questions are answered. To answer the research question: '*What should the Operations Strategy of OC Waterloo become and how could it be implemented for the following 5 years, so that it is in line with the strengths of the current production facility, business strategy and market's needs?'* The research question has been divided into seven sub-questions. Each sub-question is approached differently. Therefore, the methodology differs per sub-question.

3.1 Sub-questions

This section describes the sub-question and how these are answered.

Q1: What theories could be used to develop an operations strategy suitable for OC Waterloo?

The first sub-question is the basis for this research. This research question is answered by conducting a literature review. This literature review should answer the following questions:

- What is an operations strategy?
- How could an operations strategy be developed?

First, section 2.1 covers the method for the literature review. Section 2.2 mentions the definition of an operations strategy. Section 2.3 gives the development of an operations strategy. Thereby, it gives insights into the business/sales strategy analysis and the external environment. Section 2.4 covers the competitive priorities of an operations strategy. In addition, it discusses KPIs and measurement methodologies to measure the competitive priorities. Section 2.5 discusses a maturity model for analysing digitalisation. Section 2.6 gives the most used manufacturing methodologies to build the operations strategy upon. Last, Section 2.7 gives a summary and conclusion of the theoretical framework.

Q2: What is the business strategy of the Orange Climate group and OC Waterloo?

The second research question is of importance to make sure that the operations strategy is in line with the business strategy of OC Waterloo and the entire Orange Climate group. The following questions should be answered :

- What is the business strategy of Orange Climate?
- What is the business strategy of OC Waterloo?

These questions are answered by conducting various semi-structured interviews and thereby the analysis of business strategy reports of both OC Waterloo and the Orange Climate group. For the analysis of the strategy, the CEO of OC Waterloo and the COO of Orange Climate are interviewed. The persons are interviewed using semi-structured interviews. Semi-structured interviews are used to keep structure in the interview while maintaining the chance for the interviewee to give a broad answer. If necessary, the information could be checked during the interview using closed questions. The CEO and COO are the (co-)developers of the strategy of the firms. Therefore, these persons are of interest to interview regarding the business strategy.

Q3: What are the market demands regarding the operations of OC Waterloo?

The third research question is of importance to make sure that the operations strategy is in line with the market demands. The following questions should be answered to define the market demands:

- What are the customer groups?
- What are the product groups?
- What are the product demands? – amount of products
- What are the competitive priorities of the market?
- What is the sales strategy of OC Waterloo?

These questions are answered by analysing data of the ERP system, a brief competition analysis and a semi-structured interview with the CEO, former CCO, of OC Waterloo. The ERP system captures the sales orders of OC Waterloo. These sales orders should be analysed on customer groups, product groups, amount of products etc. Thereby, the account managers and CEO could further elaborate on these orders and the market demands. Lastly, the sales strategy should capture the first four questions and is of interest to assess and use for the development of the operations strategy.

Q4: What are the strengths and weaknesses of OC Waterloo's operations?

The fourth question is of importance to measure the current production facility. The production facility is measured using the four main competitive priorities and digitisation. The following questions should be answered to define the strengths and weaknesses of OC Waterloo's current operations:

- What are the production processes per product family?
- What is the current status of the Quality?
- What is the current status of the Costs?
- What is the current status of the Time/Delivery?
- What is the current status of the Flexibility?
- What is the current status of the Digitisation?
- What are the strengths?
- What are the weaknesses?

First, the product families, have to be defined to see which products pass a similar process. Thereafter, the main competitive priorities are analysed. First, the main competitive priority flexibility is measured. The following KPIs are used to measure this: design adjustments, product mix, changes in product volume, changeover, new product, changes in product mix, modification, modify product, volume, broad product line, rerouting, mix, responsiveness and resource mix. Second, the main competitive priority cost is measured. Although this competitive priority is not a focus of OC Waterloo, it still gives insight into the strengths and weaknesses of the current operations. The following KPIs are used to measure this: production costs, manufacturing cost, operator costs, value-added costs, material supply costs, maintenance cost, activity-based costs, running cost, rework cost, service cost, scrap cost, material cost, equipment and operating cost, tool cost and other cost. Third, the main competitive priority time/delivery is measured. The following KPIs are used to measure this: lead time, manufacturing lead time, on agreed time, rate of production introduction, delivery lead time, occupation rate, on agreed quantity, due-date performance and dependable promises. Fourth, the main competitive priority quality is measured. The following KPIs are used to measure this: defect rate, reliability, performance, product rework, defects, reliability and quality costs. Not all KPIs are measured, the reasons for this are the KPI was not measurable, does not apply to OC Waterloo or would take up too much time to measure. Furthermore, the measurement methodologies utilization and MCTs are used, because these measurement methodologies were the only methodologies that covered both only time/delivery and flexibility. The data is gathered using the dashboard and ERP system of OC Waterloo. Data is used from January till April because this is a representative period for OC Waterloo's operation according to the management and the seasonal demand is low. After the four main competitive priorities are analysed, enough data is gathered on the digitisation of the factory. The digitisation of the factory is assessed using the Industry 4.0 maturity levels.

Q5: What should the operations strategy of OC Waterloo become?

The fifth research question combines the previous four research questions. This research question creates an operations strategy based on the theory, business strategy of OC Waterloo and Orange Climate, the market demand/sales strategy and the current situation of the four main competitive priorities of the production facility. The operations strategy is developed using structure and infrastructure mentioned by Boyer and Lewis (2002) and Corbett (2008). This chapter covers structural elements as technology, sourcing, vertical integration and facility, and capacity (Boyer & Lewis, 2002; Corbett, 2008). Thereby, the following infrastructural elements are covered: production planning, organisation (structure), workforce quality, human resource and production & process development systems (Boyer & Lewis, 2002; Corbett, 2008).

Q6: What improvements in operations are needed to achieve this strategy?

The sixth research question compares the desired operations strategy with the current strengths and weaknesses. The following questions are answered in this section:

- What needs to be done to achieve the desired operations strategy?
- Which manufacturing methodologies are most applicable to the competitive priorities of OC Waterloo?

This research question gives opportunities for improvements of the operations of OC Waterloo. Especially, improvements towards the desired operations strategy. The theory on manufacturing methodologies further backs the decision for the manufacturing methodology.

Q7: How could OC Waterloo implement the operations strategy?

The last research question investigates the implementation of the operations strategy which is developed in question four. The following questions are answered in this section:

- How could the operations strategy be presented to the management of Orange Climate (Waterloo)?
- How could the operations strategy be monitored?

Monitoring of the operations strategy is of importance to keep track of the implementation of improvements during the process. Thereby, developing an operations strategy is a continuous process, so the operations strategy may need to be adjusted during the process. The presentation of the operations strategy is of importance to make sure that everyone understands and supports the plan.

In conclusion, a visual overview of the research question, methodology, output, and the end result is shown in Figure 3-1.

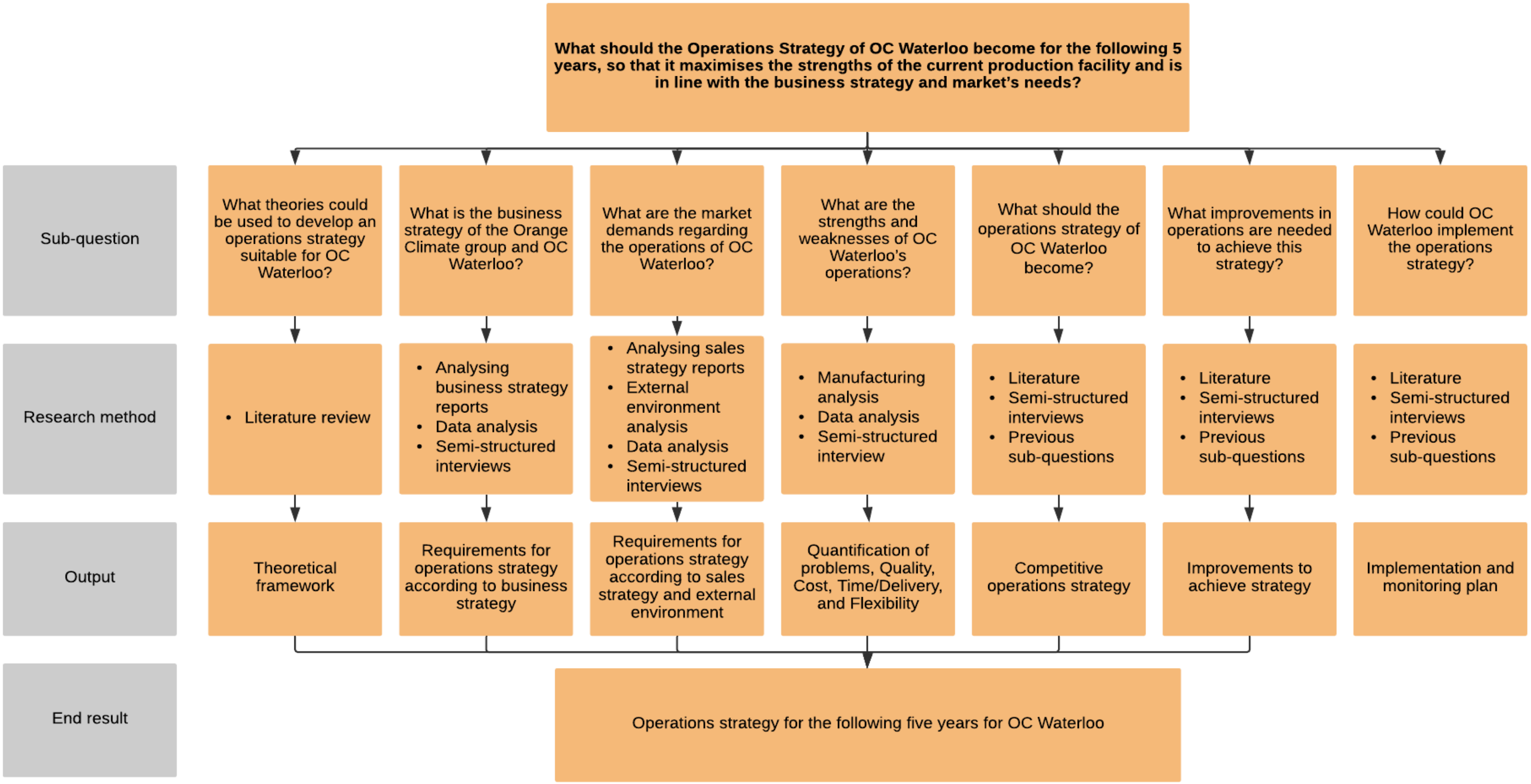


Figure 3-1 Methodology overview

3.2 Reliability and validity

Reliability and validity are important because validity is about the accuracy of the measure and reliability about the consistency of the measure. Reliability and validity are shown in Figure 3-2. Furthermore, data triangulation is used to ensure the credibility of the research. This research can be seen as a design study because this research designs/sets up an operations strategy, which can be reflected afterwards. A design study is a research project in which researchers examine a real-world problem that experts in the field encounter, design a system to solve the problem, and then validate and reflect the design (Sedlmair, 2012). For this research, it is of importance to assess whether the developed operations strategy works or not. The operations strategy can be assessed by measuring whether the strategy delivers the expected results. The expected results can be measured using KPIs, which are given in the last chapters.

Reliability

According to Scribbr[3], reliability is "The extent to which the results can be reproduced when the research is repeated under the same conditions." Reliability is ensured by using measurement methods mentioned in the theoretical framework and the sub-questions. Thereby, measurements by hand inside the factory are thought out well and measured the same over time. The measurements that are not reliable are excluded from the research.

Validity

According to Scribbr[4], validity is "The extent to which results really measure what they are supposed to measure." Validity is ensured by having conversations with the employees of OC Waterloo along with the data analysis. If the employees of OC Waterloo have a different opinion than the data suggests, the validity must be ensured by measuring the data manually. The validity of the data retrieved from OC Waterloo's ERP and production dashboard is ensured by conversations with employees about the validity of the data too. Thereby, the validity can be ensured by assessing whether the results align with the theory.

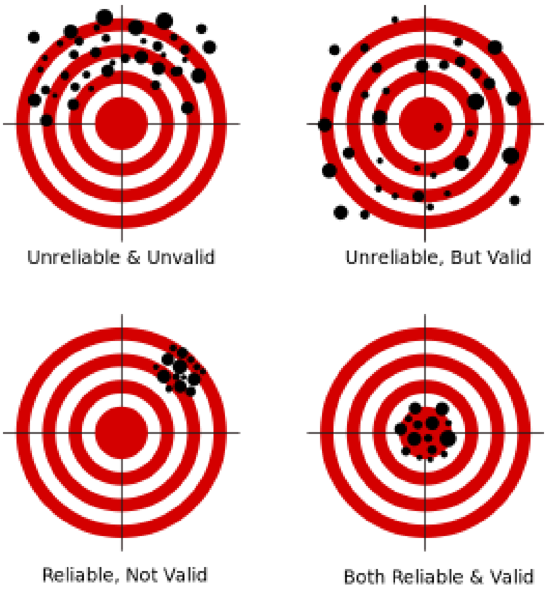


Figure 3-2 Reliability and validity[5]

[3] Reliability vs Validity in Research | Differences, Types and Examples (scribbr.com)
[4] Reliability vs Validity in Research | Differences, Types and Examples (scribbr.com)
[5] Retrieved from https://www.publichealthnotes.com/17-differences-between-validity-and-reliability/

Data triangulation

Data triangulation is the use of different sources and different methods to achieve convergent validity (Fielding, 2012). For this research, data triangulation is used to ensure the credibility of the research. The data triangle is shown in Figure 3-3. The data from the ERP system is triangulated using semi-structured interviews, observations and literature.

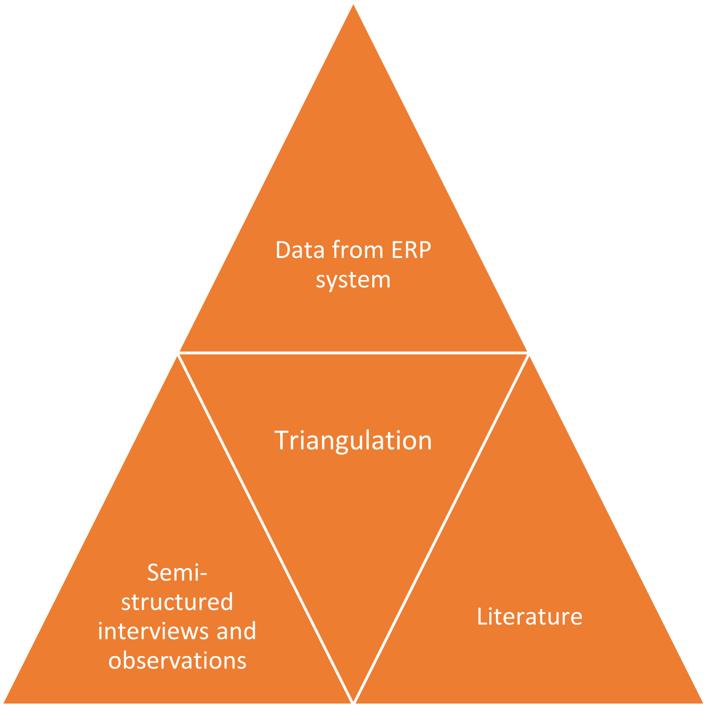


Figure 3-3 Data triangulation

4 OC WATERLOO'S STRATEGY

This chapter discusses OC Waterloo's business strategy, sales strategy, external environment and the competitive priorities. The chapter is summarized and concluded at the end of the chapter. The sections are described using Hoshin Kanri matrices, ERP system data and interviews. Section 4.1 is based on the Hoshin Kanri matrices, section 4.2 is based on the Hoshin Kanri matrices and ERP system data, section 4.3 is based on ERP system data and interviews and section 4.4 is based on the interviews. The interview questions are shown in Appendix 2: Interview Strategy Orange Climate (Waterloo).

4.1 Orange Climate (Waterloo) Strategy

This section discusses OC Waterloo's business strategy and the strategy of the holding firm Orange Climate. OC (Waterloo) has set up Hoshin Kanri matrices for their business strategy. The matrices are shown in Appendix 3: X-matrix Business Strategy and Appendix 4: X-matrix Sales Strategy. The Hoshin Kanri models are described in this subchapter. The Hoshin Kanri model consists of four aspects namely: Long term goals by Orange Climate (2021-2025), next year goals, key performance indicators (KPIs) and improvement initiatives. To assess the company Orange Climate has developed two ladders: a continuous improvement ladder and a corporate social responsibility ladder.

Long term goals

Orange Climate has set up four long term goals for the holding. These goals that have been set up by OC Waterloo are:

- Increase revenue to €100.000.000;
- Have a mean EBITDA of 8% over the revenue of the last three years with a max deviation of 2% per year;
- A score of 2,5 on the Orange Climate continuous improvement performance ladder; and
- A score of 2,5 on the Orange Climate corporate social responsibility performance ladder.

The current revenue of Orange Climate is €40.885.000,-. Thereby, Orange Climate acquired IMP Klima in Slovenia in 2020 as a new manufacturing firm. Their revenue was approximately €25.000.000,- [6]. This revenue is not included in the current revenue of Orange Climate. The current EBITDA of Orange Climate is 6,7%. Orange Climate has not tested its level on the continuous improvement ladder yet. The current score on the social responsibility ladder is 1,6.

One year goals

The one-year goals are focused on OC Waterloo. These goals that have been set up by OC Waterloo are:

- Increase revenue to €9.500.000,-;
- Have an EBITDA of 8,3% of the revenue;
- An increment on the Orange Climate continuous improvement ladder of 0,4 compared to 2020; and
- A minimum score of one on each part of the Orange Climate corporate social responsibility performance ladder.

[6] Acquisition of IMP Klima, Slovenia (orangeclimate.com)

Improvement initiatives

To achieve the goals, OC Waterloo has introduced several improvement initiatives. OC Waterloo refers to this as improvement initiatives. However, these are more goals. The improvement initiatives that have been set up by OC Waterloo are:

- Growth of projects over €100.000,- revenue by focussing on top ten national installers;
- Revenue growth export through more active market approach;
- Increase distinctiveness in the Dutch market by improvement of customer intimacy;
- Increase on-time delivery by getting insight into needed and available production capacity.
- Increase margin on sales;
- Improve productivity through optimising manual processes;
- Reduce failure costs through improving first time right in the primary process;
- Introduce the continuous improvement ladder and conduct a baseline measurement; and
- Measuring and mapping the corporate social responsibility parts.

OC Waterloo wants to grow the amount of bigger projects due to increasing costs at the organisation. The CEO mentioned that OC Waterloo is well known by small and medium-sized installers, but the investments require more large projects and therefore bigger-sized installers. Furthermore, the improvement initiatives are focused on increasing the revenue, EBITDA, continuous improvement ladder and social responsibility ladder.

Key performance indicators

OC Waterloo has set up key performance indicators/goals to measure the progress of the business strategy. OC Waterloo calls these goals KPIs. However, these are more likely goals, because these should be measured using KPIs. There is no deadline added to the KPIs. The KPIs that have been set up by OC Waterloo are:

- Ten projects over €100.000,- revenue billed;
- €2.250.000,- export revenue;
- €7.250.000,- revenue in the Netherlands;
- >90% of the orders delivered on time on the first agreed upon delivery date;
- 3% margin increment on the sales side compared to 2020;
- Direct labour costs of the production is a maximum of 22% of the production revenue;
- The number of defects in the primary production is reduced by 50%;
- All thirteen parts of the corporate social responsibility ladder are mapped and measurable.;
- The parts of the continuous improvement ladder are mapped and a baseline measurement has been conducted.; and
- A growth of 0,4 on the continuous improvement ladder compared to the baseline measurement.

Continuous improvement ladder

The goal of the Orange Climate continuous improvement ladder is to assess the performance of continuous improvement in the company. The continuous improvement ladder consists of thirty rows with different disciplines. The disciplines are customer, process, control, behaviour & leadership and organisation & skills. The disciplines are further narrowed down to categories. The categories are customer understanding, customer anticipation, process: optimisation, process: standardization, controls: visual management, controls: short-cycle steering, controls: performance cascading, control: capacity management, behaviour: result orientation & customer focus, behaviour: cooperation, leadership: coaching, leadership: commitment and continuous improvement, leadership: vision and ambition and organisation and skills. Some categories have the same description. Therefore, there are not thirty categories.

These columns consist of five stages. These disciplines are assessed in the columns. The stages are change, build, professionalise, connect and inspire. The higher the stage, the higher the level of the stage. The stages are also measured on a lean scale in the columns. The steps in this scale are: lean not implemented, lean somewhat implemented, lean implemented well, lean to great extent implemented and lean fully implemented. The steps are measured on a lean scale because Orange Climate uses this methodology for the organisations. The disciplines are assessed using the described stage in the lean scale. For example, the discipline customer consists of the stages (1: Change/Lean not implemented) There is no insight in the customer, (2: Build/Lean somewhat implemented) the employees have base insights in the customer, (3: Professionalise/Lean implemented well) employees are aware which customers there are and have clear insights in customer needs, (4: Connect/Lean implemented to great extent implemented) employees are fully aware of their customers and distinguish different customer groups with their own needs and (5: Inspire/Lean fully implemented) Employees are fully aware of customers, distinguish different customer groups with their own needs and proactively seek to improve services.

Corporate social responsibility ladder

The goal of the corporate social responsibility ladder is to assess the performance of social responsibility in the company. The corporate responsibility ladder consists of thirteen rows with different themes. The themes are human rights, labour practice, environment and community. The topics are human rights at suppliers, absence through illness, progress risk assessment and evaluation action plan, training employees, age distribution, accidents, employee satisfaction, electricity consumption, fuel-efficient company cars, waste per employee, total CO_2 emissions, traineeships and social return. The topics consist of six levels, from zero to five. The higher the level of the theme the better the topic is addressed. The topics are measured via KPIs which belong to each level and theme.

4.2 Sales strategy

This section discusses OC Waterloo's sales strategy. The sales strategy has been defined using the X-matrix/Hoshin Kanri model and semi-structured interviews. The Hoshin Kanri model consists of four aspects, namely: Long term goals by Orange Climate (2021-2025), next year goals, key performance indicators (KPIs) and improvement initiatives. The long term and next year goals for the sales strategy are the same as for the business strategy. The improvement initiatives and key performance indicators are applied to the sales department of OC Waterloo. Furthermore, the sales per customer group and product group have been analysed to get insights into OC Waterloo's customers and products.

Improvement initiatives

OC Waterloo has introduced sales improvement initiatives to achieve the strategic goals. Just as the previous improvement initiatives, these are goals. The sales improvements initiatives that have been set up by OC Waterloo are:

- One account manager on national installers to increase the sales per installer;
- Receive more requests for bigger projects to get more (bigger) orders and therefore more revenue;
- Focus on projects in Germany to increase the revenue in Germany;
- Revenue with ten new customers in Belgium to increase the revenue in Belgium;
- A lower number of customers under €5.000,- in the Netherlands to focus more on customers who deliver more revenue to the company;
- Increment of margin on specials to increase the EBITDA;
- Establishment of A, B and C customers, where C customers have a minimum order quantity of €500,- to make a clear distinction between customers;
- Active market approach with four account managers to improve the customer relation.

These improvement initiatives have been draft up to achieve the one-year goals of OC Waterloo. The main focus of these improvement initiatives is getting more bigger projects as well as customers.

Key performance indicators

OC Waterloo has set up the following key performance indicators to measure the progress of the sales strategy:

- All business locations and decision-making units of national installers mapped;
- €7.250.000,- revenue in the Netherlands;
- 50% more quotations of above €100.000,- in comparison to 2020;
- Fifteen new customers with more than €500.000,- revenue in Germany;
- 50% reduction of customers under €5.000,- revenue in comparison to 2020;
- Margin increment of 15% on specials in comparison to 2020;
- Next to Lidl, achieve ten new customers with €100.000,- revenue;
- All customers have an A, B or C status in the CRM;
- No C customers with a revenue lower than €500,-;
- Organise 16 events with A customers;
- Thousand visits at A and B customers in 2021.

4.2.1 Sales per customer group

OC Waterloo has to comply with the customer demands. However, the competitive demands could vary per customer (group). Therefore, the size of the customer groups has to be analysed to determine which competitive priority to focus on. OC Waterloo's major customer groups are installers, end-users, group debtors, trading companies, contractors, shipbuilders and air duct manufacturers. Installers are companies that lead construction projects and install OC Waterloo's products. End users are customers who use the products for their own activities. Group debtors are customers which are part of the Orange Climate group or Van Dorp group (which is another holding). Van Dorp is a national installer. Trading companies are customers who trade the products of OC Waterloo. Contractors are customers who use OC Waterloo products for their building projects. Shipbuilders use OC Waterloo's products for the ships they build and air duct manufacturers use OC Waterloo's products to mount them on the air ducts they produce. Group debtors are considered installers because the Van Dorp Group is a national installer. The category is divided to get insights into how much of OC Waterloo's turnover comes from group debtors. The percentage of sales per customer group is shown in Figure 4-1.

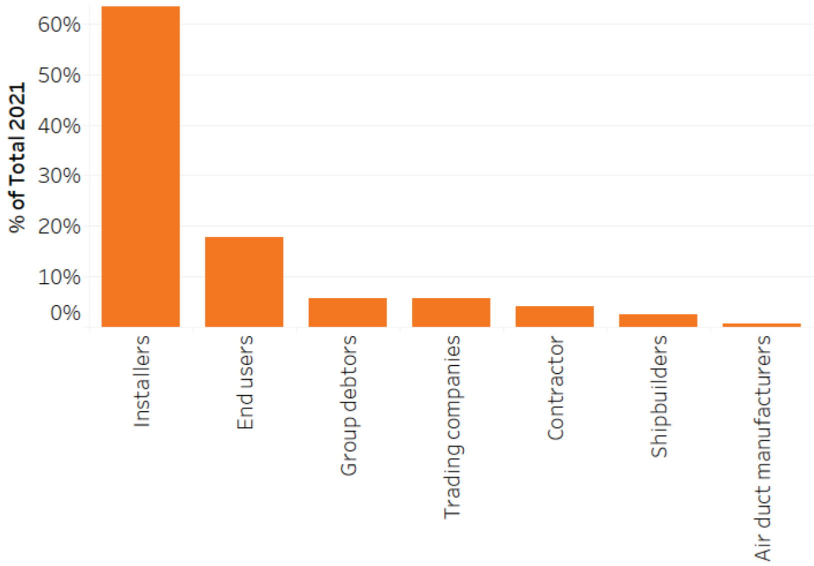


Figure 4-1 Sales per customer group

4.2.2 Sales per product group

The competitive priority could vary per product group. Therefore, the size of the product groups have been analysed. Preferably, the competitive priority is assured per product group. However, it could be possible that trade-offs in operations strategy have to be made. Therefore, the sales per product group have been analysed, to analyse the most successful product groups. The percentages of sales per the ten biggest product groups are shown in Figure 4-2.

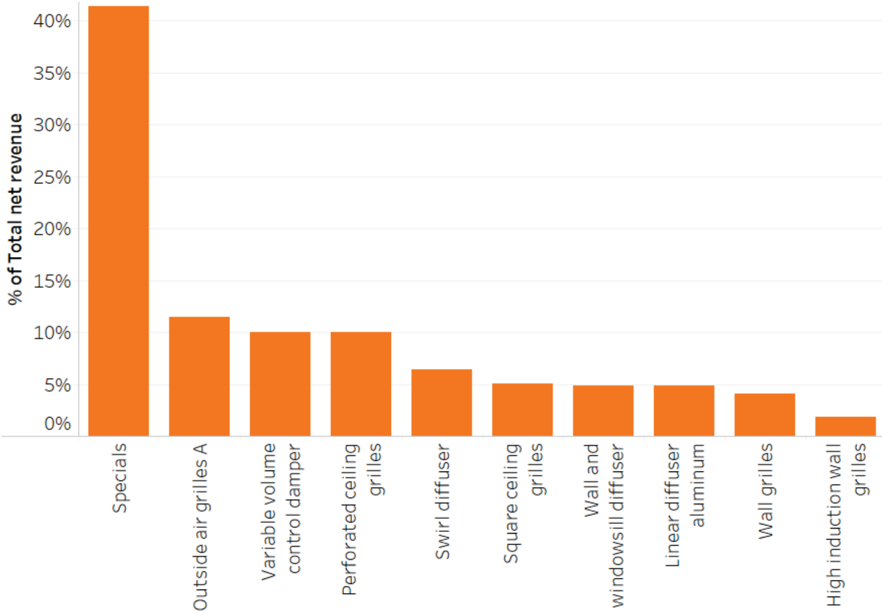


Figure 4-2 Sales per product group.

4.3 External environment

As mentioned in the theoretical framework, the operations strategy builds upon the external environment. Therefore, OC Waterloo's external environment is assessed. First, OC Waterloo's consumers are industrial companies, care and educational institutions, hospitality and leisure facilities, government buildings, business services etc. However, most installations are delivered by third parties. These third parties are contractors, installers, end-users, shipbuilders, trading companies and air duct manufacturers. These third parties are OC Waterloo's customers. The customers in the sales strategy and external environment correspond to each other. This means that OC Waterloo serves all clients in the market. However, the company does not have the same turnover per customer. The main customer in the market are installers. According to the CEO, installers especially require the supplier to focus on time/delivery and flexibility.

According to the CEO, OC Waterloo has three main competitors: SolidAir, Barcol-Air and Trox. In addition, the COO also mentions SolidAir and Trox as main competitors. Trox is the global market leader. However, Trox does not deliver the same flexibility as OC Waterloo. According to the CEO, SolidAir is OC Waterloo's biggest competitor. SolidAir delivers the same flexibility in products. The prices are similar too because both companies produce in the Netherlands. OC Waterloo's and SolidAir's products do not differ that much either. The CEO mentioned: "… if you hang a Waterloo ceiling next to a SolidAir one, you have to be quite an expert to see the difference" (Interview Business Strategy). The overall differences between SolidAir and OC Waterloo are "marginal". However, the CEO mentioned that "SolidAir has the advantage of being part of a ducting company that includes everything [from duct manufacturing to mounting]" (Interview Business Strategy). Therefore, OC Waterloo wants to be distinct by being independent and only supplying products. OC Waterloo stands out in terms of delivery time reliability and customer relationship.

4.4 Competitive priorities

The competitive priorities have been gathered by conducting two interviews partly based on the business strategy, sales strategy and external environment. An interview has been conducted with the CEO of OC Waterloo and an interview with the COO of Orange Climate (Interview CEO OC Waterloo & Interview COO Orange). The interviews have been coded and summarized in Table 4-1.

Both directors mention the importance of flexibility of the organisation and product design. Currently, this is seen as the biggest competitive strength of OC Waterloo. The CEO of OC Waterloo mentioned that the products produced by Waterloo are simple and can be produced by anyone. Therefore, the CEO mentions the importance of short delivery times. The COO of Orange Climate wonders whether the delivery time is important to OC Waterloo. Especially because the fast delivery "gets in the way of the rest and disturbs your process". Most likely, lead time is of importance, because the CEO has worked at OC Waterloo for almost twenty-one years in various sales positions, including CCO. The COO of Orange Climate has not worked at OC Waterloo and the argumentation is internally driven (faster lead time disturbs the process). Thereby, the COO mentioned that "Paul [CEO OC Waterloo] probably has the best insight into this."

Furthermore, the CEO of OC Waterloo mentioned that the competitive priorities differ per customer group. Original equipment manufacturers (OEMs)/end users, mainly require OC Waterloo to be flexible. Installers mainly require OC Waterloo to have a short delivery time. Third, air duct companies base their decision mainly on price. Last, the other customer groups require mainly flexibility. Logically, quality is of importance to every customer. In addition, the differentiation strategy also differs per product group. The delivery time focus is mainly on wall and ceiling grilles. The flexibility applies to all products of OC Waterloo. Based on the sales per customer group (mainly installers and end-users), sales per product group (mainly specials) and the requirements from the customers and market, OC Waterloo focuses on flexibility and time/delivery.

Table 4-1 Coding scheme interviews business/sales strategy and competitive focus

Theme	Quotes	Quotes
	CEO OC Waterloo	COO Orange Climate
Differentiation of Orange Climate	"… another point that we can win on is customer intimacy and we're going to focus a lot on that."	"Well I think by contacts, so relationships with customers. I think we can respond quickly to customer needs."
Competitive priorities of OC Waterloo	"Flexibility, responding quickly to the market, short delivery times, being able to produce a special quickly is what sets us apart."	"Respond quickly to customer needs"
Reason for differentiation	"Anyone can make our products in large containers and have them shipped here. It is precisely the flexibility, the adaptation in sizes and the speed of delivery that makes us unique, that is our real chance of survival."	"We do try to make products with standard parts, but around that, we are quite flexible if something needs to be fitted in, technical space or a technical adjustment is required. I think that is the case with all companies [in the Orange Climate group]. I think that if something is wrong, we are there, so we don't run away from problems."
Importance of delivery time	"We are at the very end of the construction phase, so very often there is a sudden rush because the project must be delivered and the goods still have to be installed. So we have to be able to fully anticipate on that."	"I wonder, I don't know." "For Waterloo, I've sometimes said, do you have to deliver a grid in two or three days? Maybe it's an argument that if they can't deliver the product anywhere then you get the order. But I don't know if you have to organise your entire production on that basis. What you see now is that your fast delivery constantly gets in the way of the rest and disturbs your process."
Main investments in the coming years	"In Slovenia [IMP Klima]"	"At IMP Klima they have old machinery, we are looking at how we can invest to make it better."

4.5 Conclusion

This chapter has described the business strategy of Orange Climate and OC Waterloo. Thereby, this chapter has described and analysed the market demands for the operations of OC Waterloo. Therefore, this chapter answers the following research questions:

"What is the business strategy of the Orange Climate group and OC Waterloo?"

And

"What are the market demands regarding the operations of OC Waterloo?"

Orange Climate has set goals for the group to increase the revenue to €100.000.000,-, increase the mean EBITDA to 8% of the revenue, have a score of 2,5 on the continuous improvement ladder and a score of 2,5 on the corporate social responsibility ladder. These goals have been scaled down to OC Waterloo. For that reason, OC Waterloo wants to increase their revenue to €9.500.000,-, increase their EBITDA to 8,3% of the revenue, achieve a 0,4 increment on the continuous improvement ladder and have a minimum score of one on the corporate social responsibility performance ladder. To achieve this OC Waterloo wants to focus more on bigger projects and therefore bigger installers. Furthermore, OC Waterloo wants to improve its margins, grow its revenue internationally and improve its productivity.

The main competitive priorities of OC Waterloo are flexibility and time/delivery. These main competitive priorities are in line with the customer's as well as the market's demand. Therefore, the sales strategy and market demands are in line with each other. The biggest customer group of OC Waterloo and the market are installers. In addition, the biggest product group for OC Waterloo is special products. However, the KPIs set in the business strategy and sales strategy do not correspond with the KPIs of flexibility and time/delivery mentioned in the theoretical framework. The only KPI which is covered in the business strategy is due-date performance. Other KPIs are neglected. Therefore, the business strategy needs adjustments to comply with the competitive priorities.

In conclusion, the main focus of OC Waterloo is to increase their revenue, increase their EBITDA margin and focus on flexibility and delivery time.

5 STRENGTHS AND WEAKNESSES OF OPERATIONS

This chapter discusses the strengths and weaknesses of OC Waterloo's operations based on the four main competitive priorities: Flexibility, Cost, Time/delivery and Quality. The data comes from the ERP system, production dashboards and an interview with the production manager. The interview questions are shown in Appendix 5: Interview Production Manager. The data has been cleaned and prepared for analysis using R-Studio. The visualisation is done via Tableau and Excel. Most KPIs in this chapter were measured in this research. However, OC Waterloo has measured the changeover times, the planning/utilization, the on-time delivery, the turnover per hour and the quality. The on-time delivery and turnover per hour are being used as KPIs.

5.1 Flexibility

This section assesses the flexibility of OC Waterloo's operations. According to OC Waterloo's strategy, flexibility was one of the competitive priorities of OC Waterloo. Flexibility in the operations is of importance to find a balance between distinctiveness and commonality. The following KPIs could be measured to analyse the flexibility: material quality, design adjustments, product mix, output quality, changes in product volume, changeover, new product, changes in product mix, modification, modify product, changes in product lifecycle, volume, deliverability, broad product line, rerouting, material, mix, responsiveness and resource mix (Gerwin, 1993; Liu & Liang, 2014; Neely et al., 1995). The KPIs material quality and output quality are not measured in this section, because it belongs more to quality competitive priority. Changes in product lifecycle are not included, because OC Waterloo's products are very durable. Deliverability is excluded because it belongs more to the time/delivery competitive priority. Lastly, material is excluded because the materials of OC Waterloo are sheet metal plates and profiles. Therefore, the following KPIs are measured: design adjustments, product mix, changes in product volume, changeover, new product, changes in product mix, modification, modify product, volume, broad product line, rerouting, mix, responsiveness and resource mix. (Gerwin, 1993; Liu & Liang, 2014; Neely et al., 1995). Thereby, product families are created. Table 5-1 gives the measured KPI(s) per subheading. These subheadings are needed to assess the current strengths and weaknesses of OC Waterloo's operations and are based on the KPIs from the theoretical framework.

Table 5-1 Measured KPI(s) per subheading flexibility

Subheading	Measured KPI(s)
Products, product design and product families	Design adjustments, broad product line, modify production, modification, product mix, new product, mix
Production process	Rerouting, mix, resource mix
Volume	Volume, product mix
Order quantity	
Variability	Changes in product volume, changes in product mix,
Personnel	Resource mix
Changeover times	Responsiveness, changeover

5.1.1 Products, product design and product families

OC Waterloo delivers a wide range of products. 117 different products types have been in process from the 4th of January 2021 till the 30th of April 2021. These products are from small wall grilles to huge roof hoods. The products are described in Appendix 6: Product amount per product type. All products can be further customized to the customer's wishes. For example, the product 1H (adjustable wall grille) has been delivered in 40 types in the dataset. The customization is in the dimensions, colour and attachment method. In addition, OC Waterloo has delivered 2790 different product configurations out of the 117 product types. For this reason, OC Waterloo delivers a vast number of products and product modifications. As mentioned before by the CEO, OC Waterloo's products are similar to the competitors products.

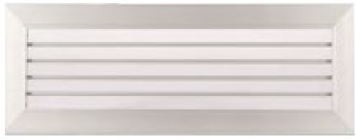
To simplify the analysis for this research and to get further insights into the products, product families have been created. As mentioned in the theoretical framework product families are: "… a group of products that passes through similar downstream processing. By downstream processing, we mean the flow of product to the customer after the shared resources" (Duggan, 2013, p. 31). The products and processes have been coupled using a product family matrix. This matrix develops product families by filling in the process steps per product (Duggan, 2013). Then, product families are created from products that undergo similar processes and have a similar design (Duggan, 2013). Afterwards, the product families have been checked by the technical manager and CEO of OC Waterloo. The technical manager and CEO were unanimous about the product families. The product family matrix can be found in Appendix 7: Product family matrix. The product families are:

- Airlines;
- Outside air grilles;
- Adjustable grilles;
- Linear grilles;
- Sheet products;
- Steel linear grilles;
- Volume control dampers;
- Other grilles;
- RW-series;
- Trade products;
- Panels and induction units;
- Volume control;
- Swirl diffusers; and
- Specials.

On the next page, examples of the product families are shown, the product type is mentioned between the brackets. These examples are of one product in the product family, other products could look different. The full list of product types per product family can be found in Appendix 6: Product amount per product type.

Airlines (RTC)

Outside air grilles (WG)

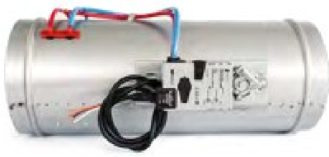


Adjustable grilles (1H)

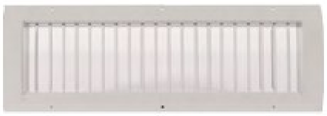
Linear grilles (CS)

Sheet products (WPD)

Steel linear grilles (STCS)



Volume control dampers (WRS)

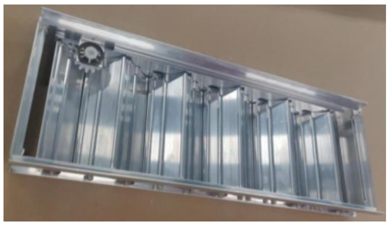


Other grilles (1RV)

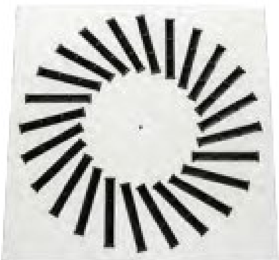
RW series (RWI)

Trade products (CU)

Panels and induction units (ABM-300)



Volume control (O)



Swirl diffusers (SDV)

5.1.2 Production process

To get more insight into OC Waterloo's production, the processes have been analysed. The production map is shown in Appendix 1: Production map. To get further insights into the process steps of the product families, process flow diagrams have been created of the product families. The process flow diagrams of the product families are shown in Appendix 8: Product family routing. Although, product families are created the product families still not undergo exactly the same process steps. This implies that there is much variability in the process steps. For the development of the process flows simplified process steps are used. For a detailed description of the process steps, see Appendix 8: Product family routing. Figure 5-1 gives the process flow of the most ordered product family, sheet products.

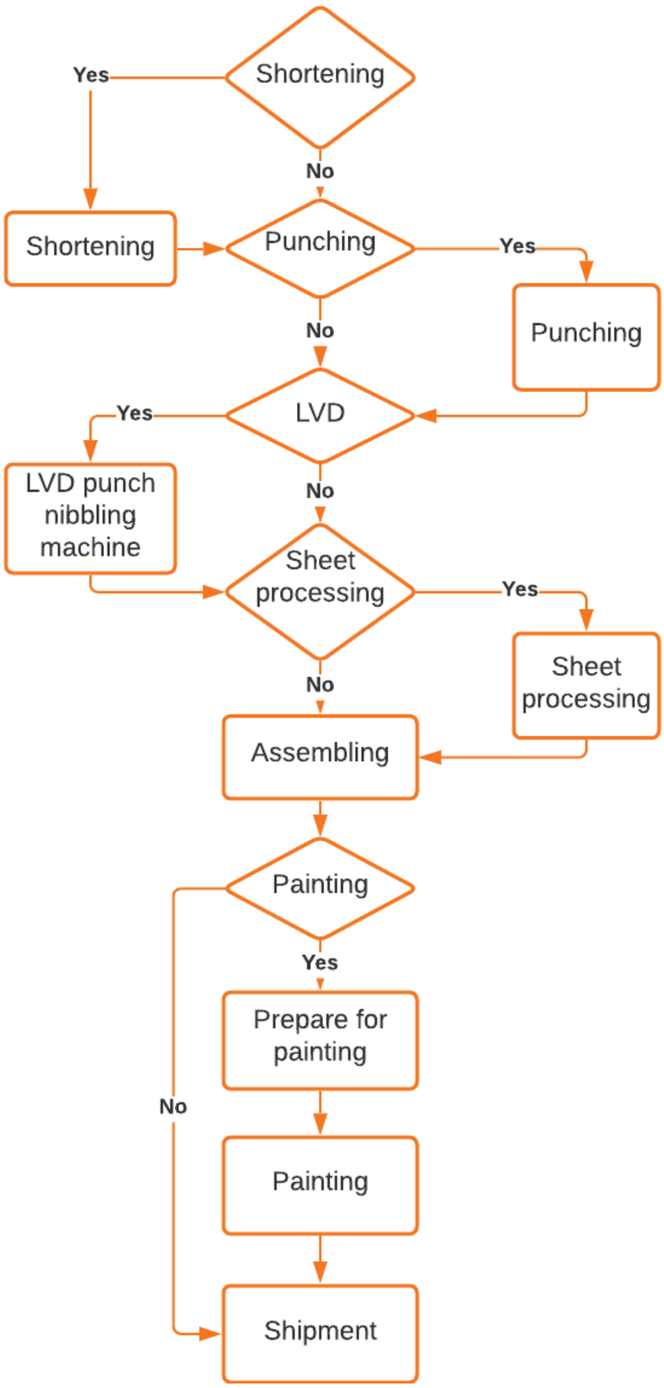


Figure 5-1 Process flow sheet products

The first step in the process depends on the type of product. Most of the products start with the LVD or shortening. The processes concerning the LVD are the processing of sheets using the LVD punch nibble machine. The LVD punch nibbling machine is shown in Figure 5-2. The LVD punch nibbling machine can punch, nibble, bend, tap and form sheet metal. The machine is provided with sheet metal from the sheet metal tower and is automatically loaded and unloaded. The machine can operate 24/7.

Figure 5-2 LVD Punch nibbling machine

The shortening production step shortens profiles from the Ciampalini fully automatic profile storage. The Ciampalini fully automatic profile storage is shown in Figure 5-3. This machine stores profiles which are used in the shortening department. The machine automatically takes the necessary container for the products to be sawed. After the right products are gathered from the profile storage, the profiles are sawed using saw machines with automatic measurement systems.

Figure 5-3 Ciampalini fully automatic profile storage

After these steps, the product could go to the punching department where holes are punched in the profiles to assembly the air grilles. Thereafter, the tubes of the air grilles are expanded to ensure a tight fit of the blades. The sheet metal products could also go to the sheet processing department where sheet metal is bend using Safan press brakes. Later, the products are assembled. Logically, the assembly process differs per product type. If desired, the products are painted by an external painter. Lastly, the products are packed and shipped to the customer.

5.1.3 Volume

To get further insight into OC Waterloo's flexibility the volume of the product families have been analysed. OC Waterloo has delivered 25718 products from the 4th of January 2021 till the 30th of April 2021. In this period, there were 81 working days. Thus, OC Waterloo delivers 318 products a day on average and 318*5=1.590 products per week on average. OC Waterloo produced 22761 of these products, which is an average of 1405 products per week and 281 products per day. In Table 5-2 the product amounts per product family are shown. The most delivered products are sheet products, thereafter airlines and thirdly specials. Remarkable is that OC Waterloo delivers a high amount of specials to its customers. To produce the specials, OC Waterloo has to remain flexible in its operations, because of the variation in the process steps a special product goes through. For further insights, the product amounts per product type are shown in Appendix 6: Product amount per product type.

Table 5-2 Product amount per product family

Product family	**Product amount**
Sheet products	6337
Airlines	3594
Special	3064
Trade	2957
Other grilles	2137
Linear grilles	2096
Volume control	1883
Volume control dampers	1252
Panels and induction units	636
Swirl diffusers	602
Outside air grilles	524
Adjustable grilles	467
RW-series	149
Steel linear grilles	20
End total	**25718**

5.1.4 Order quantity

The order quantity is also of importance to the flexibility of the production. Table 5-3 gives the mean order quantity and the standard deviation of the order quantity per product family. The mean order quantity per product family is low because OC Waterloo delivers on average six products per order. The standard deviation shows that most order quantities are dispersed in relation to the mean. This means that OC Waterloo receives orders with different order quantities. Combining the volume and the order quantity, OC Waterloo delivers a lot of small orders to its customers, considering OC Waterloo delivers on average 306 products per day with an average order quantity of six. Therefore, the variability in OC Waterloo's operation is high. So, flexibility in the operations is needed to cope with this.

Table 5-3 Order quantity per product family

Product family	Mean quantity	Standard deviation order quantity
Adjustable grilles	4,1	8,8
Airlines	5,7	17,9
Linear grilles	25,9	85,2
Other grilles	6,4	10,8
Outside air grilles	2,1	2,1
Panels and induction units	12,2	10,2
RW-series	3,8	3,7
Sheet products	7,4	12,3
Special	5,7	13,0
Steel linear grilles	10,0	0,0
Swirl diffusers	8,7	10,2
Trade	5,9	15,2
Volume control	9,5	26,7
Volume control dampers	2,1	2,6
Mean	**6,0**	**17,9**

5.1.5 Variability

To assess the variability in the process the product amounts have been gathered. Table 5-4 and Figure 5-4 show the product amount per product family per month. This table shows that there is high variability in product demand between the months. In March, OC Waterloo delivered three times the amount of products as in January. The demand in product families also differs per month. For example, in March, OC Waterloo delivered almost 1000 specials and in April and January around 500. This is the case for several product families.

Table 5-4 Product amount per product family per month

Product family	**January**	**February**	**March**	**April**
Adjustable grilles	53	143	72	199
Airlines	341	801	1166	1286
Linear grilles	109	721	984	282
Other grilles	417	642	709	369
Outside air grilles	112	125	163	124
Panels and induction units	122	85	247	182
RW-series	22	73	22	32
Sheet products	765	1853	1995	1724
Specials	514	1047	997	506
Steel linear grilles		20		
Swirl diffusers	148	164	164	126
Trade	38	924	1298	697
Volume control	142	744	776	221
Volume control dampers	123	349	301	479
End total	**2906**	**7691**	**8894**	**6227**

Furthermore, the product amount per product type per month is shown in Appendix 9: Product amount per product type per month. This table further explains the variability in OC Waterloo's production process. The CEO mentioned that some products are not delivered for several months, but after that, there is a large order of fifty products. The CEO mentioned: "We still don't really understand the reason for this". However, there are no/limited seasonal influences.

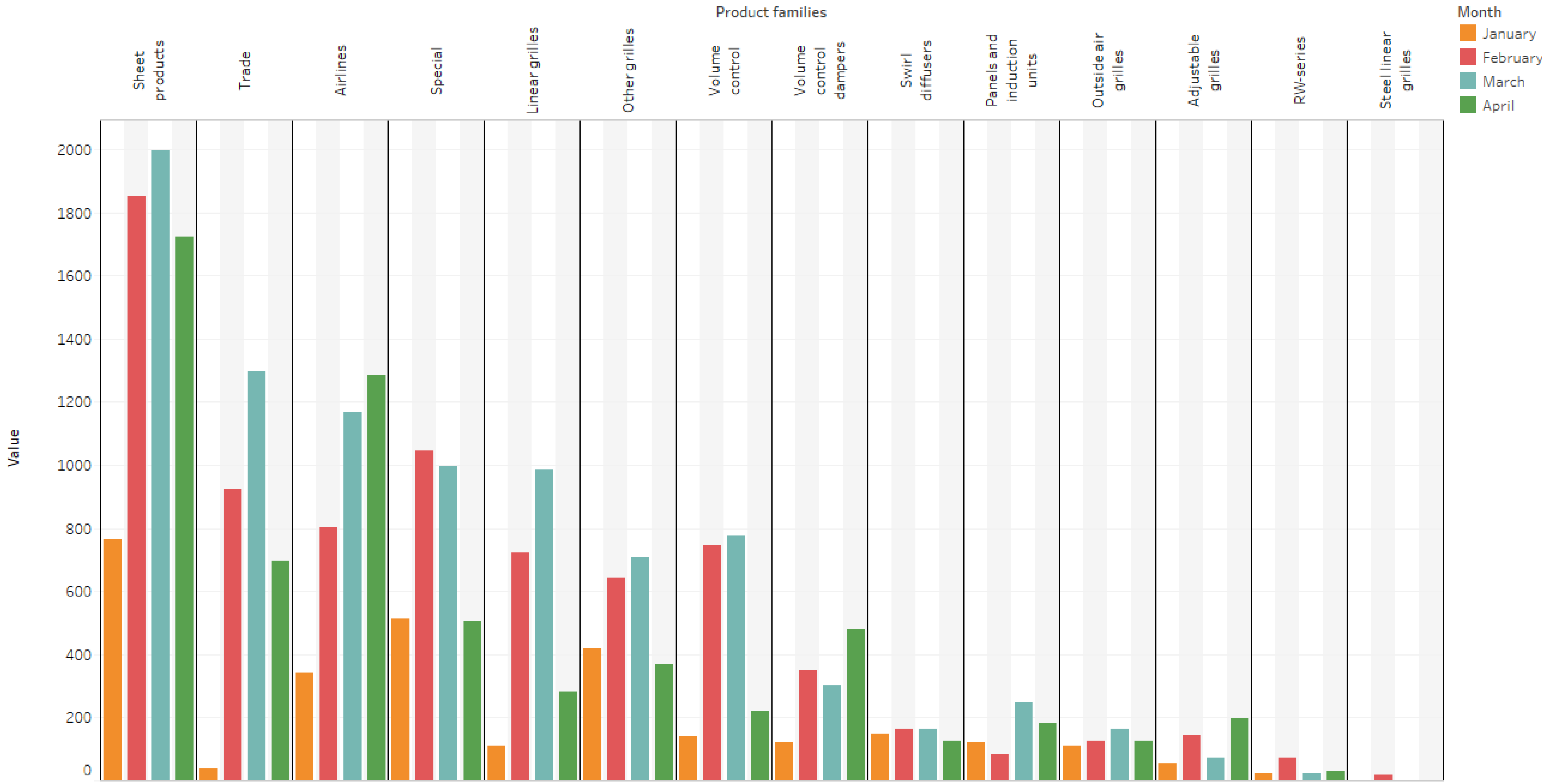


Figure 5-4 Product amount per product family per month

5.1.6 Personnel

Personnel, team dynamics and informalities have an impact on the operations strategy. Therefore, it is of importance to analyse the personnel of OC Waterloo's production site. According to the production manager, the production personnel is reasonably versatile within the departments. OC Waterloo has four production departments with four team leaders. In that team, the goal is to cross-train the personnel wherever possible. For example, three persons are able to operate the LVD punch nibbling machine, thus OC Waterloo has ensured that critical processes are not at risk in terms of human resources. Furthermore, most production employees work at OC Waterloo for a reasonable amount of time, so the employees have knowledge of the products of OC Waterloo. However, most employees did the same job all that time, so there are some difficulties with changing the mindset of the employees. In conclusion, OC Waterloo has made sure that critical processes are ensured and that employees are more and more cross-trained so that OC Waterloo has more flexibility in terms of scheduling and filling vacancies.

5.1.7 Changeover times

The changeover times have been measured per production department using a stopwatch. The times are measured by the work preparation department. These are the mean changeover times. The changeover time can differ per order size. These departments are shortening, punching, tube expanding, press brakes and assembly of outside air vents. The other assembling departments have almost no changeover time.

At the shortening department four changeover times are measured: the automatic profile storage (once per order), the saw table supply bin (depends on the size of the order), the changeover of saw blocks (not needed for every profile, mostly done while the storage is getting the material) and the measurement of the first profile (each first saw cut, more than once for large orders). The changeover times are shown in Table 5-5.

Table 5-5 Changeover times shortening department

Changeover step	Time (in minutes)
Automatic profile storage	3,9
Saw table supply bin	0,7
Changeover of the saw blocks	3,7
Measurement of the first profile	1,5

At the punching department also four changeover steps are measured. The steps are blade changeover time, edge changeover time, changeover time E1 blade and bundling blades. The changeover times are shown in Table 5-6.

Table 5-6 Changeover times punching department

Changeover step	Time (in minutes)
Changeover times blades	2,2
Changeover times edges	1,9
Changeover time E1 blade	0,7
Bundling blades	0,8

At the tube expander, two changeover times are measured. The changeover time of the fin spacing and tube pitch. The changeover times are shown in Table 5-7.

Table 5-7 Changeover times tube expander

Changeover step	Time (in minutes)
Changeover time of the fin spacing	3,8
Changeover time tube pitch	1,3

At the press brakes (sheet processing) department, three types of changeover times have been measured, namely writing the press brake program, selecting an existing press brake program and placing/changing the tooling. The changeover times are shown in Table 5-8.

Table 5-8 Changeover times press brakes

Changeover step	Time (in minutes)
Writing the press brake program	5,8
Selecting an existing press brake program	0,4
Placing/changing the tooling	4,6

At the assembly department for the outside air grilles, three changeover times have been measured. The changeover times are changeover punch YG-WG, changeover time for the punch and changeover for the milling machine. The changeover times are shown in Table 5-9.

Table 5-9 Changeover times outside air grilles

Changeover step	Time (in minutes)
Changeover punch YG-WG	6,2
Changeover time punch	2,6
Changeover milling machine	2,6

Almost all changeover times of the production departments are under five minutes, so OC Waterloo has low changeover times. The low changeover times could reduce the production batch sizes, which could lead to less work in progress and inventory and therefore a lower lead time.

5.2 Costs

Costs are not part of OC Waterloo's competitive priorities. However, analysing costs is still important to analyse OC Waterloo's current strengths and weaknesses. The costs could be measured using the following KPIs: production costs, manufacturing cost, operator costs, value-added costs, material supply costs, quality costs, selling price, maintenance cost, activity-based costs, running cost, rework cost, continuous improvement costs, service cost, scrap cost, material cost, equipment and operating cost, tool cost and other cost (Andersson & Bellgran, 2015; Liu & Liang, 2014; Neely et al., 1995). Quality and rework costs are excluded because these are discussed in the quality subchapter. Thereby, selling price is excluded, because OC Waterloo delivers many products with different configurations at different prices. Lastly, continuous improvement costs are excluded, because these are not measured at OC Waterloo. The following KPIs are measured: production costs, manufacturing cost, operator costs, value-added costs, material supply costs, maintenance cost, activity-based costs, running cost, rework cost, service cost, scrap cost, material cost, equipment and operating cost, tool cost and other cost (Andersson & Bellgran, 2015; Liu & Liang, 2014; Neely et al., 1995). The KPIs are discussed in the operating budget. The turnover per hour is discussed because OC Waterloo uses this KPI. Furthermore, the cost focus from the interviews is discussed.

5.2.1 Operating budget

OC Waterloo has made an operating budget for the organisation. This budgeting applies to the entire organisation. This budgeting is used to calculate the KPIs. All these costs are based on a revenue of €9.515.570,-. Thereby, all costs are based on a year, if not mentioned otherwise.

The total production costs of OC Waterloo are €7.399.122. These costs include material cost and hourly cost of the production. The material costs of OC Waterloo are €3.770.000. Last year, these costs were €3.631.000. Of these material costs, €2.630.000 is assigned to the sales of production products. The other €1.140.000 are buy-in costs assigned to the trade products. So, 30% of OC Waterloo's total buy-in/material costs are assigned to trade products. The total material costs account for 51% of the production costs. The scrap costs are between 10-15% of the buy-in costs. The scrap costs differ because the amount of scrap differs per product type. Therefore, the scrap costs are between €377.000 and €565.500.

The labour costs of the production are €1.671.887. The labour costs are divided between the machine work (LVD punch nibbling operator) and assembly work (labour intensive work). The total labour costs are €42.671 for machine work and €1.629.216 for assembly work. The costs for the equipment and personal protection equipment are €108.000.

To get further insights into the costs of the production, hourly costs have been set up. The hourly costs are divided between machine work (LVD punch nibbling) and assembly work (labour intensive work). The hourly rate for the LVD punch nibbling machine is €109,87. Thereby, the hourly rate for the assembly personnel is €59,82. The difference in hourly rate is due to costs associated with the machine. The total hourly costs are €210.949 for the machine work and €3.418.173 for the assembly work. The hourly costs of the production are €3.629.122. The yearly assembly work hours are 57.145 and the machine hours are 1.920. The hourly costs account for 49% of the production cost. So, the production is labour intensive. The direct shipping and transport costs are €389.000. The depreciation costs are €430.831 based on machine and inventory. The building depreciation is €36.074. Furthermore, the maintenance costs are €35.000. These costs are included in the hourly rate.

OC Waterloo adds a surcharge to the production costs for sales costs. This surcharge is 21.6% over €7.399.122. So, the sales costs are €1.594.987.

The total costs of OC Waterloo are €8.994.109. Therefore, the break-even revenue is €8.994.109. Last year this was €8.712.000. Including a 5.8% profit margin to achieve the desired net return of 77% on invested capital after-tax, the revenue has to be €9.515.570. The value-added costs cannot be calculated per product due to the number of products OC Waterloo delivers. The overall value-added costs are the total production costs of €7.399.122. Therefore, the value-added costs are 78% of the budgeted turnover. The operating budget is shown in Table 5-10. The costs show that OC Waterloo has a labour-intensive production process. Thereby, it shows that OC Waterloo's cost price is 40% of the turnover.

Table 5-10 Operating budget

Operating budget	**Total**
Materials/purchasing	€3.770.000
Average hourly rate	€3.629.122
Subtotal materials/purchasing hourly costs	**€7.399.122**
Surcharge sales expenses	€1.594.987
Break-even turnover	**€8.994.109**
Minimum profit surcharge	€521.461
Budgeted turnover	**€9.515.570**

5.2.2 Turnover per hour

OC Waterloo measures the turnover per hour for the efficiency and performance of the operations. As mentioned before, efficiency has a lot to do with operations expenses and cost. Figure 5-5 shows the turnover per hour. The turnover per week is calculated by dividing the turnover per week by the available hours for a week. The solid black line is the target turnover per hour which is €150,-. The turnover/hour per week is shown in the orange bars. The dotted black line shows the linear trendline of the turnover. The linear trendline has an increasing slope, this means that the turnover/hour slightly increases over the weeks.

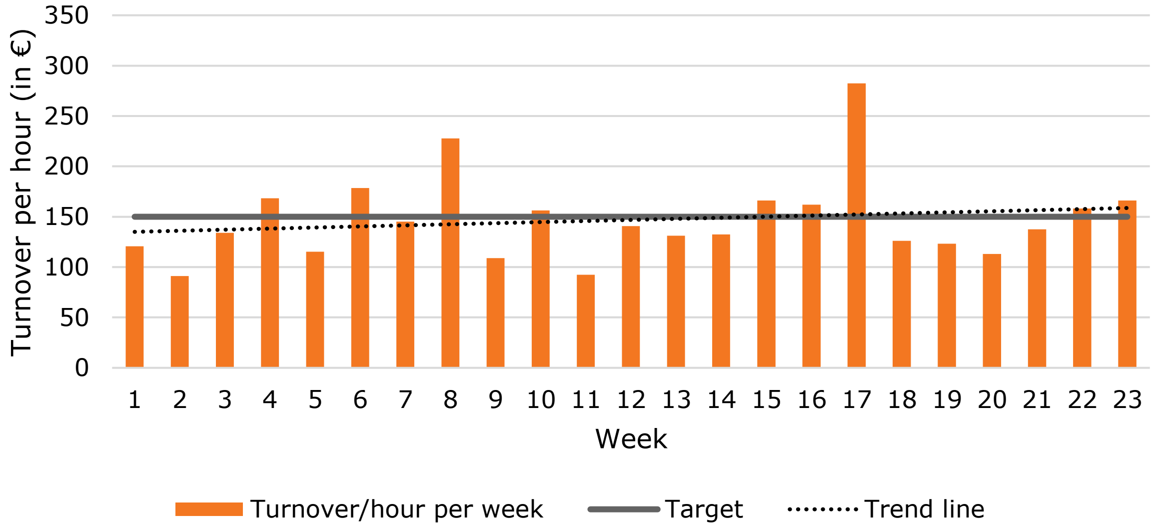


Figure 5-5 Turnover per hour

5.2.3 Cost focus

From the interviews, it appears that OC Waterloo mainly focuses on costs in its operations. Table 5-11 shows quotes that imply the cost focus by the management. The main focus is on efficiency. The focus on efficiency does not have to be a problem, but the focus seems to be on the machine level, which, as mentioned before, has a negative effect on the lead time (Suri, 2011). Considering OC Waterloo wants to focus on time/delivery, this is not the right focus. Thereby, the usage of roller tracks has been discussed. Roller tracks could be used to achieve high efficiency if used with standardized products. However, the usage of roller tracks is not applicable to OC Waterloo, because the company wants to be flexible and the variability in the products is too high for that. Lastly, the changeover times and therefore costs are reduced by high batch sizes.

Table 5-11 Cost-focus by management

Quotes	Source
"At those moments, you often see that efficiency decreases"	COO Orange Climate
"I have experience figures, you lose between 10-15% in efficiency."	COO Orange Climate
"The unit is being built, it's standing there, there are all sorts of people around it and then we're still waiting for fans. That costs you 10-15% in efficiency."	COO Orange Climate
"It makes a big difference to people and efficiency"	COO Orange Climate
"We've been thinking for a long time about how we could use roller tracks, how we could ensure that the flow goes past the various work stations."	COO Orange Climate
"Ultimately, our goal is to do more with the same people. This means that we really need to increase our production efficiency, and that will not be as much about how we make the products, but mainly about good organisation and good planning, reducing walking distances. Just really working more efficiently."	CEO OC Waterloo
"I am really curious that you are going to look into that and how can we produce as efficiently as possible for each department."	CEO OC Waterloo
"We do try to reduce the changeover time within a day. By clustering, it becomes less, but how long that takes varies."	Production manager OC Waterloo

5.3 Time/Delivery

This section assesses the second competitive strength of OC Waterloo, time/delivery. Time/delivery is of importance to OC Waterloo, because of the delivery reliability and the lead time/speed of the processes. The following KPIs could be measured to analyse the time/delivery: lead time, manufacturing lead time, variability, on agreed time, rate of production introduction, location of variability, on agreed quality, delivery lead time, occupation rate, on agreed quantity, due-date performance, movement of batches, dependable promises and frequency of delivery (Hopp & Spearman, 2011; Liu & Liang, 2014; Neely et al., 1995). On agreed quality is excluded, because this is included in the quality section. Thereby, variability, location of variability and frequency of delivery are excluded, because these have been measured in the flexibility section. Last, the movement of batches has been excluded, because OC Waterloo does not use batch production. Therefore, the following KPIs are measured: lead time, manufacturing lead time, on agreed time, rate of production introduction, delivery lead time, occupation rate, on agreed quantity, due-date performance and dependable promises (Hopp & Spearman, 2011; Liu & Liang, 2014; Neely et al., 1995). Thereby, the methodologies manufacturing-critical-path times and utilization graph are used. Table 5-12 gives the measured KPI(s) per subheading.

Table 5-12 Measured KPI(s) per subheading time/delivery

Subheading	**Measured KPI(s)**
Standard delivery time list	On agreed time, dependable promises, delivery lead time
Internal lead time	Lead time, delivery lead time
Manufacturing lead time	Lead time, manufacturing lead time
MCT diagrams	Lead time, manufacturing lead time
On-time delivery	Rate of production introduction, dependable promises, on agreed quantity, due-date performance
Utilization rate	Occupation rate
Work in progress	Occupation rate

5.3.1 Standard delivery time list

OC Waterloo has a standard delivery time list for products to be delivered to the customers. This list is used by OC Waterloo's sales department, to issue the correct delivery times to the customer. The most ordered products are listed including the delivery time. Thereby, the max amount of products are given at the end, ordering more than the max amount leads to an increase of delivery days. The delivery days could also be higher when the production runs at full capacity or the customer wants a special colour in which a product has to be painted. Due to the outsourced spraying, the lead time for products that have to be sprayed is on average 3-5 days higher. The standard delivery time list is shown in Table 5-13.

Table 5-13 Standard delivery time list

Product type	Delivery days	Max amount
WSDT	6	Stock
Aircell M and 2000 series	4	
CS *Anod*	7	25
DF *RAL 9010*	15	25
DF-41 *RAL 9010*	4	Stock
MWVPD, MWVP *RAL 9010*	4	20
SDV, SDB *RAL 9010*	7	20
MWPD *RAL 9010*	10	20
Plenum	15	25
RWA *RAL 9010*	15	20
RWH *RAL 9006*	10	20
RWI, RWK, RWV *RAL 9010*	4	10
STCS *RAL 9010*	6	25
WID *RAL 9010*	4	30
WID-FR *RAL 9010*	3	30
WPD *RAL 9010*	4	30
WTF,MWTF,RWTF *RAL 9010*	4	20
AV, KAV, ZV *white*	2	Stock
1H, 2H, 1V, 2V *Anod*	7	20
1RV, 2RV *RAL 9006*	10	10
2RRTC, RRTC *RAL 9006*	10	10
2RTC, RTC *Anod*	7	20
ACG, ACGV, ACGE *Anod*	7	20
Aircell S, D, G, A, T, E *white*	15	*Stock WAP*
AL, 2AL *Anod of RAL 9010*	7	20
DSR *Anod*	7	20
DV, DVA, DVC *Anod*	7	20
GC5 *Anod*	7	20
NF-15 *Anod*	7	20
PER/PER V/PER OA *RAL 9010*	10	20
WPT, WVU *RAL 9010*	10	30
Volume control	7	20
WG/YG/YGT *Anod*	7	10
WGA/WGD/WSR *in RAL colour*	12	5
Roof hood *Anod*	7	
WGK/YGK *Anod*	7	10
WRM/WSDSD	2	Stock
WLMS/WLMD/WRS/WRD	7	Incl. Engine
WDD	7	Incl. Engine
WVSV-S, WVSV-E	7	Incl. Engine
ABM *RAL 9010*	10	25
Round fire damper	2-4	
Rectangular fire damper small	3-5	
Rectangular fire damper large	4-8	
LBF (dampers and wings)	± 15	
PRD/WDVV	± 15	
LVV/LVH	± 15	
WSLU	± 10	
Fan coils	25-30	
Germany Dachser	3	
Germany GLS	2	
England (WAP)	2	
Switserland (excl Zehnder)	4	
Zehnder	1	
GLS other	-	
Helder	-	
Other	-	

5.3.2 Internal lead time

The internal lead time measures the time from the entry of the order in the ERP system towards the delivery date. The result is shown in Table 5-14. The lead time could be a lot higher than the manufacturing time because the order could be ordered a long time before the delivery date. This lead time indicates how long an order is in OC Waterloo's systems. The mean total lead time is 23,2 days, this means that an order on average is 23,2 days in OC Waterloo's system. If a customer orders a product for over a few months the internal lead time will be high, because the order is early in the system and it takes a few months before the product is delivered. The table shows that OC Waterloo gets few orders with a delivery date more than one/two months away because the mean order entry till delivery lead time is lower than a month. The internal lead time makes clear that OC Waterloo is not able to plan far ahead because most orders are ordered and delivered in a month time. Appendix 10: Mean order entry till delivery lead time per product gives the mean order entry till delivery lead time per product instead of product family.

Table 5-14 Mean lead time entry till delivery per product family (days)

Product family	Mean order entry till delivery lead time (days)
Adjustable grilles	26,5
Airlines	21,1
Linear grilles	20,7
Other grilles	22,1
Outside air grilles	25,2
Panels and induction units	18,0
RW-series	20,3
Sheet products	20,1
Specials	30,1
Steel linear grilles	14,0
Swirl diffusers	18,5
Trade	25,1
Volume control	19,9
Volume control dampers	22,9
Mean	23,2

5.3.3 Manufacturing lead time

To assess the operations of OC Waterloo the manufacturing lead time has been analysed. The manufacturing lead time measures how long it takes to produce a product from start to finish. Thereby, the manufacturing lead time is the start for the development of Manufacturing Critical-path Time (MCT) diagrams. Table 5-15 gives the mean manufacturing lead time in days per product family. The overall mean lead time is 8,2 days, so on average an order is 8,2 days in the production facility. No opinion can be formed on this because the touch time has not yet been determined. The touch time has been calculated in the MCT section.

Appendix 11: Mean, median, mode and standard deviation manufacturing lead time per product gives the mean, median, mode and standard deviation manufacturing lead time per product instead of per product family. The mean, median, mode and standard lead time are included because these give more insights into the distribution of the lead times and the deviation in lead time between different orders.

Table 5-15 Mean manufacturing lead time (days)

Product family	**Mean manufacturing lead time (days)**
Adjustable grilles	11,2
Airlines	11,8
Linear grilles	7,1
Other grilles	11,5
Outside air grilles	11,4
Panels and induction units	7,0
RW-series	6,2
Sheet products	4,9
Specials	10,5
Steel linear grilles	11,0
Swirl diffusers	3,8
Trade	3,0
Volume control	5,8
Volume control dampers	9,1
End total	8,2

5.3.4 MCT Diagrams

To get further insights into the manufacturing lead time, MCT diagrams have been made. As mentioned before, Manufacturing Critical Path (MCT) is defined as the amount of calendar time of the moment when a customer gives the other, following the critical path, till the first delivery of the order to the customer (Suri, 2011). Thereby, MCT diagrams give insights into the touch time versus the manufacturing lead time (Suri, 2011).

The touch time comes from OC Waterloo's production dashboard. Currently, the ERP system is not able to measure the touch time per product. Due to the number of products, OC Waterloo cannot measure the touch per product manually. Thus, to include touch time in the production planning, a time study has been conducted. Afterwards, the touch time was included per product using factors based on the net production time. Factors have been used, because the production time has not been measured per product, due to the number of products. Thus, the dashboard calculates the touch time by using the net production time times a factor for the production step which has been measured. For example, the punching of a grille takes two minutes of net production time, then the wastes are included by multiplying the net production time with a factor. The factor in the production dashboard for punching is 1,9, so the touch time for the production step punching will be 1,9*2= 3,8 minutes. These factors are needed because there is no real-time data available on the touch time and there is high variability in product mix.

Currently, OC Waterloo is looking for a new ERP system and the company is measuring the factors per production step again. The measured factors match the factors which have been measured two years ago but are a bit lower, so the production department became more efficient. Overall, the new factors are 25% lower. However, this is for 50% based on assumptions by the work preparation department, since the measurements of the new factors have not been finished. This means that 50% of the factors have not been measured yet. These assumptions have been made to speed up the process of factor measurement.

Therefore, the new factors are not yet implemented in the dashboard/planning software for the production. Due to the fact that the new factors have not been finished and the touch times are not measured in real-time, the data from the production dashboard is used. However, it is of importance to keep in mind that the touch time will likely be lower than shown in the MCT diagrams.

The MCTs have been made for the critical path, so all process steps of a product family with the mean touch and lead time. The product amounts are included in the touch and lead time, so the mean time include times of the production of one product and time of the production of more than one product. For example, the touch and lead time of one product is included, but also the touch and lead time of several products. This is done because it gives the best overview of the mean touch time and mean manufacturing lead time of a product family in the production. The lead time per process step is the end date minus the starting date of the production plus one. The touch time is shown as a red bar. Normally, the MCT is white with grey touch time bars in it, but in this case, red is chosen for a clearer view. The number on the grey bar is the lead time for that particular process step. The manufacturing lead time per product family in Table 5-15 differs from the MCTs because for the MCTs the mean lead time for each possible process step in a product family is chosen. In the mean lead time, the lead time of products with fewer process steps are also considered. The touch time is included at the beginning of each process step because there is no data available on when the touch time happens, except the start and end date of the process step in which the touch time is included. According to Suri (2011), the data should be representative, without the need for many data analyses. These MCTs are representative and developed with the data available. The MCTs are shown in Appendix 12: Manufacturing critical path per product family.

Touch time/non-touch time per product family

Table 5-16 shows the touch time and non-touch time per product family. The mean touch time is 1,03% over all product families. The touch time of the volume control lies significantly higher than the other product families. The touch time is higher because OC Waterloo had a few big orders (above 100) which positively affects the touch time and has a lower effect on the lead time. Thus, OC Waterloo's operations is more equipped for large than small series. The fact that OC Waterloo's operations is more suitable for large series contradicts with the average low order quantity of 6,0 in section 5.1.4.

On average a product is 98,97% of the time not being processed. Suri (2011) mentions that most companies who do not focus on time have a touch time of 5% or lower. Therefore, this touch time is considered low. The low touch time has a negative effect on the lead time of the production. On average the touch time of all product families is 264,5 minutes (4,4 hours) and the non-touch time is on average 18,1 days. In addition, the low touch time also implies that there are possibilities to reduce the lead time/MCT (Suri, 2011).

The low touch time is caused by OC Waterloo's planning. The planning system plans each process step on a different day. So, a process step that takes five minutes is planned on one day and the next step on a consecutive day. OC Waterloo has arranged it this way, because the planning system will otherwise plan all products and process steps on one day, without taking into account the utilization of machines and personnel. This leads to overutilization (more than 100%) of machines and personnel.

Furthermore, the touch time is low because the current ERP system is not able to do parallel planning. For example, process steps (1) shortening and punching and (2) LVD and sheet processing could be planned parallel. Currently, this is sometimes solved by entering orders separately.

Table 5-16 Touch time and non-touch time per product family

Product family	Non-touch time	Touch time	Non-touch time/ lead time (in days)	Touch time (in minutes)
Adjustable grilles	99,49%	0,51%	17,8	130,5
Airlines	99,44%	0,56%	22,3	178,3
Linear grilles	99,64%	0,36%	22,3	115,5
Other grilles	99,42%	0,58%	22,0	183,7
Outside air grilles	98,95%	1,05%	27,9	421,8
Panels and induction units	99,44%	0,56%	20,0	162,0
RW-series	99,62%	0,38%	16,9	91,7
Sheet products	99,42%	0,58%	21,7	180,8
Specials	99,17%	0,83%	22,3	266,3
Steel linear grilles	98,75%	1,25%	14,5	261,3
Swirl diffusers	99,38%	0,62%	10,4	92,8
Trade	99,70%	0,30%	3,0	12,9
Volume control	94,02%	5,98%	16,2	1394,6
Volume control dampers	99,08%	0,92%	15,9	210,9
Total	98,97%	1,03%	18,1	264,5

5.3.5 On-time delivery

To satisfy the customers, products have to be delivered on time. Therefore, the On-Time Delivery (OTD) is measured. The mean OTD of OC Waterloo is 74% (with a goal of 95%) from week one till and including week nineteen of 2021. This is a low OTD delivery because more than a quarter of the products ordered by the customer are delivered too late. The production manager mentioned that these measurements are on basis of the original delivery date. It often occurs that OC Waterloo postpones the delivery date in consultation with the customer. According to the production manager, a product is no longer too late if OC Waterloo postpones the delivery date in consultation with the customer. However, customers desire the product to be delivered on time at the first delivery date, because for installers, projects must be delivered. Therefore, agreeing to a new delivery date is not considered as on-time delivery for this research, because the customer may not be the victim of internal problems. The production manager does not change the delivery date when delivery dates are postponed, so these are the pure numbers. The OTD of the orders is shown in Figure 5-6.

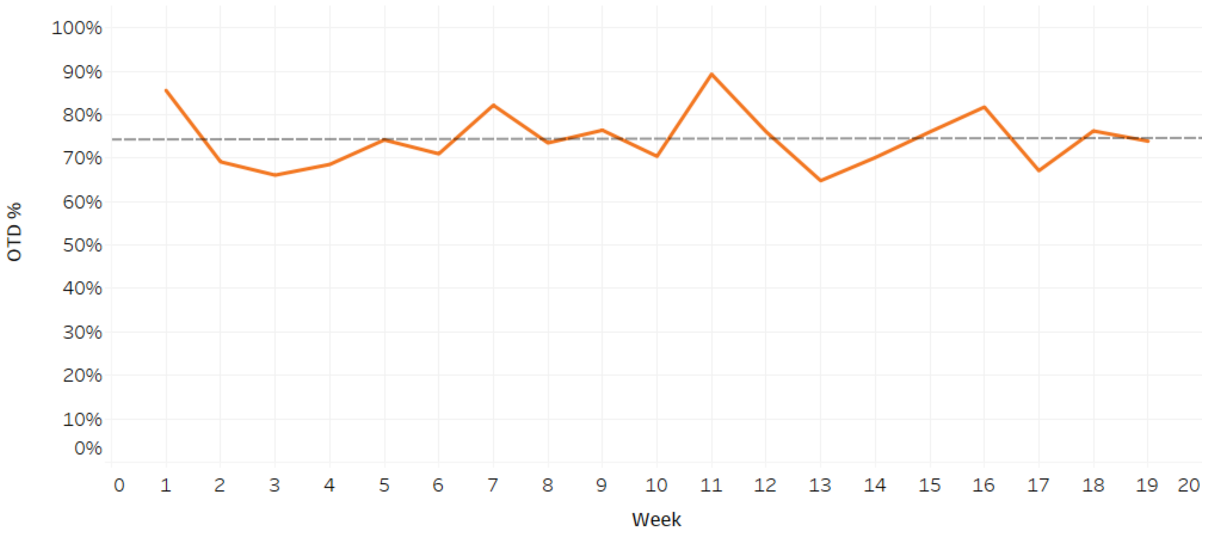


Figure 5-6 OTD orders

5.3.6 Utilization rate

OC Waterloo's machine's utilization rates are not measured. However, OC Waterloo plans its operations based on the workload of the employees and the time per product. The weekly workload based on the starting date of the operations is shown in Figure 5-7. The green line represents the number of hours available. These hours are the cumulative weekly working hours of the production employees. The blue bar is the finished products, the orange bar shows the work to do and the yellow bar shows the work which is in progress. The production manager plans the workload using his experience and with help of this chart. When the demand is there, the production is planned to 100% of its capacity. In addition, the production manager mentions: "It is order dependent. What comes in goes into production. It is not a specific batch size. It is a batch size, but it is different every time." Furthermore, this chart is scaled down per department, so the production manager has an overview of the workload per week per department. This chart also shows that OC Waterloo is not able to plan over a long period, due to the variable customer demand and the desired speed of deliveries.

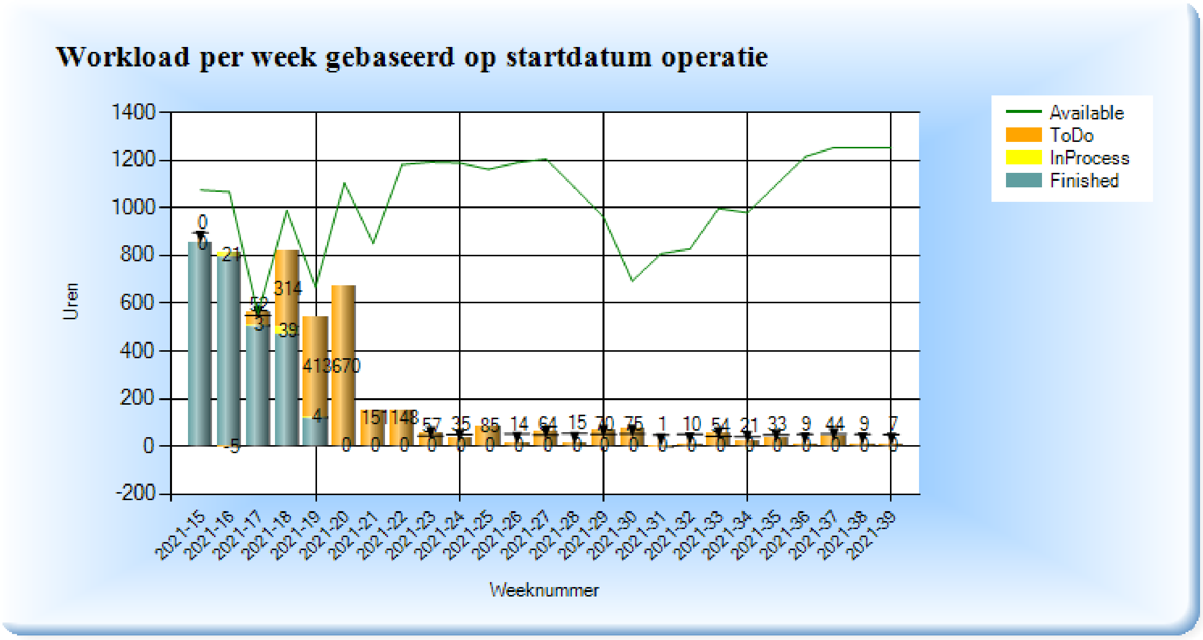


Figure 5-7 Workload per week based on starting date operations

Furthermore, OC Waterloo does not produce in batches. The orders which have to be made in three days are shown on the production dashboard. This means that a production employee can collect all products with similar steps and produce these to reduce set-up times. According to the production manager, production employees are not supposed to collect products for more than one day. However, the production manager mentioned that this sometimes happens in production. Thereby, the production employee may merge different orders of one day. According to Suri (2011), planning to maximum capacity and a large batch size could lead to high lead times.

5.3.7 Work in progress

The work in progress (WIP) is of interest to know because it affects the flexibility as well as the lead time of the production (Suri, 2011). The WIP is calculated via Little's Law[7]:

$$WIP = Cycle\ Time * Troughput$$

On average OC Waterloo delivers 1.590 products per week, so the throughput is 1.590. The mean manufacturing lead time from Table 5-15 is 8,2 days = 1,17 weeks, so the cycle time is 1,17 weeks. Therefore, WIP of OC Waterloo is 1,17 * 1590 = 1860 products. This is a high work in progress considered that the mean touch time of the product families is 264,5 minutes.

[7] Little's Law – Lean Management

5.4 Quality

Quality is of importance in every operations strategy. This section assesses the quality of OC Waterloo's production. The quality could be measured using the following KPIs: defect rate, performance, product reworks, product performance, features, material spoilage, reliability, defects in production output, environmental impacts, conformance, returned goods to total sales, certification, technical durability, on-time delivery of goods or services to customers, serviceability, number of customer complaints, aesthetics, perceived quality, humanity, value (Liu & Liang, 2014; Neely et al., 1995; Uyar, 2009). Currently, OC Waterloo does not measure all the KPIs mentioned by Liu and Liang (2014), Neely et al. (1995) and Uyar (2009). However, OC Waterloo started measuring deviations in the processes of the departments in week 15. These measures include the number of registered deviations per week, the number of registered deviations per department per week, total repair costs per department per week in euros and the distribution of registered deviations per department. The departments are production, work preparation, sales, purchasing and administrative department. The deviations are reported by the employee who encounters the deviation. As a result, employees may not report on self-made mistakes. Therefore, the current measurement method probably misses some deviations, because employees have to fill it in themselves. This leads to fewer recorded deviations than actual deviations. For this research, the deviations are still valuable to analyse which type of deviations occur and where it comes from. Thereby, for OC Waterloo, these measures are valuable and in quantity enough to analyse and act upon. However, the measures are likely not 100% reliable. The following KPIs will be measured: defect rate, reliability, performance, product rework, defects, reliability and quality costs (Liu & Liang, 2014; Neely et al., 1995; Uyar, 2009).

The deviations in the departments are categorized into seven categories, these categories are missing parts, incorrect information provision, production error, communication error, production machine error, damage and others. Average recovery/rework times are attached to these categories. These times are in order of the above categories 60, 20, 30, 15, 10, 30 and 28 minutes. The recovery/rework time costs €75,- per hour, which is €1,25 per minute. In total 95 deviations were registered from week 15 up to and including week 18 in 2021. Due to the small measurement interval, it is too early to analyse the trendline of the number of registered deviations per week. However, in the future, this trendline is of interest to assess whether or not an improvement affected the deviations.

Most deviations were registered in the production department. However, most deviations were allocated to the work preparation department. Thus, the production department encounters most of the deviations.

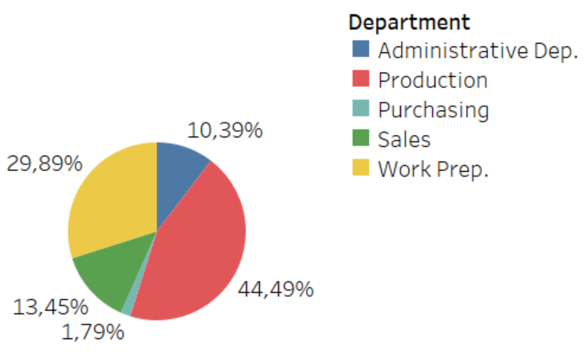


Figure 5-8 Registered deviations

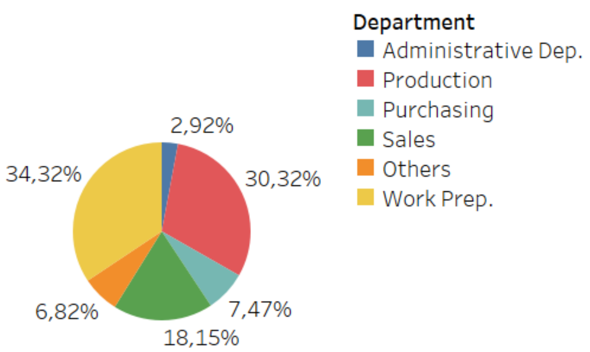


Figure 5-9 Allocated deviations

Furthermore, the deviations per category are measured. The categories are derived from OC Waterloo's measurements. Most deviations were registered in the category incorrect information provision. Examples of defects in this category are incorrect drawings, a mistake in nesting, an unclear statement about whether the product should be sprayed etc. The deviations per category are shown in Figure 5-10.

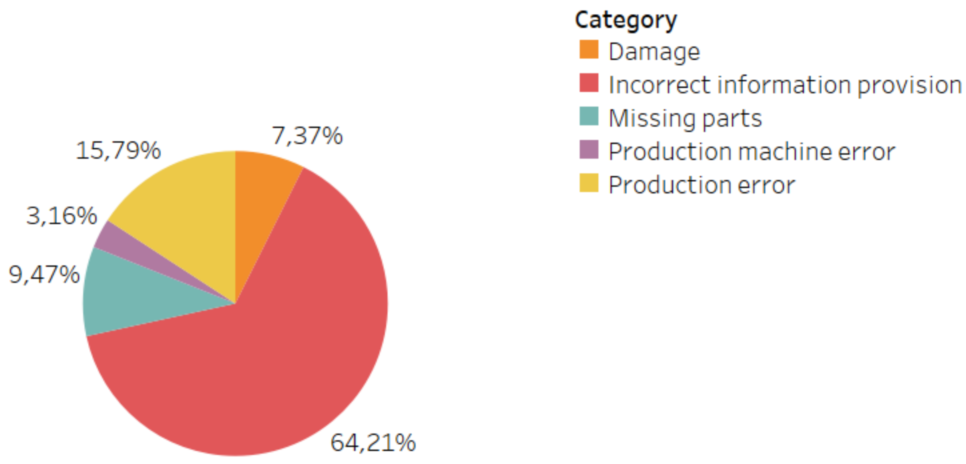


Figure 5-10 Deviations per category

Furthermore, the recovery/rework times and costs per department are analysed. Most recovery/rework time has been done in the production department. The production department has a total recovery time of 1350 minutes in the measured period. This is an average of 337,5 minutes per week and 67,5 minutes per day. Therefore, the recovery/rework costs are the highest for the production department too. The total recovery/rework costs for the production department were €1.687,50. The recovery/rework costs per department are shown in Figure 5-11.

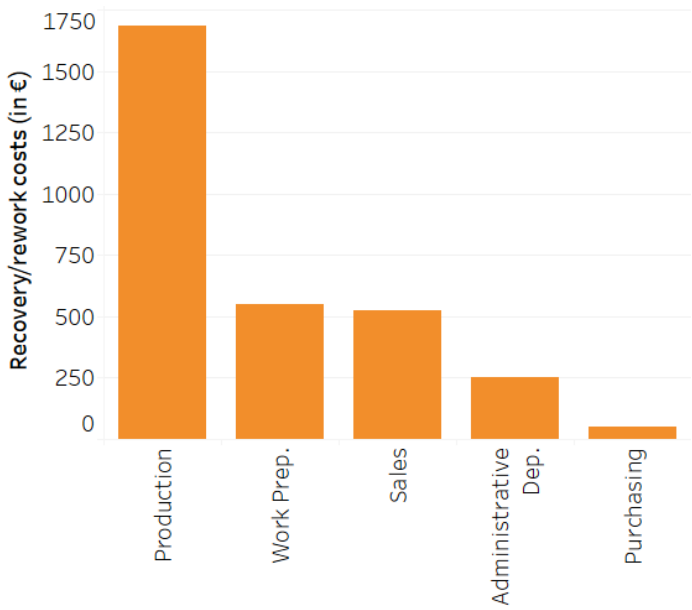


Figure 5-11 Recovery/rework costs (in €)

According to the production manager, the logistics department does the final check of the products. However, the logistics department encounter few quality errors, because most errors are noticed during the process, for example, there is no hole to put a screw in. In conclusion, OC Waterloo has few/low-quality issues and costs due to the few deviations and costs of the deviations.

5.5 Digitalisation

Digitalisation is defined as follows: "digitalization refers to usage of any digital assets organizations can use to improve their performance" (Kuusisto, 2017, p. 342). As mentioned before, digitisation affects the competitiveness of an organisation (Ghobakhloo & Fathi, 2020). Therefore, it also has an impact on the operations strategy. Caiado et al. (2020), developed a maturity model to assess the progress of a company on its Industry 4.0 development. The stages of this maturity model are: (0) non-existent, (1) conceptual, (2) managed, (3) advanced and (4) self-optimized (Caiado et al., 2020). OC Waterloo is at maturity level 1, conceptual. Conceptual is described as:

> A formal deployment process has been initiated and there is more exclusive knowledge about the process advancement. Process management is weak due to a lack of organization and/or enabling technologies. A partial maturity in the management of infrastructure development. The organization begins to address the problems of I4.0 within departments and connects existing technology applications to create data flow, data is fully integrated into a single enterprise system, but data exchange is not automated. (Caiado et al., 2020, p. 8)

There is a deployment of the process of Industry 4.0 because OC Waterloo uses a production dashboard for their production planning. Therefore, there is more exclusive knowledge about the process advancement. The management of these processes is still weak because the data of the production dashboard is not used by the management and is too unstructured for that. However, for this research, that data has been cleaned/restructured and used. Data flow is present in the organisation because orders are followed through OC Waterloo's ERP system. To advance towards a higher stage of Industry 4.0 implementation, OC Waterloo should work on standardization and implementation across departments. This also leads to the detection of improvement potentials and automation in processes. As mentioned before, currently OC Waterloo is researching a new ERP system. Therefore, requirements and wishes in line with Industry 4.0 and QRM are set up in the operations strategy.

5.6 Conclusion

This chapter has analysed the current strengths and weaknesses of OC Waterloo's operations. Therefore, this chapter answers the following research sub-question:

What are the strengths and weaknesses of OC Waterloo's operations?

The question has been answered using data from the ERP system, production dashboard, deviation measurement and an interview with the production manager.

OC Waterloo delivers a vast amount of products types, with 117 products and 2790 different product configurations in four months. There are fourteen product families in OC Waterloo's production. These product families are:

- Airlines;
- Outside air grilles;
- Adjustable grilles;
- Linear grilles;
- Sheet products;
- Steel linear grilles;
- Volume control dampers;
- Other grilles;
- RW-series;
- Trade products;
- Panels and induction units;
- Volume control;
- Swirl diffusers; and
- Specials.

Furthermore, OC Waterloo delivers on average 1.590 products per week. Most of these products are delivered in small orders, the mean order size is six products. Thereby, there is variability in the product amounts/families per month. Therefore, OC Waterloo is distinctive in its flexibility, which is in line with the competitive priorities.

OC Waterloo focuses on costs. The directors and manager use efficiency measures for the production department to reduce costs. Furthermore, OC Waterloo uses a KPI which measures the turnover per hour. The focus on cost is a misalignment in comparison to the competitive priorities because costs are no focus according to the sales strategy and market demands.

Due to the focus on costs, OC Waterloo's time/delivery leaves something to be desired. A product in OC Waterloo's production process is waiting to be processed 98,97% of the time. So, OC Waterloo is processing the product 1,03% of the time the product is in production. Thereby, OC Waterloo has a concerning average on-time delivery of 74%. Furthermore, OC Waterloo plans to full capacity and large batches which leads to a high work in progress and therefore a higher lead time. The lack of focus on time/delivery or the lack of understanding to excel in time/delivery leads to a misalignment in comparison to the competitive priorities, because the sales strategy and external environment require short delivery times and on-time delivery.

The quality of OC Waterloo is measured, however, the company started with this in week fifteen of 2021 and the reliability of the measurement is questionable. In total 95 deviations were registered from week 15 up to and including week 18. Most deviations were registered in the production department, however, most deviations were allocated to the work preparation. Thereby, Most deviations were registered in the category incorrect information provision. The total quality costs were €3.062,50. The quality is high, however, it should be measured more reliable in the future.

Furthermore, to improve OC Waterloo's deployment of Industry 4.0 from conceptual to managed, the company must take industry 4.0 into account when choosing and implementing a new ERP system.

In conclusion, OC Waterloo's weaknesses are the focus on cost (which is not in line with the competitive focus) and therefore a lack of time/delivery focus. Thereby, OC Waterloo's strengths are the flexibility and quality of the products and operations.

6 OPERATIONS STRATEGY

This chapter develops the operations strategy of OC Waterloo. The operations strategy is based on the previous chapters; the business and sales strategy and the strengths and weaknesses of the current operations. This chapter describes the operations strategy and the needed improvements/changes. Operations strategy is defined as follows: "... the development of specific competitive strengths based on the operations function that is aimed at helping an organization achieve its long-term competitive goals" (Amoako-Gyampah & Boye, 2001, p. 59). Thereby, operations strategy is divided into two categories: structure and infrastructure. There are different insights into what is part of structure and infrastructure (Garrido et al., 2007). This chapter covers structural elements as technology, sourcing, vertical integration and facility, and capacity. Thereby, the following infrastructural elements are covered: production planning, organisation (structure), workforce quality, human resource and production & process development systems.

6.1 Structure

6.1.1 Technology

Technology is described as an aspect of the structure of an organisation. For this section technology describes the desired manufacturing methodology of the organisation. Currently, OC Waterloo does not have a clear focus on one manufacturing methodology, however, Lean Manufacturing is mentioned most often. In addition, the company focuses on the wrong competitive priority cost instead of the competitive priorities time/delivery and flexibility expected by the external environment and the sales strategy. Thereby, the operations of the company functions better when the company receives bigger orders. The focus on Lean applies to the entire Orange Climate group, especially considering Orange Climate developed a continuous improvement ladder based on the lean concept. However, OC Waterloo produces different products, has different product volumes, has a higher variability and other resources than for example OC Verhulst, which produces air handling units with a lead time of multiple weeks. Thus, Lean manufacturing may fit other Orange Climate business units, but it does not fit OC Waterloo.

According to the theoretical framework, Quick response manufacturing (QRM) is most suitable for OC Waterloo. This is because OC Waterloo and QRM both mainly focus on time/delivery and flexibility. Thereby, World Class Manufacturing is suitable for OC Waterloo, because it captures all competitive priorities. However, World Class Manufacturing is most often a combination of manufacturing methodologies. Because OC Waterloo is not well developed in the area of manufacturing methodologies, focusing on two manufacturing methodologies may lead to unclarities. Therefore, OC Waterloo should focus on implementing QRM first. QRM is described in section 2.6.

6.1.2 Sourcing, vertical integration and facility

Vertical integration is taking over steps of other businesses in the supply chain. To improve the vertical integration, OC Waterloo should measure and select the supplier based on the MCT. This can be done the same as the internal measure. However, it will be harder to determine the touch time of the supplier. It is not necessary for suppliers to use the MCT, but OC Waterloo need suppliers that have a short lead time to improve its flexibility and time/delivery.

Furthermore, OC Waterloo sends products to an external painter. The external painter takes up 35% to 49% of the non-touch time of the MCTs of the product families. Therefore, it is of interest to research the possibilities of another external painter, applying QRM at the current painter or insourcing the painting. OC Waterloo has already researched the possibility to insource the painting. The total investment costs for a powder coating installation are €290.280. The powder coat installation is depreciated in five years, which is €58.056,00 per year. The interest is 6% and is €17.416,80 per year. The operational costs for the powder coat installation are €5.309 per year, the powder costs are

€35.836 per year. The maintenance and chemical costs are both €10.000 per year, so in total €20.000 per year. The electrical costs are €1.475 per year. The surface is 150 m2 and costs €6.000 per year. Lastly, the personnel is two FTE which is €64.513 per year. The total yearly costs for a powder coating installation are €208.606. The total yearly cost for outsourcing is €353.199. Of the outsourcing, €260.000 are costs of Aalderink (the current external powder coater) and €93.119 are internal packing, planning, transport and packaging costs. Therefore, insourcing the power coating installation leads to a saving of €144.593 (€353.199 – €208.606) per year. At that time, OC waterloo decided to purchase an automatic profile storage instead of insourcing the spraying (and therefore expanding the factory).

However, in this saving OC Waterloo made at that time, the saving on MCT reductions are not considered. External painting takes up 8.2 days on average of the product families which are painted. The total average non-touch time is 21.5 days. On average the external painting takes up 38% of the non-touch time. Suppose, the lead time of the external painting can be reduced from 8.2 days to two days by insourcing the external painting, so a saving of 6.2 days. The lead time can be reduced to two days, because Orange Climate Verhulst has an powder coating installation and the products are ready and dry directly after the coating, so the touch time is several minutes. The Power of Six rule is used to calculate additional MCT reduction cost savings (Suri, 2011).

$$The\ MCT\ ratio = MV = \frac{Expected\ MCT\ after\ QRM\ implementation}{Current\ MCT}$$

$$MV = \frac{21.5 - 6.2}{21.5} = 0.712$$

So the MCT ratio is 0.712. To calculate the cost ratio the MCT ratio will be raised to the power of one-sixth. The reason for this is that Suri (2011) developed this ratio based on several QRM-projects and it has been used for a lot of QRM projects. This ratio has proven to be powerful in its predictions (Suri, 2011).

$$KV = (MV)^{1/6}$$

$$KV = (0.712)^{1/6} = 0.945$$

The cost ratio is 0.945. Thus, the MCT reduction leads to an additional saving of 5.5% on the product families. This cost-saving has an impact on the following product families: adjustable grilles, airlines, linear grilles, other grilles, outside air grilles, panels and induction units, RW-series, sheet products and specials. These product families account for 74% of the products OC Waterloo delivers. It is assumed that these products account for 74% of the costs of the operations, because the costs cannot be narrowed down exactly to the product family. The reason for this is that the hours are not booked properly. Assuming the 74%, the costs are €5.475.350,28 (€7.399.122 x 0.74). Thus, the additional savings due to MCT reduction are €301.364,39 (€5.475.350,28 x 0.055). This makes a total yearly cost saving of €445.957,31. The investment and installation costs are €290.280,00. Thus, the powder coating installation will be earned back in 0.65 year.

However, the costs of expanding the factory are not included in this yearly savings. There is no price available on the costs of the factory expanding. However, an indication can be given. The factory needs to be expanded to the parking space, which is around 1000 m^2. The price of a building fluctuates between €380 and €460 per m^2 on the internet[8]. Assuming a negative scenario, the expansion of production will cost €460.000, so the total investment costs are €750.280,00. When the factory expanding is depreciated over 20 years, the yearly depreciation costs are €23.000. The yearly savings are then €422.957,31 (€445.957,31-€23.000). Therefore, the powder coating installation inclusive

[8] Wat kost een bedrijfspand? Concreet antwoord én 5 factoren die deze prijs bepalen | Heembouw

factory expanding will be earned back in 1.77 years. Thus, OC Waterloo should invest in a powder coating installation.

Likely, OC Waterloo has made a wrong investment decision in the past, because OC Waterloo invested in storage which did not affect the MCT. Thereby, reducing the MCT and focusing on QRM leads to a lower required inventory (Suri, 2011). Suri (2011), also mentions that companies often make the mistake to invest in warehouses instead of machines (which lead to MCT reduction). As mentioned by the directors of Orange Climate (Waterloo) most investments will be done at OC IMP Klima. Therefore, this investment will probably not be made in the short term. However, in the future, it would certainly make sense to insource powder coating. Especially, if OC Waterloo's turnover continues to increase. Furthermore, OC Waterloo should consider lead time reduction in its future investments.

6.1.3 Capacity

Currently, OC Waterloo plans to 100% of its capacity. As mentioned before, planning to 100% leads to a higher work in progress, a higher lead time and likely a lower due date performance (Suri, 2011). Therefore, planning to 100% (partly) explains the high lead time and the low due date performance of OC Waterloo. In the future, OC Waterloo should not plan the operations to full capacity. Thereby, the variability influences the lead time of the operations. Variability and utilization have a combined effect on the flow time of the products, see Figure 2-14. In addition, the variability in OC Waterloo's process flows and product demand is high. As mentioned by Suri (2011), companies with high variability in manufacturing output should have an even lower utilization than companies with a lower variability. Therefore, OC Waterloo should plan the operations to a <u>maximum</u> of 75%, based on the variability and utilization graph. The utilization has to be calculated with the formula below (Suri, 2011).

$$u = \frac{Total\ Utilized\ Time}{Total\ Scheduled\ Time}$$

In this percentage, all times are included, also wastes and maintenance. The utilization applies to both machines as personnel. The utilization may be higher for the bottleneck in the process, however, an improvement project must then be started to reduce the bottleneck. Furthermore, the flow time per resource should be measured. The flow time could be measured using the following formula (Suri, 2011):

$$Flow\ Time = \frac{TJ}{1-u}$$

The TJ is the average time taken by the resource to work on a job (Suri, 2011). In the average time, all times are included, so also changeover times and wastes. The u is the utilization of the resource. For OC Waterloo, the flow time measurement could trigger improvements on resource level. Moreover, the variability of the arrival times and job times have to be measured. The variability of arrivals (VA) has to be calculated using the formula given below, where SA is the standard deviation of time between arrivals and TA is the time between arrivals (Suri, 2011).

$$VA = \frac{SA}{TA}$$

The variability of job times (VJ) has to be calculated using the formula given below, where SJ is the standard deviation of the time to complete a job and TJ is the average time to work on a job (Suri, 2011).

$$VJ = \frac{SJ}{TJ}$$

When the VA and VJ have been calculated the average variability can be calculated, which is used in the flow time formula. The formula for the average variability is as follows:

$$AV = (VA^2 + VJ^2)/2$$

The flow time through a QRM cell can be calculated using the formula given below. The M in this formula is the utilization divided by one minus the utilization.

$$\text{Flow Time} = (\text{AV X M X TJ}) + \text{TJ}$$

Furthermore, OC Waterloo's Work in Progress needs to be reduced. Currently, the average (calculated) WIP is 1790 products. A part of the reason for this is OC Waterloo's planning. To reduce the WIP, OC Waterloo has to start working in batches. The goal is to get that batch out of the process as soon as possible. Suri (2011), has provided a formula to calculate the recommended batch size for a particular resource, see below. The formula calculates the batch size for which you get the shortest flow time.

$S = Average\ setup\ time\ for\ a\ job, in\ hours$

$H = Total\ Scheduled\ Time\ at\ the\ resource\ for\ the\ selected\ time\ period, in\ hours$

$Q = Total\ number\ of\ pieces\ (of\ all\ products)\ made\ by\ the\ resource\ during\ the\ same$

$time\ period$

$R = Total\ of\ all\ run\ times\ at\ the\ resource\ during\ the\ period$

$Z = Total\ of\ all\ \text{“}other\ times\text{”}\ at\ the\ resource\ during\ the\ period$

$U_r = Run\ utilization\ (proportion\ of\ time\ it\ was\ actually\ working\ on\ a\ product), \frac{R}{H}$

$U_z = Other\ utilization\ (proportion\ of\ time\ it\ spent\ in\ these\ \text{“}other\ times\text{”}), \frac{Z}{H}$

$$Optimal\ Batch\ Size = B* = \frac{S * Q * \left(U_r + \sqrt{(U_r} * (1 - U_z))\right)}{H * U_r * (1 - U_z - U_r)}$$

The average setup time for a job is 8.54 minutes, based on the times measured of the shortening, punching, tube and press brakes. The setup times of the process steps do not differ much from each other. The total scheduled time is 39 hours because, on Friday, the operations stops an hour earlier than usual. OC Waterloo produced 1405 products per week on average. The total of all run time is 1,03% of the scheduled time because that is the touch time that has been measured. The total of all other times is not available and has not been added.

$$Optimal\ Batch\ Size = B* = \frac{0.14 * 1405 * \left(0.010 + \sqrt{(0.010} * (1 - 0))\right)}{39 * 0.010 * (1 - 0 - 0.010)}$$

$$Optimal\ Batch\ Size = B* = 56.2\ products$$

Currently, OC Waterloo delivers on average 281 products a day. As mentioned before, the current batch size are the products that are due on that particular day for the department. Although this is a rough calculation for the batch size, there is enough difference from the current batch size that it implies that OC Waterloo needs to reduce its batch size. Logically, this batch size does not apply to every department of OC Waterloo, because of the high variation in products and product routings. Therefore, the goal is to achieve a batch size of 20% of the current batch size (56.2/281=0.2). Thereby, it is advisable to reduce the batch size of every department by 15-20% per month and measure the effect on the flow time/MCT. In the future, it is of importance to measure the optimal batch size per department. However, due to the current software it is a study on itself.

The utilization rate and batch size reduction lead to higher costs, because machines and personnel can only be planned to 75% and the changeover times become five times as high (20% of the current batch size). The average setup time for a job is 8.54 minutes. However, currently the jobs are clustered. After the batch size reduction, the jobs will be split in five jobs. So, the average setup time stays the same, but it will be executed five times as much. The setup time will become 42.7 minutes. Thus, the setup time costs will become five times as high. The total setup time costs are then 42.7/60 x €59.82 (hourly labour costs) = €42.57. This calculation is a rough estimation, because it dependents on how often the machines needs to be changed over. Currently, there is no data available on that. Nevertheless, OC Waterloo should reduce its batch size to comply with the competitive priority time/delivery.

OC Waterloo's labour costs of the production are €1.671.887. When the organisation focuses on planning to 75%, the production needs more personnel. The personnel costs will then become €1.671.887/0,75= €2.229.183. However, these costs are likely lower, because implementing QRM in the organisation leads to a better flow in the organisation, which improves the productivity. In addition, it is likely that currently not every employee is always 100% scheduled. The utilization of the machines also need to be reduced. However, there is no data available on the utilization of the machines. Thus, no calculation can be made about the expansion of the machine park to reduce the utilization.

The costs of the utilization rate and batch size reduction are high. However, these plans lead to lead time reduction which leads to significant savings. The current average non-touch time (MCT) is 18,1 days over all product families with a touch time of 1,03%. If OC Waterloo reduces the lead time/non-touch time with 30% the lead time is 12,67 days. A reduction of 30% is a realistic goal, because the touch time of OC Waterloo's products is only 1,03%. The MV is then 0.70.

$$MV = \frac{12.67}{18.1} = 0.70$$

Using Suri's (2011) cost ratio calculation, the MCT reduction leads to a saving of 6% on the operation costs.

$$KV = (0.70)^{1/6} = 0.94$$

The total production costs are €7.399.122, so the MCT reduction leads to a saving of €443.947,32. In addition, in the long term the MCT reduction may become even higher.

6.2 Infrastructure

6.2.1 Production planning

One of the problems of OC Waterloo is the lack of flow through the factory. From the interviews and conversations with employees, OC Waterloo tried to achieve this with process improvements. These process improvements were focussed on the touch time, so the time the product is being produced. However, as shown by the MCT diagrams, the touch time is only 1,03% of the operations. Therefore, OC Waterloo needs to reduce the MCT. The improvements in MCT should be measured by the QRM number. Furthermore, OC Waterloo should stop planning a day between every process step, because that is the major issue in the long lead times. Thereby, it is harder to assess the bottleneck in the process when a day is planned between each process step. The production planning should be based on the three-way strategy (variability, utilization and batch size) mentioned by Suri (2011) and discussed in section 6.1.3 Capacity.

6.2.2 Organisation (structure)

The current production organisational structure looks as follows:

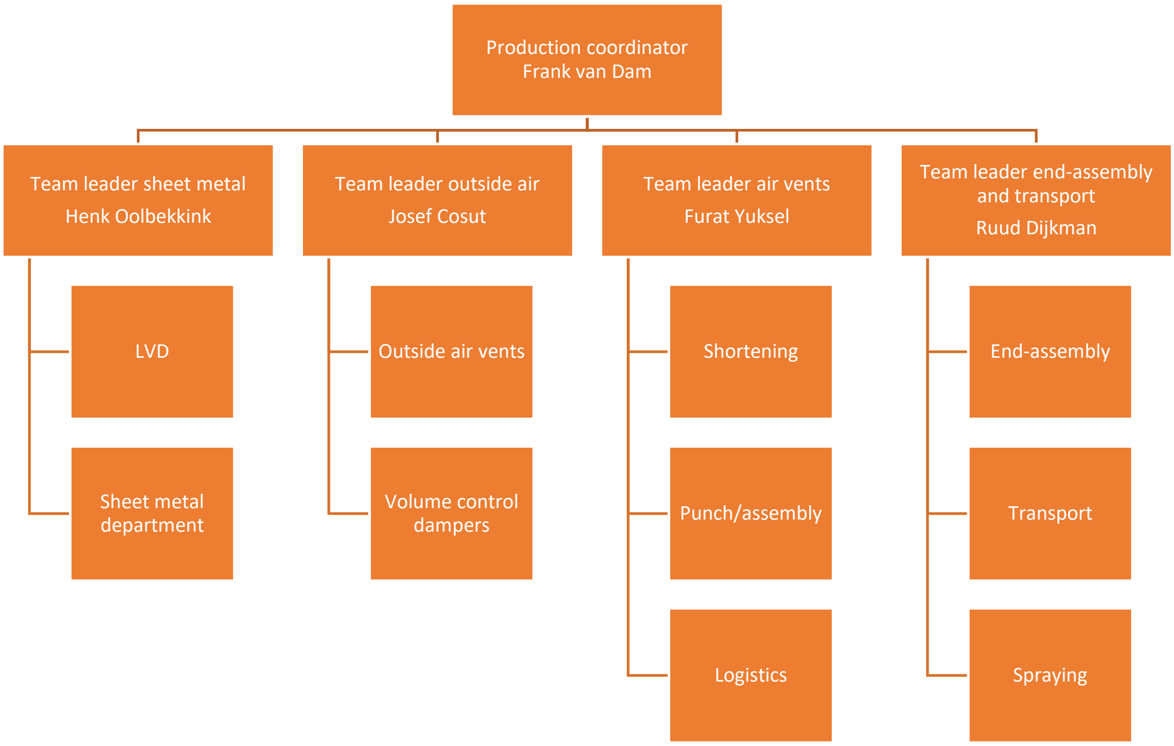


Figure 6-1 Organisational structure production facility

To comply with the requirements for a QRM organisation. The organisation has to be divided into cells as much as possible. However, due to the variability in OC Waterloo's products, there is no possibility to make a cell for every product type or product family. Therefore, cells have to be created where possible. OC Waterloo has already tried to implement some parts of QRM. While doing so, OC Waterloo already created two cells namely: the outside air vents cell and the volume control dampers cell. For the other departments, it is not possible to create cells based on the product type/product family. However, the current departments have multiple steps in it which are executed by different persons. To comply with the requirements for QRM a person should be able to finish a product or process step all on its own, because currently the products goes from workstation to workstation. So, the employees need to be trained to execute all steps in the cell/process step. In conclusion, the departments are well organised, but the organisation in the departments requires improvement by cross-training employees. Lastly, the QRM-cells should be rolled out through the entire organisation, this should be done via another research focusing on the other departments of OC Waterloo. Figure 6-2 shows the QRM cells OC Waterloo should use.

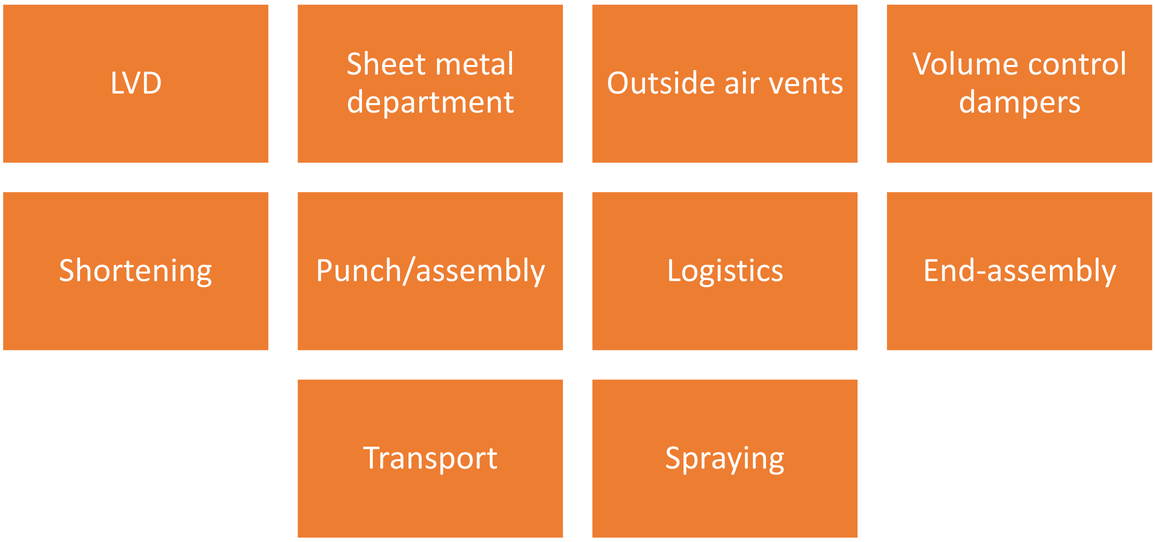


Figure 6-2 QRM cells

6.2.3 Workforce quality

OC Waterloo should focus more on employees who are willing to learn more in their organisation. This is needed to cope with the need of cross-training employees. Thereby, the employees must have high quality standards, because the employees must assess whether a product meets the quality standard. Especially concerning OC Waterloo's quality system is based on deviations the employees encounter. These deviations are registered by the employees.

6.2.4 Human resource

Training

Employees and managers need to be trained to work with QRM. Especially managers need to have a solid understanding of QRM. A lack of understanding could lead to actions that increase lead time instead of reducing the MCT. For example, the changeover time could be a KPI or a measure. However, this KPI needs to be understood well. The manager could reduce the changeover time by simplifying the changeover process. However, the manager may not reduce the changeover time by increasing the batch size, because that has a negative effect on the MCT. Both 'improvement' actions lead to a reduction in changeover time and a better KPI. However, the second measure negatively influences the MCT. Therefore, managers need to get training in working with QRM. The QRM Institute provides four levels of QRM understanding. For the management it is advisable to follow the QRM Silver course, this leads to analysis & support implementation[9]. It is best to give the lead implementer at OC Waterloo a QRM Gold training. However, this training is not yet available. This training will be available in 2022. The production employees need to have an understanding of QRM, a bronze level leads to this. The

[9] Training & Certification – QRM Institute

costs for the QRM Silver education are €2.770,- per person and the costs for the QRM Bronze education are €875,- per person[10][11]. See Table 6-1 for the total costs of the QRM training.

Table 6-1 Costs QRM training entire company

Job	Number of employees	Costs per person	Costs
Management team	4	€ 2.770	€ 11.080
Other personnel	66	€ 875	€ 57.750
		Total costs	**€ 68.830**

Incentive policies
To motivate employees to adjust to the operations strategy, incentives have to be used. When the operational goals have been achieved, employees have to be rewarded for their work. Incentives could be letting a fries stand come, treating with cake, or another party or fun activity. In OC Waterloo's informal culture a party of festive activity would fit best. The incentives should be focused on achieving MCT goals. Furthermore, the MCT should be visible in the production for each department, because MCT reduction is the main goal. It can be visualised using digital dashboards which shows the MCT ratio.

6.2.5 Production & process development systems

As mentioned before, OC Waterloo is researching a new ERP system. This ERP system applies to the entire Orange Climate group. To further develop the production and the processes, the ERP system has to fulfil requirements and wishes. Currently, QRM provides no/limited requirements for ERP systems, because Suri (2011) criticizes ERP systems for its lack of considering system dynamics. However, most companies use ERP/MRP systems in their organisation. Therefore, requirements and wishes have been set up according to the four core concepts of QRM and the requirements of OC Waterloo. Thereby, requirements are stated for advancement to the Industry 4.0 maturity stage 'managed'. The requirements and wishes are listed in Table 6-2.

Table 6-2 ERP requirements and wishes

ERP Requirement	Requirement/wish	Source
Measure batch sizes in production	Requirement	QRM
Measure the Work-in-Progress	Requirement	QRM
Measure throughput per QRM cell	Requirement	QRM
Measure utilization rate of employees	Requirement	QRM
Measure utilization rate of machines	Requirement	QRM
Measure Flow time through a cell	Requirement	QRM
Measure MCT per product family	Requirement	QRM
Measure MCT per product	Wish	QRM/OC Waterloo
Measure average variability	Requirement	QRM
Measure the QRM-number	Requirement	QRM

[10] Opleiding tot QRM Silver® specialist Tilburg - QRM managementcenter (qrm-managementcenter.nl)
[11] Opleiding tot QRM Bronze® specialist - QRM managementcenter (qrm-managementcenter.nl)

Measure changeover times	Requirement	QRM
Parallel planning of process steps	Requirement	OC Waterloo/QRM
Divide planning into batches	Requirement	QRM
Planning takes utilization into account	Requirement	OC Waterloo/QRM
Measure quality and deviations	Requirement	OC Waterloo
Measure external lead time	Requirement	QRM
Measure internal lead time	Requirement	QRM
Automate data flows between departments	Requirement	Industry 4.0
Create structured data	Requirement	Industry 4.0

Furthermore, OC Waterloo should measure how well the company is reaching their competitive priorities. The theoretical framework provided a list of KPIs. Logically, not every KPI can be measured by OC Waterloo. Therefore, the following KPIs are selected: defect rate, lead time, manufacturing lead time, delivery lead time, due-date performance, variability and occupation/utilization rate, changes in product volume, changes in product mix and changeover (Gerwin, 1993; Hopp & Spearman, 2011; Liu & Liang, 2014; Neely et al., 1995; Uyar, 2009). These KPIs cover OC Waterloo's three main competitive priorities flexibility, time/delivery and quality.

One of the biggest threats for OC Waterloo, as a smaller member of the OC Group in comparison to OC Verhulst, is that the ERP system will mainly be selected for OC Verhulst. Therefore, OC Waterloo should use this strategic operations plan and the ERP requirements for the ERP selection. The plan could be used to discuss the current problems and solutions for OC Waterloo's operations.

6.3 Conclusion

This chapter has described the operations strategy and needed improvements for OC Waterloo. Therefore, this chapter answers the following research sub-questions:

What should the operations strategy of OC Waterloo become?

And;

What improvements in operations are needed to achieve this strategy?

The questions have been answered using the literature and the analyses from previous chapters. OC Waterloo should mainly focus on improving their competitive priority time/delivery. QRM is the most suitable technology for OC Waterloo. The company should improve the time/delivery via the three-way strategy (variability, utilization and batch size) described by QRM. OC Waterloo should plan using batches of 20% of the current batch size, plan to a maximum utilization of machines and personnel of 75% (except for the bottleneck) and measure and reduce variability by process improvements. In addition, OC Waterloo should train every employee to have a basic understanding of QRM and every manager to have a good understanding of QRM. Furthermore, OC Waterloo should select its ERP system based on the requirements set by the company, QRM and Industry 4.0. Lastly, OC Waterloo should measure the quality more effectively by using the ERP system. Table 6-3 gives the main competitive actions to comply with the business strategy, sales strategy, external environment and current operations.

Table 6-3 Main competitive actions

Competitive priority	Measure	Capability/current	Gap	Action
Time/delivery	Utilization	100%	Target is maximum of 75%	Plan to a maximum of 75% of capacity, except for the bottleneck.
Time/Delivery	Batch size	281 products	Target is 20% of the current batch size	Plan using batches in production.
Time/Delivery	Average variability	Non-measurable	A goal cannot be defined due to no measurement	Reduce variability by process improvements
Flexibility and Time/Delivery	WIP	1790	The goal is to reduce WIP	Implement the three-way strategy (variability, utilization and batch size)
Time/delivery	MCT	On average 18,1 days (non-touch time)	Reduce to 30% of initial measure	Implement the three-way strategy (variability, utilization and batch size)
Time/Delivery	Delivery reliability	74%	95%	Implement QRM and the three-way strategy (variability, utilization and batch size)

7 IMPLEMENTATION PLAN

This chapter develops the implementation plan for OC Waterloo. The implementation is based on all previous chapters, especially the implementation literature on QRM.

7.1 Hoshin Kanri/X-matrix

To give a clear insight into the operations strategy a Hoshin Kanri model/X-matrix has been set up. In addition, this matrix contributes to clear communication of the operations strategy. Thereby, this framework is excellent for deploying the operations strategy. The matrix is shown in Figure 7-1. The parts in bold are the most important parts of the operations strategy. The most important parts consist of MCT measurement and reduction, which is QRM's main goal. The Hoshin Kanri model builds upon the operations strategy and the previous subchapters.

Long term goals

The main long term goal is MCT reduction. Due to the planning with one day between each process step and the outsourced powder coating, the MCT can be reduced to 30% of the initial measure. All employees need to be trained in QRM for the methodology to work. Thereby, a lot of time is wasted outside the production department (Suri, 2011). Therefore, QRM should be implemented in all departments. The long term goals (2021-2025) are:

- **MCT in operations reduced to 30% in comparison to the initial measure**
- Powder coating insourced
- All employees have a basic understanding (Bronze) and all managers have a good understanding (Silver/Gold) of QRM
- QRM is implemented in all departments

One-year goals

The one-year goals are based upon the long term goals. Therefore, the goals are similar, but with a different target. The new ERP system should be implemented to simplify the KPI measurement and the QRM/Industry 4.0 implementation. The one-year goals are:

- **Average MCT real-time measurable and reduced to 80% (of initial measure) in the production department;**
- 100% of the management has a good understanding of QRM, 20% of the employees have basic understanding;
- Applying QRM to every department has been researched, so that OC Waterloo has a plan to roll out QRM across the entire organisation;
- ERP Implemented according to OC Waterloo's, QRM's and Industry 4.0's ERP requirements.

Improvement projects

The improvement projects are selected to achieve the one-year and long term goals. The MCT ratio should be measurable and visualised in the production department. Thereby, the MCTs should be created for each department. The MCTs could be created more easily with a new ERP system, so the system should be selected and implemented according to the requirements. The batch size of the production needs to be reduced to achieve a lower lead time. The batch size can be reduced on short notice. The same applies to utilization reduction. Thereby, OC Waterloo should stop planning one day between each process step (this also depends on the ERP system). Furthermore, employees need to be cross-trained in the QRM cells. Last, the average variability in job time and arrivals needs to be reduced (without adjusting the batch size and utilization rate). The improvement projects are:

- **Visualising MCT ratio in the production department**
- **Create MCTs for each department**
- Research applying QRM to all departments
- Reducing batch size in production to 20% (or till best flow time is achieved) of current batch size in steps of maximum 15/20% per month
- Utilization of personnel and machines to a maximum of 75%, except for the bottleneck
- Train employees to get basic (Bronze) and managers to have a good (Silver/Gold) understanding of QRM
- Plan production without one day between each process step
- Select and implement ERP according to OC Waterloo's, QRM's and Industry 4.0's ERP requirements and wishes
- Cross-train employees in the QRM cells
- Reduce average variability in job time and arrivals by process improvement (without adjusting the batch size and utilization rate)

KPIs

To monitor the long term goals, short term goals and improvement projects, KPIs have been set up. Not every KPI has a goal set to it, because the goal depends on the initial measure. Thereby, the goal changes over time. The KPIs should be measured ideally real time by the (new) ERP system. Furthermore, the KPIs should be calculated by the controller, because he has the most knowledge of controlling and QRM. The KPIs are:

- **MCT per product (family);**
- MCT Ratio;
- Delivery reliability, as a measure, not as focus;
- Production batch size Work in progress;
- Throughput per QRM cell;
- Utilization rates <75%, except for the bottleneck (employees and machines);
- Average variability;
- Changes in product mix and volume;
- Defect rate.

Operations

1-year goal 4	1-year goal 3	1-year goal 2	1-year goal 1	#	Improvement projects	KPI 1	KPI 2	KPI 3	KPI 4	KPI 5	KPI 6	KPI 7	KPI 8	KPI 9	KPI 10
			●	1	Reducing batch size in production to 20% (or till best flow time is achieved) of current batch size in steps of maximum 15/20% per month	●	●	●	●	●					
			●	2	Utilization of personnel and machines to a maximum of 75%, except for the bottleneck	●	●	●		●		●			
●				3	Train employees to get basic (Bronze) and managers to have good (Silver/Gold) understanding of QRM	●									
			●	4	Plan production without one day between each process step	●	●	●							
		●		5	Select and implement ERP according to OC Waterloo's, QRM's and Industry 4.0's ERP requirements and wishes	●	●	●	●	●	●	●	●	●	●
●			●	6	Cross-train employees in the QRM cells	●	●								
			●	7	Reduce average variability in job time and arrivals by process improvement (without adjusting batch size and utilization rate)					●			●		
			●		**Visualising MCT ratio in production department**	●	●								
	●			8	**Create MCTs for each department**	●	●								
	●			9	Research applying QRM to all departments	●	●								

1 year goals

	1 year goal
1	**Average MCT real time measurable and reduced to 80% (of initial measure) in the production department**
2	ERP Implemented according to OC Waterloo's, QRM's and Industry 4.0's ERP requirements
3	Applying QRM to every department has been researched
4	100% of the management has good understanding of QRM, 20% of the employees have basic understanding.

KPI's

	KPI
1	**MCT per product (family)**
2	MCT Ratio
3	Delivery reliability, as measure, not as focus.
4	Production batch size
5	Work in progress
6	Throughput per QRM cell
7	Utilization rates <75%, except for the bottleneck (employees and machines)
8	Average variability
9	Changes in product mix and volume
10	Defect rate

Long term goals 2021 - 2025

1-year goal 4	1-year goal 3	1-year goal 2	1-year goal 1	#	Long term goals 2021 - 2025	KPI 1	KPI 2	KPI 3	KPI 4	KPI 5	KPI 6	KPI 7	KPI 8	KPI 9	KPI 10
●	●	●	●	1	**MCT in operations reduced to 30% in comparison to initial measure**	●	●	●	●	●	●	●	●	●	
●	●	●	●	2	All employees have basic understanding (Bronze) and all managers have good understanding (Silver/Gold) of QRM	●	●								
●	●	●		3	QRM is implemented in all departments	●	●	●	●	●	●	●	●	●	●
●			●	4	Powder coating insourced	●	●								

Figure 7-1 Hoshin Kanri/X-matrix Operations Strategy

7.2 Organisation of implementation

Suri (2011) describes how to implement QRM. To implement QRM the following teams have to be present: a QRM steering group, a QRM cross-functional scheduling team and a QRM implementation team. Thereby, a QRM facilitator has to be part of the QRM steering group. The QRM facilitator is an expert in QRM and supports the scheduling team. For OC Waterloo the teams have to be organised as shown in Table 7-1. The QRM facilitator is Theo Meulman (Controller). The controller is chosen as the facilitator because he has the most knowledge of QRM inside the organisation. In addition, he strongly believes in QRM. The QRM steering group is the managing group of QRM. The steering group will not execute projects but will monitor the progress. The QRM steering group consists of Paul Lustig (CEO), Hans Wijtvliet (COO Orange Climate) and the QRM-facilitator Theo Meulman (Controller). Hans Wijtvliet (COO Orange Climate) is present one day a week at OC Waterloo. These managers are selected for the steering group, because they are the management of OC Waterloo. The cross-functional scheduling team consist of Frank van Dam (Production Coordinator), Jeroen Assink (Technical Manager) and partly QRM-facilitator Theo Meulman (Controller). These members have the most knowledge of the functional areas and the processes and are therefore selected in the cross-functional scheduling team. The cross-functional scheduling team develops the recommendations for QRM projects to shorten the MCT. The implementation team consists of Frank van Dam (Production Coordinator), Jeroen Assink (Technical Manager) and all members of the QRM cell. These persons are selected for the implementation team, because they already implement improvements in the organisation. In addition, the implementation team must get support from the steering group and facilitator. The implementation team carries out the project(s). The QRM steering group and cross-functional scheduling team have the responsibility of executing and planning the goals set in the Hoshin Kanri.

Table 7-1 Team members per QRM team

QRM team	Team members
QRM facilitator	Theo Meulman (Controller)
QRM steering group	Paul Lustig (CEO) Hans Wijtvliet (COO Orange Climate) Theo Meulman (Controller)
QRM cross-functional scheduling team	Frank van Dam (Production Coordinator) Jeroen Assink (Technical Manager) (Theo Meulman (Controller))
QRM implementation team	Frank van Dam (Production Coordinator) Jeroen Assink (Technical Manager) All members of the QRM cell

7.3 Contingencies

Currently, the management and employees have limited knowledge of QRM and time/delivery, which explains the misalignment between costs and time/delivery. It is of importance that the employees and especially the management get sufficient knowledge on QRM (by training). A lack of knowledge could lead to a relapse into old habits and an unsuccessful implementation of the operations strategy.

To make sure that OC Waterloo will not relapse into old habits, the company must ensure that it is no longer possible to schedule up to 100% (except for the bottleneck) and must ensure that the production staff adhere to the lowered batch size. This can be done by setting up the new ERP system in such a way that managers have to take into account planning up to 75% on machines and personnel. In addition, production staff should no longer receive orders for three days on their screens, but only orders in the batch that has to be produced. These relatively simple adjustments in software prevent staff from relapsing into old habits.

Furthermore, the implementation of the operations strategy highly depends on the implementation of the new ERP system as this causes a large part of the (planning) problems. Therefore, many solutions are linked to the implementation of the ERP system. Due to the high dependence on the ERP system, OC Waterloo has to make sure that the right ERP system is selected and implemented according to the requirements set in the previous chapter.

8 CONCLUSION, LIMITATIONS AND FURTHER RESEARCH

This study researched an answer to the following main question:

> *What should the Operations Strategy of OC Waterloo become and how could it be implemented for the following 5 years, so that it is in line with the strengths of the current production facility, business strategy and market's needs?*

To answer the main question, qualitative as well as quantitative research has been conducted on the operations strategy, business strategy, external environment and sales strategy, strengths and weaknesses of OC Waterloo's operations, the operations strategy and the implementation of the strategy. The topics and research methods are selected based on the theory about operations strategy.

Out of the business strategy, external environment and sales strategy, it can be concluded that OC Waterloo desires to increase its revenue and improve its profit margin. Furthermore, it can be concluded that OC Waterloo mainly focuses on the competitive priorities flexibility and time/delivery. The competitive priorities are in line with the sales strategy and market demand. However, KPIs in the business strategy do not correspond with the KPIs in the theoretical framework.

OC Waterloo is distinctive in its flexibility because the company has delivered 2790 different products in the past four months. Thereby, the variability in the products, processes and monthly demand is high. Furthermore, the company has an average order quantity of six. Product families have been created to get an overview of the products. The product families are:

- Airlines;
- Outside air grilles;
- Adjustable grilles;
- Linear grilles;
- Sheet products;
- Steel linear grilles;
- Volume control dampers;
- Other grilles;
- RW-series;
- Trade products;
- Panels and induction units;
- Volume control;
- Swirl diffusers; and
- Specials.

In contrast to the desired competitive priorities, OC Waterloo focuses on costs by focusing on efficiency in the operations. The company does this by using high batch sizes and high utilization of machines and personnel, which has negative effects on time/delivery.

Due to the focus on costs, time/delivery leaves something to be desired. A product in OC Waterloo's production process is waiting to be processed 98.97% of the time. So, OC Waterloo is processing the product 1.03% of the time the product is in production. Thereby, OC Waterloo has a concerning average on-time delivery of 74%. Furthermore, OC Waterloo's current ERP system lacks functions to plan well and the outsourced powder coating takes up 35% to 49% of the non-touch time of the MCTs of the product families. The lack of focus on time/delivery or the lack of understanding to excel in time/delivery leads to a misalignment in comparison to the competitive priorities, because the sales strategy and external environment require short delivery times and on-time delivery.

The quality of OC Waterloo's products are being measured, however, the company started with this in week fifteen of 2021 and the reliability of the measurement is questionable. The total quality costs were €3.062,50 from week 15 up to and including week 18. The quality of OC Waterloo's products is high, however, it should be measured more reliable in the future.

Based on these conclusions OC Waterloo should mainly focus on improving the competitive priority time/delivery. To do this, OC Waterloo should implement QRM as its manufacturing methodology, because QRM focuses on time/delivery and flexibility in the operations. The main focus of OC Waterloo should become reducing the Manufacturing Critical Path Time (MCT) to 30% of the current MCT. To achieve this MCT reduction and therefore excel in time/delivery, OC Waterloo should use the three-way strategy (variability, utilization and batch size) described by QRM. The batch size needs to be reduced to 20% of the current batch size, the machine's and personnel's utilization needs to be reduced to a maximum of 75% (except for the bottleneck) and the variability needs to be measured and reduced in the process. In addition, the powder coating needs to be insourced to achieve an average MCT reduction of 28,8% of the product families. The investment of insourcing the powder coating is earned back in 1,77 years. Furthermore, OC Waterloo should select its new ERP system based on QRM's, Industry 4.0's and the company's requirements set in the operations strategy. Lastly, OC Waterloo should train its employees to get sufficient knowledge of QRM and expand the QRM strategy to the entire organisation.

Reducing the MCT by 30% leads to a total saving of €443.947,32. However, the organisation also needs to reduce the utilization of machines and personnel. So, the employee costs will become higher than before. Thereby, the organisation may need to expand the machine park to achieve the lower utilization. Due to the lack of data, no exact calculation can be made about the increasing costs of reducing the utilization. Furthermore, the changeover times become five times as much due to lowering the batch size. Thus, the setup time will become 42.7 minutes. The total setup time costs are then €42.57 per setup. This calculation is a rough estimation, because it dependents on how often the machines needs to be changed over. Currently, there is no data available on that.

The implementation/deployment of the operations strategy has to be done using the Hoshin Kanri model/X-matrix, where OC Waterloo is familiar with. The implementation of QRM has to be organised using various teams. These teams are a QRM steering group (the managing group), the QRM cross-functional scheduling team (members with the most knowledge on the functional areas and processes, who develop the recommendations for QRM projects) and the QRM implementation team (the team that executes the recommendations). To help guide the project a QRM facilitator is selected, the QRM facilitator has the most knowledge of QRM and strongly believes in the strategy.

Limitations

The limitations of the study are discussed below:

- Due to the scope of this study, no market analysis has been conducted. Therefore, the competitive priorities time/delivery and flexibility are based on the opinions of the employees. It could be that the competitive priorities the market desires differ from the opinion of the employees.
- OC Waterloo's ERP system and production dashboard have limited real-time data available. Therefore, the research is partly based on previous measurements. However, this data is discussed and analysed with OC Waterloo's employees and is valid.

Theoretical implications

The results of this study have theoretical implications. The theoretical framework has shown that research in operations strategy and its competitive priorities are far developed. However, the theory on Quick Response Manufacturing is limited. Most research on QRM is conducted by its developer Suri. QRM pushes ERP systems aside, despite the fact that most organisations use ERP systems (Suri, 2011). The reason for this is that ERP systems do not consider the effects of system dynamics in operations. However, OC Waterloo is currently selecting a new ERP system that can be configured to take system dynamics into account. For this reason, requirements for the new ERP system have been set up based on the three-way strategy (variability, utilization and batch size) mentioned by Suri (2011). Therefore, the findings in this research contradict with QRM's view. Thus, ERP systems could be combined with QRM, when the ERP system is configured using the right requirements.

Future research

Future research should focus on how to combine system dynamics with ERP systems for companies that focus on time/delivery. Thereby, it is also interesting to know the effect of ERP systems that take system dynamics into account on operations.

Concerning practical future research, OC Waterloo should research the implementation of QRM across the entire organisation. This research mainly focuses on OC Waterloo's operations. Furthermore, it is of interest to research the market demands, because this research based the market demands on the opinion of OC Waterloo's employees (due to the scope of this study). A thorough market analysis could confirm or contradict the market demands, as well as the competitive priorities, set in this research.

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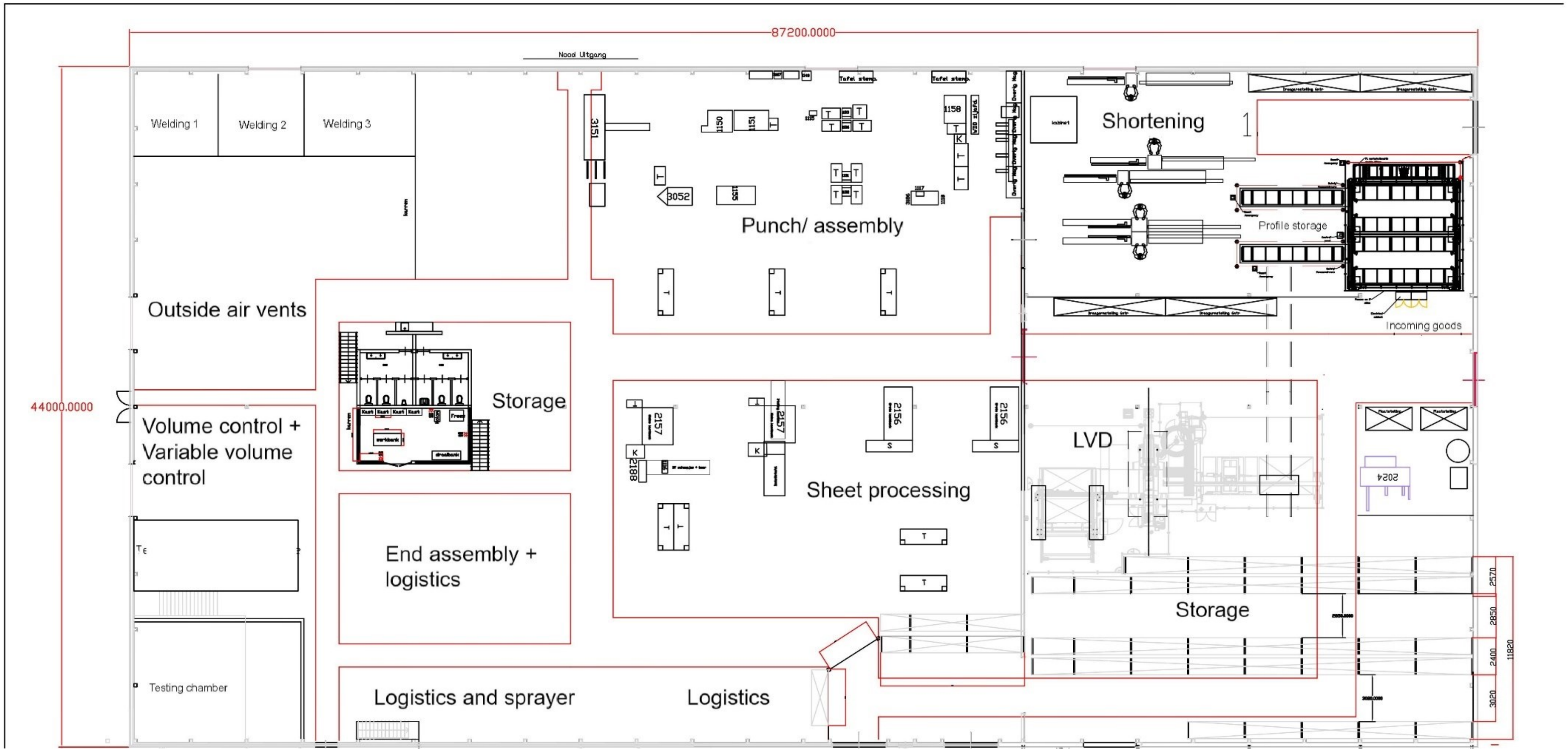
APPENDIX 1: PRODUCTION MAP



APPENDIX 2: INTERVIEW STRATEGY ORANGE CLIMATE (WATERLOO)

As discussed, you agree to the interview being recorded, transcribed and used for the research and report. You may withdraw this consent at any time.

Strategy

What is Orange Climate's strategy?

What is this strategy based on?

What differentiates Orange Climate from the competition at this time?

How does Orange Climate plan to distinguish itself?

- Quality of service

- Cost of ownership

- Time/delivery

- Flexibility

What will be the main investments in the coming years?

Do the companies in the group have the same strategy?

In what way are you trying to create unity?

Operations

What is the operations strategy of Orange Climate?

What is this strategy based on?

Which production technology does Orange Climate focus on the most?

OC Waterloo

What are the current distinguishing features of OC Waterloo?

How will OC Waterloo improve its performance in the future?

What differentiates OC Waterloo in the future?

- Quality of service

- Cost of Services

- Time/Delivery

- Flexibility

What will be the main investments in the coming years?

What are OC Waterloo's areas for improvement?

To what extent should OC Waterloo's strategy be aligned with Orange Climate's strategy?

What is the main focus of Orange Climate's strategy?

Waterloo operations

How do you see Waterloo's operations in the future?

How should OC Waterloo differentiate itself in the market?

- Quality
- Costs
- Time/delivery
- Flexibility

Final

Do you have any aspects that I should take into account regarding the operations strategy?

APPENDIX 3: X-MATRIX BUSINESS STRATEGY

Directie

Verbeterinitiatieven – Projecten /Thema's Waterloo

1 jaar doelen Waterloo

KPI's – Hoe veel?

Doorbraakdoelen Orange Climate 2021 - 2025

Afdelingen

4	3	2	1	#	Verbeterinitiatieven	KPI 1	KPI 2	KPI 3	KPI 4	KPI 5	KPI 6	KPI 7	KPI 8	KPI 9	KPI 10	verkoop	Marketing	productie	inkoop	Werkvoorbereiding	Administratie
			●	1	groei aantal projecten > € 100.000 door focus op top 10 landelijke installateurs	●										●					
			●	2	omzetgroei export door actievere marktbenadering		●									●					
			●	3	onderscheidend zijn in de NL markt door verbeteren customer intimicy			●								●	●				
		●		4	on time delivery vergroten door inzicht in benodigde en beschikbare productie capaciteit				●									●			
		●		5	Verhogen marge op de verkopen,					●						●					
		●		6	productiviteit verbeteren door optimaliseren handmatige processen						●							●			
		●		7	faalkosten verminderen door first time right te verbeteren in het primaire proces							●				●		●	●	●	
	●				Verbeterladder introduceren en 0 meting									●	●	●	●	●	●	●	●
●				8	Meten en in kaart brengen van MVO onderdelen								●								●
				9																	

1 jaar doelen Waterloo:

1. Omzetgroei (gefaktureerd) naar € 9,5 mlj
2. EBITDA 8,3% van de omzet
3. Groei op de OC continue verbeteren prestatieladder van 0,4 t.o.v. 2020
4. Een score van minimaal 1 op ieder onderdeel van de OC MVO prestatieladder

KPI's:

1. 10 projecten > € 100.000 gefaktureerd
2. € 2,25 omzet export
3. € 7,25 omzet NL
4. >90% orderregels op tijd geleverd op eerst afgesproken leverdatum
5. 3% margeverhoging aan de verkoopzijde tov 2020
6. directe loonkosten productie is maximaal 22% van de productie omzet
7. aantal "defects" (info of product dat je ontvangt is niet goed / duidelijk / compleet) in het primaire proces verminderen met 50%
8. alle 13 onderdelen in kaart gebracht en meetbaar gemaakt
9. Onderdelen zijn in kaart gebracht en 0 meting is uitgevoerd
10. Groei op de ladder van 0.4 tov de o-meting

4	3	2	1	#	Doorbraakdoelen	KPI 1	KPI 2	KPI 3	KPI 4	KPI 5	KPI 6	KPI 7	KPI 8	KPI 9	KPI 10
			●	1	Omzetgroei (gefaktureerd) naar € 100.000.000	●	●	●							
		●		2	EBITDA gemiddeld 8% van de omzet over de laatste 3 jaar met een afwijking van max. 2% in een jaar				●	●	●	●			
	●			3	Een score van 2,5 op de OC continue verbeteren prestatieladder									●	●
●				4	Een score van 2,5 op de OC MVO prestatieladder								●		

Directie

APPENDIX 4: X-MATRIX SALES STRATEGY

Afdeling verkoop

Verbeterinitiatieven Projecten /Thema's Afdeling — Verbeterinitiatieven Waterloo — KPI's Hoe veel? — Doorbraakdoelen Orange Climate 2021-2025

Verbeterinitiatieven Waterloo:

	Verbeterinitiatieven Projecten /Thema's Afdeling	7 faalkosten verminderen door first time right te verbeteren in het	6 optimaliseren handmatige processen	5 Verhogen marge op de verkopen,	4 on time delivery vergroten door inzicht in benodigde en beschikbare	3 onderscheidend zijn in de NL markt door verbeteren customer intimicy	2 omzetgroei export door actievere marktbenadering	1 groei aantal projecten > € 100.000 door focus op top 10 landelijke
1	Accountmanager volledig op landelijke installateurs							●
2	Meer aanvragen ontvangen voor grote projecten							●
3	Focus op projecten in Duitsland						●	
	Omzet met 10 nieuwe klanten in BE						●	
4	verlaging aantal klanten onder de 5000 Euro in NL			●	●			
5	Verhoging marge op specials			●				
6	Inrichting A, B en C klanten, waarbij C klanten een minimum orderbedrag krijgen van 500 Euro			●		●		
7	Met 4 accountmanagers actief de markt benaderen					●		
8								

KPI's Hoe veel?:

	Verbeterinitiatieven Projecten /Thema's Afdeling	1 Alle vestigingen en DMU's volledig in kaart gebracht bij de landelijke installateurs	€ 7,25 omzet NL	2 50% meer offertes uitbrengen van 100K + tov 2020	3 15 nieuwe klanten met 500K omzet in DL	4 5000 Euro tov 2020	5 stijging marge op specials met 15% tov 2020	6 Naast Lidl 10 nieuwe klanten vinden met 100K omzet	7 *Alle klanten hebben een A, B of C status in het CRM*	8 geen C klanten met omzet lager dan 500 Euro	9 Organiseren 16 evenementen met A klanten	10 1000 bezoeken bij A en B klanten in 2021
1	Accountmanager volledig op landelijke installateurs	●										
2	Meer aanvragen ontvangen voor grote projecten			●								
3	Focus op projecten in Duitsland				●							
	Omzet met 10 nieuwe klanten in BE							●				
4	verlaging aantal klanten onder de 5000 Euro in NL					●						
5	Verhoging marge op specials						●					
6	Inrichting A, B en C klanten, waarbij C klanten een minimum orderbedrag krijgen van 500 Euro								●	●		
7	Met 4 accountmanagers actief de markt benaderen		●								●	●
8												

Medewerkers

Doorbraakdoelen Orange Climate 2021-2025 (Afdeling):

- Omzetgroei (gefaktureerd) naar € 100.000.000
- EBITDA gemiddeld 8% van de omzet over de laatste 3 jaar met een afwijking van max. 2% in een jaar
- Een score van 2,5 op de OC continue verbeteren prestatieladder
- Een score van 2,5 op de OC MVO prestatieladder

APPENDIX 5: INTERVIEW PRODUCTION MANAGER

To what extent are people versatile?

What are the changeover times between different products?

How often do rush jobs occur in production?

What is the effect of these rush jobs on production?

What is the cause of products being delivered too late?

How often does it occur that the delivery date of customers is changed?

Why are the start and end dates in WIP always one day apart?

What is the "planned time" in the WIP file?

What is the batch size of the production?

Does planned time include the factor?

How do you guarantee the quality of the production?

APPENDIX 6: PRODUCT AMOUNT PER PRODUCT TYPE

Product type	Product family	Product description	Product amount
3H	Airlines	Wall and ceiling grill	62
AL2	Airlines	Wall and windowsill	38
2RTC	Airlines	High inducing wall grille	304
AL	Airlines	Wall and windowsill	1092
ALC	Airlines	Insert grille	27
ALC-Y	Airlines	Insert grille	98
ALPC	Airlines	Insert grille	785
ALZ	Airlines	Wall and windowsill	260
NF-15	Airlines	Door/ overflow grid	26
RTC	Airlines	Wall grille	664
RTCC	Airlines	Insert grille	49
RTCC-Y	Airlines	Insert grille	77
RTC-STUC	Airlines	Wall grille	64
RTC-Y	Airlines	Wall grille	23
SUPAIR	Airlines	Rotacore inlay grille	25
WGDDAK	Outside air grilles	Roof curb	20
ABRS4	Outside air grilles	Outside air grille	126
ASR	Outside air grilles	Line grid	28
SL	Outside air grilles	Counter-rotating valve register	4
WG	Outside air grilles	Outside air grill	144
WGD	Outside air grilles	Roof hood aluminum	28
WG-HEERING	Outside air grilles	Outside air grill	30
WGK	Outside air grilles	Outside air grill	1
YG	Outside air grilles	Outside air grill	135
YGHF	Outside air grilles	Outside air grill	5
YGK	Outside air grilles	Outside air grill	2
YGT	Outside air grilles	Outside air grill	1
1H	Adjustable grilles	Adjustable wall grille	227
1V	Adjustable grilles	Adjustable wall grille	20
2H	Adjustable grilles	Double adjustable wall grille	207
2V	Adjustable grilles	Double adjustable wall grille	13
CS	Linear grilles	Aluminum linear grille	224

CSVZ	Linear grilles	Aluminum linear grille	1872
AFDEK	Sheet products	Cover segment	22
WPD	Sheet products	Square ceiling grille	345
MWPD	Sheet products	Square perforated grille	30
WID	Sheet products	Square ceiling grille	150
WID-FR	Sheet products	Perforated ceiling grille	1056
FDC	Sheet products	Heavy-duty valve	225
GR	Sheet products	Plenum	54
OLP	Sheet products	Lay on plenum	198
RWH	Sheet products	Jet grille	18
WKA	Sheet products	Plenum	1
WKA-Y	Sheet products	Plenum	10
WS	Sheet products	Swirl diffuser	986
MWVPD	Sheet products	Perforated ceiling	2376
GKR	Sheet products	Plenum	34
KV	Sheet products	Plenum	4
MKV	Sheet products	Plenum	26
TKV	Sheet products	Plenum	244
UKV	Sheet products	Plenum	128
WKV	Sheet products	Plenum	351
AKA	Sheet products	Plenum for (K)CS	13
AKB	Sheet products	Plenum for (K)CS	56
AKC	Sheet products	Plenum for (K)CS	10
STCS	Steel linear grilles	Steel linear grille	20
OCK	Volume control dampers	Counter-rotating valve register	358
OBD2	Volume control dampers	Valve register	68
VKT	Volume control dampers	Valve register	57
OBD	Volume control dampers	Valve register	28
WDD	Volume control dampers	Counter-rotating valve register	110
WLMS	Volume control dampers	Variable volume control	171
WRS	Volume control dampers	Variable volume control	456
WRS-OD	Volume control dampers	Round open/close control	4
ACGP	Other grilles	Floor grille	11
PEROA	Other grilles	perforated overflow grille	72

1RV	Other grilles	Round duct grille	327
2RRTC	Other grilles	Round duct grille	10
2RV	Other grilles	Round duct grille	226
ACG	Other grilles	Floor grille	12
AF	Other grilles	Installation frame	46
BERKVENS	Other grilles	Sound-absorbing grille	367
DSR	Other grilles	Sound-absorbing grille	304
DT-2M	Other grilles	Drain register	7
DT-2MG	Other grilles	Drain register	25
DV	Other grilles	Door grille	132
GC5	Other grilles	Return grille	311
LVV	Other grilles	Fire resistant vent.	49
PER	Other grilles	Return/ overflow grille	98
PER-G	Other grilles	Reinforced return overflow grille	15
RRTC	Other grilles	Round duct grille	10
SVEDEX	Other grilles	Sound-absorbing grille	115
RWI	RW-series	Round ceiling grille	53
RWK	RW-series	Round ceiling grille	60
RWV	RW-series	Round ceiling grille	4
RWA	RW-series	Round ceiling grille	32
AC	Trade	Square ceiling grille	172
ACV	Trade	Plastic grille	5
AV	Trade	Round valve	662
CR	Trade	Fire damper	57
CU	Trade	Fire damper	34
DF	Trade	Ceiling grille	24
ISOPLENUM	Trade	Plastic plenum	125
PKIC	Trade	Fire damper	35
PKIR	Trade	Round fire damper	22
PKIS	Trade	Square fire damper	29
SAPZ	Trade	Jet nozzle	4
SC	Trade	Fire damper	6
SI	Trade	-	981
VVB	Trade	-	5
WDJ	Trade	Drum Jet grille	37

WRM	Trade	Constant volume control	333
WSDSD	Trade	Control valve	365
WSLU	Trade	Round silencer	2
WSRS	Trade	Silencer	55
WVK2	Trade	Constant volume control	4
WISL	Panels and induction units	Inspection hatch	26
LBK	Panels and induction units	Air handling unit	520
LBKKAP	Panels and induction units	Air handling unit	80
PANEEL	Panels and induction units	Perforated panel	2
ABM300	Panels and induction units	Ceiling induction universal	8
O	Volume control	Volume control	1028
O-ALWA	Volume control	Volume control	650
OBSSD	Volume control	Volume control	205
SDV	Swirl diffusers	Swirl diffuser	65
WTF	Swirl diffusers	Swirl diffuser	537
S	Special	Special	3064

APPENDIX 7: PRODUCT FAMILY MATRIX

Type	Product family	Product description	Product am	1000	1001	1002	1003	1004	1007	1008	1009	1010	1011	1104	2000	2001	2002	2003	3000	3001	4000	4001	5000	5002	5003	5004	5005	5006	5007	5008	5009	5010	5011	5100	5101	5102	5103	5104	5109	5110	5200	5300	6000	7000	8000	9000
3H	Airlines	Wall and ceiling grill	62					x	x						x											x			x														x	x		
ALZ	Airlines	Wall and windowsill	38					x	x						x											x			x														x	x		
2RTC	Airlines	High inducing wall grille	304					x							x											x																	x	x		
AL	Airlines	Wall and windowsill	1092					x	x	x					x											x																	x	x		
ALC	Airlines	Insert grille	27					x							x											x																	x	x		
ALC-Y	Airlines	Insert grille	98					x							x											x																		x		
ALPC	Airlines	Insert grille	785					x							x											x																		x		
ALZ	Airlines	Wall and windowsill	260					x							x											x																	x	x		
NF-1S	Airlines	Door/ overflow grill	26					x							x											x																	x	x		
RTC	Airlines	Wall grille	664					x							x											x																	x	x		
RTCC	Airlines	Insert grille	49					x							x											x																		x		
RTCC-Y	Airlines	Insert grille	77					x							x											x																	x	x		
RTC-STUC	Airlines	Wall grille	64					x							x				x		x					x																	x	x		
RTC-Y	Airlines	Wall grille	23					x							x											x																	x	x		
SUPAIR	Airlines	Rotacore inlay grille	25					x							x											x																		x		
WGDDAK	Outside air grilles	Roof curb	20																x		x			x														x						x		
ABRS4	Outside air grilles	Outside air grille	126			x													x		x			x																			x	x		
ASR	Outside air grilles	Line grid	28			x									x									x																				x		
SL	Outside air grilles	Counter-rotating valve reg	4			x									x				x		x			x																				x		
WG	Outside air grilles	Outside air grill	144			x																		x																			x	x		
WGD	Outside air grilles	Roof hood aluminum	28			x									x				x		x			x																			x	x		
WG-HEERING	Outside air grilles	Outside air grill	30			x																		x																				x		
WGK	Outside air grilles	Outside air grill	1			x																		x																			x	x		
YG	Outside air grilles	Outside air grill	135			x																		x																			x	x		
YGHF	Outside air grilles	Outside air grill	5			x																x		x																			x	x		
YGK	Outside air grilles	Outside air grill	2			x																x		x																				x		
YGT	Outside air grilles	Outside air grill	1			x													x			x		x																				x		
1H	Adjustable grilles	Adjustable wall grille	227				x		x						x										x				x														x	x		
1V	Adjustable grilles	Adjustable wall grille	20				x		x						x										x				x														x	x		
2H	Adjustable grilles	Double adjustable wall gril	207				x								x										x																		x	x		
2V	Adjustable grilles	Double adjustable wall gril	13				x								x										x																		x	x		
CS	Linear grilles	Aluminum linear grille	224	x											x				x		x		x																				x	x		
CSVZ	Linear grilles	Aluminum linear grille	1872	x											x								x																				x	x		
AFDEK	Sheet products	Cover segment	22																								x										x							x		
WPD	Sheet products	Square ceiling grille	345	x					x						x				x		x		x				x		x														x	x		
MWPD	Sheet products	Square perforated grille	30						x						x				x		x						x		x														x			
WID	Sheet products	Square ceiling grille	150																								x																	x		
WID-FR	Sheet products	Perforated ceiling grille	1056																x		x																						x	x		
FDC	Sheet products	Heavy-duty valve	225																		x																	x								
GR	Sheet products	Plenum	54																x		x	x																x						x		
OLP	Sheet products	Lay on plenum	198																x		x																	x						x		
RWH	Sheet products	Jet grille	18						x						x				x		x																	x					x	x		
WKA	Sheet products	Plenum	1																x		x																	x						x		
WKA-Y	Sheet products	Plenum	10																x		x																	x						x		
WS	Sheet products	Swirl diffuser	986								x			x					x		x	x																x					x	x		
MWVPD	Sheet products	Perforated ceiling	2376																x		x													x			x						x	x		
GKR	Sheet products	Plenum	34																x			x												x										x		
KV	Sheet products	Plenum	4																x															x												
MKV	Sheet products	Plenum	26																x		x	x												x												
TKV	Sheet products	Plenum	244																x															x										x		
UKV	Sheet products	Plenum	128																x															x										x		
WKV	Sheet products	Plenum	351																x															x										x		
AKA	Sheet products	Plenum for (K)CS	13																x		x													x											
AKB	Sheet products	Plenum for (K)CS	56																x		x													x									x		
AKC	Sheet products	Plenum for (K)CS	10																x		x													x											
STCS	Steel linear grilles	Steel linear grille	20	x											x				x		x	x													x									x		
OCK	Volume control dampers	Counter-rotating valve reg	358									x	x		x																	x	x											x		
OBD2	Volume control dampers	Valve register	68			x							x		x						x			x									x								x				x		
VKT	Volume control dampers	Valve register	57			x							x		x				x		x			x									x												x		
OBD	Volume control dampers	Valve register	28			x									x						x			x																				x		
WDD	Volume control dampers	Counter-rotating valve reg	110									x							x		x	x										x												x		
WLMS	Volume control dampers	Variable volume control	171									x			x				x		x											x												x		
WRS	Volume control dampers	Variable volume control	456									x			x				x		x											x												x		
WRS-OD	Volume control dampers	Round open/close control	4									x							x		x											x												x		
ACGP	Other grilles	Floor grille	11						x	x					x				x		x								x	x														x		
PEROA	Other grilles	perforated overflow grille	72						x	x					x				x			x							x	x													x	x		
1RV	Other grilles	Round duct grille	327						x										x										x														x	x		
2RRTC	Other grilles	Round duct grille	10						x						x				x		x	x							x														x	x		
2RV	Other grilles	Round duct grille	226						x						x				x										x														x	x		
ACG	Other grilles	Floor grille	12						x						x														x															x		
AF	Other grilles	Installation frame	46						x						x														x															x		
BERKVENS	Other grilles	Sound-absorbing grille	367						x						x														x														x	x		
DSR	Other grilles	Sound-absorbing grille	304						x						x				x		x								x														x	x		
DT-2M	Other grilles	Drain register	7						x										x		x								x															x		
DT-2MG	Other grilles	Drain register	25						x										x		x								x															x		
DV	Other grilles	Door grille	132						x						x														x														x	x		
GCS	Other grilles	Return grille	311						x						x														x														x	x		
LVV	Other grilles	Fire resistant vent.	49						x						x							x							x														x	x		
PER	Other grilles	Return/ overflow grille	98						x						x							x							x														x	x		
PER-G	Other grilles	Reinforced return overflov	15						x						x				x			x							x														x			
RRTC	Other grilles	Round duct grille	10						x						x				x		x	x							x															x		
SVEDEX	Other grilles	Sound-absorbing grille	115						x						x														x														x	x		
RWI	RW-series	Round ceiling grille	53																		x							x																x		
RWK	RW-series	Round ceiling grille	60																x		x							x															x	x		
RWV	RW-series	Round ceiling grille	4																x		x							x															x	x		
RWA	RW-series	Round ceiling grille	32																x		x																						x	x		
AC	Trade	Square ceiling grille	172																																									x		
ACV	Trade	Plastic grille	5																																									x		
AV	Trade	Round valve	662																																									x		
CR	Trade	Fire damper	57																																									x		
CU	Trade	Fire damper	34																																									x		
DF	Trade	Ceiling grille	24																																									x		
ISOPLENUM	Trade	Plastic plenum	125																																									x		
PKIC	Trade	Fire damper	35																																									x		
PKIR	Trade	Round fire damper	22																																									x		
PKIS	Trade	Square fire damper	29																																									x		
SAPZ	Trade	Jet nozzle	4																																									x		
SC	Trade	Fire damper	6																																									x		
SI	Trade	-	981																																								x	x		
VVB	Trade	-	5																																										x	
WDJ	Trade	Drum jet grille	37																																									x		
WRM	Trade	Constant volume control	333																																									x		
WSDSD	Trade	Control valve	365																																									x		
WSLU	Trade	Round silencer	2																																									x		
WSRS	Trade	Silencer	55																																									x		
WVK2	Trade	Constant volume control	4																																									x		
WISL	Panels and induction units	Inspection hatch	26																x		x																	x					x	x		
LBK	Panels and induction units	Air handling unit	520																x		x																							x		
LBKKAP	Panels and induction units	Air handling unit	80																x		x																							x		
PANEEL	Panels and induction units	Perforated panel	2																x			x																					x	x		
ABM300	Panels and induction units	Ceiling induction universal	8																x		x															x							x	x		
O	Volume control	Volume control	1028							x					x															x														x		
O-ALWA	Volume control	Volume control	650							x					x				x		x									x														x		
OBSSD	Volume control	Volume control	205							x																				x														x		
SDV	Swirl diffusers	Swirl diffuser	65								x								x		x	x									x							x						x		
WTF	Swirl diffusers	Swirl diffuser	537																																								x	x		
S	Special	Special	3064	x	x	x	x								x	x	x	x	x	x	x	x		x	x	x	x	x	x			x					x	x		x	x	x	x	x	x		x

Figure 0-1 Product family matrix OC Waterloo

APPENDIX 8: PRODUCT FAMILY ROUTING

To get further insights into de product families the routing per product family is visualised. The trade products have been excluded because this product family only passes expedition. In addition, specials have been excluded too, because of the variation in the process steps a special product goes through. Furthermore, due to the number of specific process steps, the process steps have been simplified. For example, all shortening process steps are in one process step "shortening". The process flow diagrams are shown below.

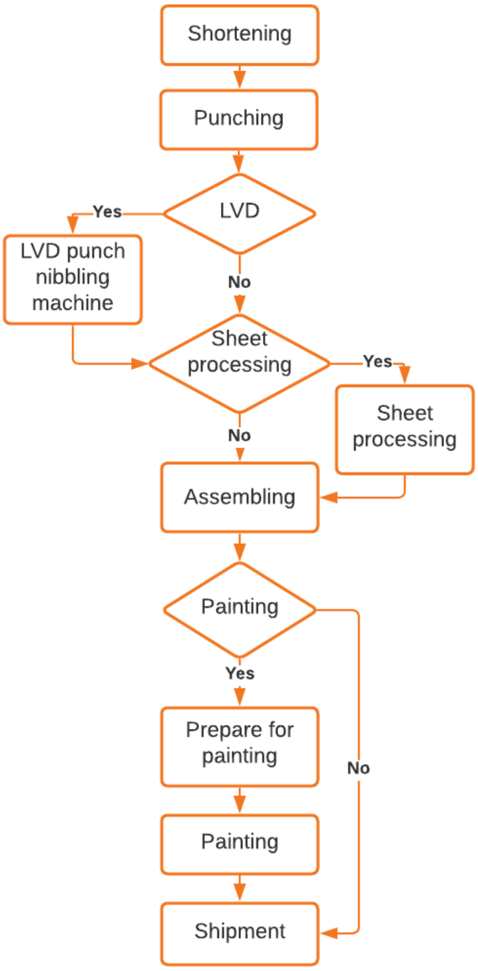


Figure 0-1 Process flow Airlines

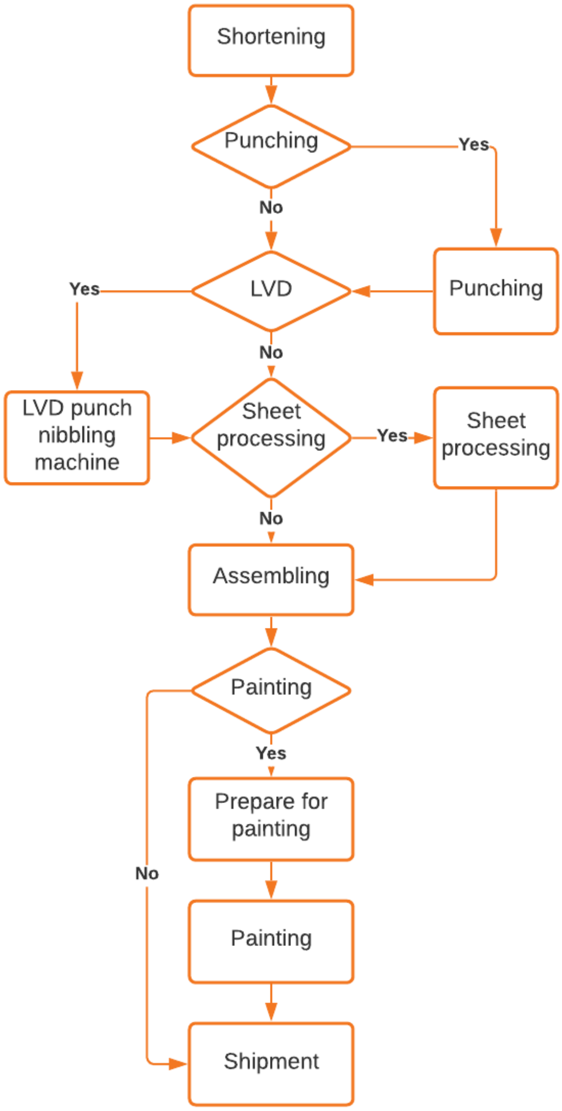


Figure 0-2 Process flow Outside air grilles

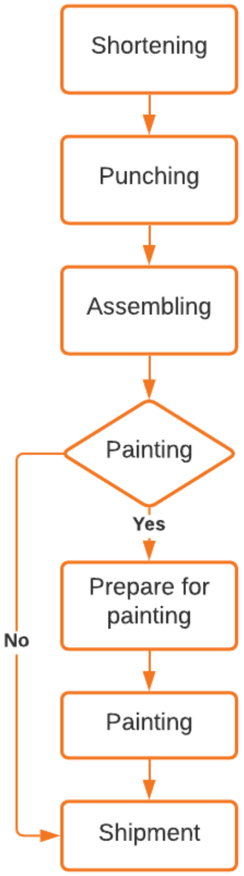


Figure 0-3 Process flow Adjustable grilles

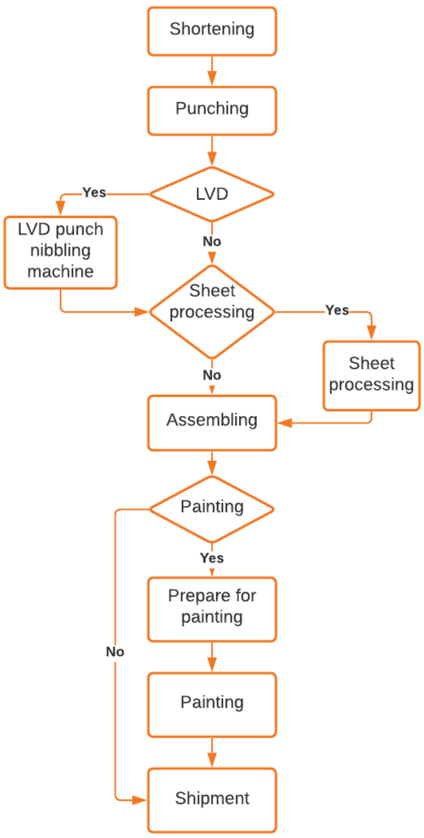


Figure 0-4 Process flow Linear grilles

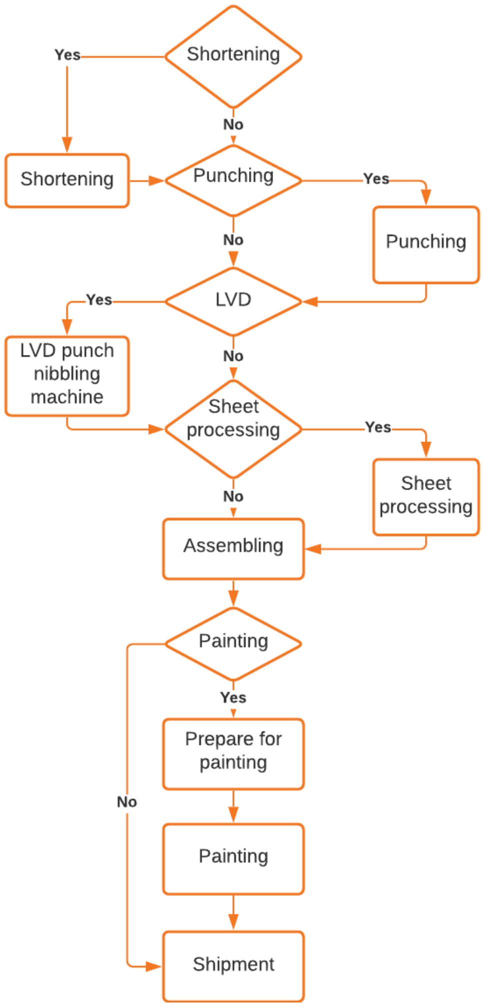


Figure 0-5 Process flow Sheet products

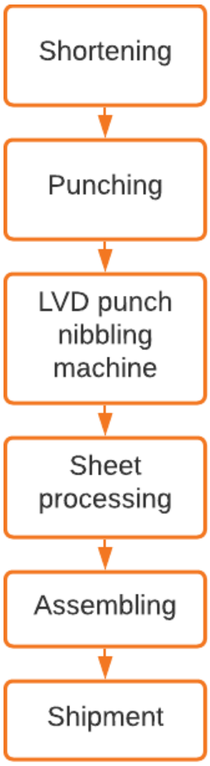


Figure 0-6 Process flow Steel linear grilles

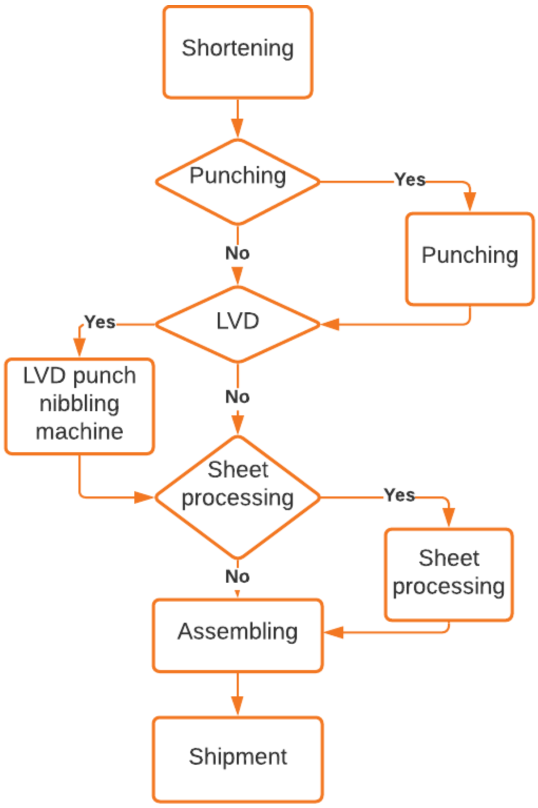


Figure 0-7 Process flow Volume control dampers

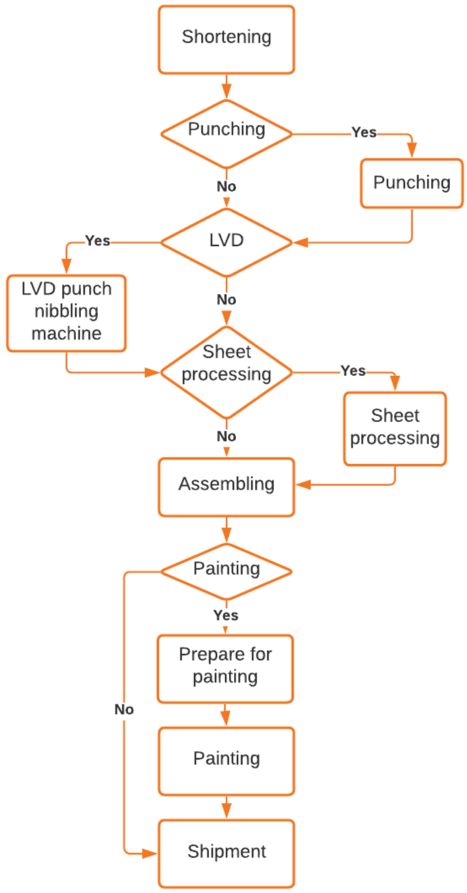


Figure 0-8 Process flow Other grilles

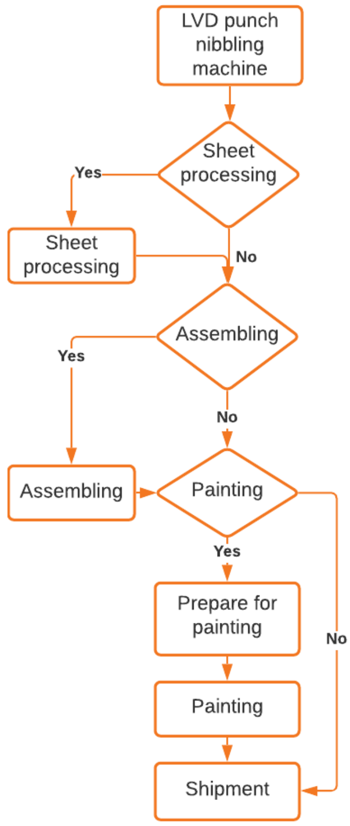


Figure Process flow 0-9 RW-series

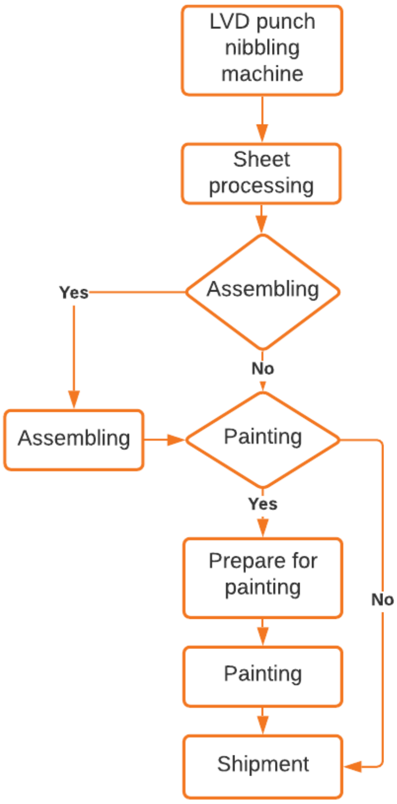


Figure 0-10 Process flow panels and induction units

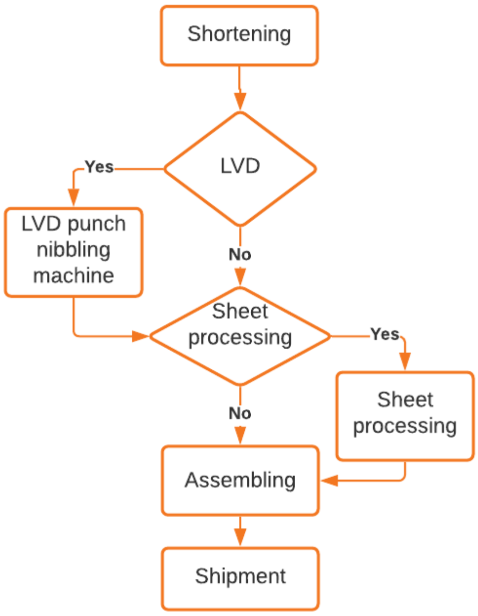


Figure 0-11 Process flow volume control

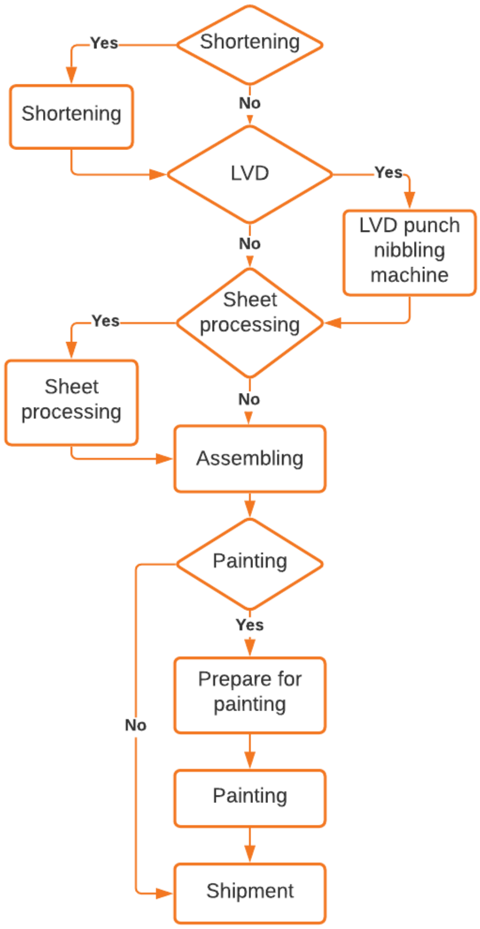


Figure 0-12 Process flow Swirl diffusers

APPENDIX 9: PRODUCT AMOUNT PER PRODUCT TYPE PER MONTH

Product type	Jan	Feb	Mar	Apr
1H	12	45	26	144
1RV	102	85	75	65
1V	8	1	3	8
2H	33	95	43	36
2RRTC		3	7	
2RTC	54	75	106	69
2RV	25	21	115	65
2V		2		11
3H	6	8	22	26
ABM300	1	7		
ABRS4	30	37	36	23
AC	4	38	102	28
ACG	2	1	3	6
ACGP		1	10	
ACV				5
AF		46		
AFDEK		10	9	3
AKA				13
AKB	21	27		8
AKC	8	2		
AL	101	65	440	486
AL2	3	2	25	8
ALC		5	20	2
ALC-Y	15	83		
ALPC		239	346	200
ALZ		20		240
ASR	18	10		
AV		181	221	260
BERKVENS	50	70	202	45
CR		19	33	5
CS	84	44	48	48
CSVZ	25	677	936	234
CU		16	12	6
DF		14	10	
DSR	82	112	70	40
DT-2M				7
DT-2MG	13		5	7
DV	2	96	17	17
FDC	62	54	25	84
GC5	104	25	119	63
GKR	3	11	20	
GR	12	2	27	13
ISOPLENUM		75		50
KV		4		
LBK	120	70	180	150
LBKKAP			49	31
LVV	1	14	16	18
MKV		8	18	
MWPD	30			
MWVPD	257	640	889	590
NF-15	4		7	15
O	114	339	386	189
O-ALWA		300	350	
OBD	11	17		
OBD2	4	12	36	16
OBSSD	28	105	40	32
OCK	50	71	100	137
OLP			120	78
PANEEL		2		
PER	4	82	6	6
PER-G		15		
PEROA	5	63	4	
PKIC		35		
PKIR		2	9	11
PKIS		6	2	21
RRTC	2	8		
RTC	91	214	133	226
RTCC	15	20	10	4
RTCC-Y	43	19	13	2
RTC-STUC	8	15	41	
RTC-Y	1	11	3	8
RWA		26	4	2
RWH		18		
RWI	13	34	5	1
RWK	9	11	13	27
RWV		2		2
S	514	1047	997	506
SAPZ	1			3
SC		4	1	1
SDV	4	5	13	43
SI	33	383	427	138
SL				4
STCS		20		
SUPAIR		25		
SVEDEX	25		60	30
TKV	86	93	30	35
UKV	13	49	17	49

VKT	14	10	18	15
VVB				5
WDD	10	29	31	40
WDJ			1	36
WG	24	21	52	47
WGD	11	2	13	2
WGDDAK	10	2	6	2
WG-HEERING		8	9	13
WGK		1		
WID	44	8	83	15
WID-FR	46	252	327	431
WISL	1	6	18	1
WKA				1
WKA-Y			10	
WKV	106	73	114	58
WLMS	8	52	28	83

WPD	48	82	147	68
WRM		109	151	73
WRS	26	158	88	184
WRS-OD				4
WS	29	520	159	278
WSDSD		42	323	
WSLU			2	
WSRS				55
WTF	144	159	151	83
WVK2			4	
YG	19	44	40	32
YGHF			5	
YGK			2	
YGT				1
End total	**2906**	**7691**	**8894**	**6227**

APPENDIX 10: MEAN ORDER ENTRY TILL DELIVERY LEAD TIME PER PRODUCT

Product family	Mean order entry -> Delivery lead time
1H	29,3
1RV	20,9
1V	15,3
2H	27,2
2RRTC	15,3
2RTC	19,5
2RV	19,1
2V	15,3
3H	19,4
ABM300	21,0
ABRS4	29,1
AC	28,4
ACG	14,3
ACGP	13,5
ACV	20,5
AF	16,9
AFDEK	4,2
AKA	27,0
AKB	22,3
AKC	15,0
AL	23,0
AL2	19,0
ALC	16,0
ALC-Y	52,4
ALPC	23,9
ALZ	21,2
ASR	14,4
AV	24,4
BERKVENS	18,1
CR	13,6
CS	20,7
CSVZ	20,4
CU	15,4
DF	13,5
DSR	19,6
DT-2M	21,0
DT-2MG	18,9
DV	17,3
FDC	19,1
GC5	29,9
GKR	16,2
GR	18,8
ISOPLENUM	18,0
KV	7,0
LBK	17,3
LBKKAP	17,4
LVV	28,8
MKV	20,5
MWPD	16,0
MWVPD	21,5
NF-15	16,3
O	19,8
O-ALWA	30,5
OBD	16,5
OBD2	20,4
OBSSD	19,3
OCK	26,0
OLP	31,8
PANEEL	36,0
PER	17,0
PER-G	38,0
PEROA	16,8
PKIC	16,0
PKIR	23,4
PKIS	25,9
PRD	22,0
RRTC	16,5
RTC	21,2
RTCC	15,1
RTCC-Y	21,7
RTC-STUC	17,2
RTC-Y	20,9
RWA	23,6
RWH	20,0
RWI	21,2
RWK	19,1
RWV	18,7
S	30,1
SAPZ	24,4
SC	10,5
SDV	21,1
SI	29,1
SL	69,0
STCS	14,0
SUPAIR	15,0
SVEDEX	21,5
TKV	21,7
UKV	19,4

VKT	29,1	WLMS	20,7
VVB	45,0	WPD	13,8
WDD	18,7	WRM	21,5
WDJ	26,0	WRS	21,0
WG	24,6	WRS-OD	15,0
WGD	26,4	WS	22,8
WGDDAK	23,6	WSDSD	21,4
WG-HEERING	29,3	WSLU	19,0
		WSRS	19,7
WGK	30,0	WTF	17,2
WID	18,7	WVK2	15,3
WID-FR	20,7	YG	22,8
WISL	18,0	YGHF	25,7
WKA	16,0	YGK	10,0
WKA-Y	38,5	YGT	11,0
WKV	14,1	**Mean total**	**23,2**

APPENDIX 11: MEAN, MEDIAN, MODE AND STANDARD DEVIATION MANUFACTURING LEAD TIME PER PRODUCT

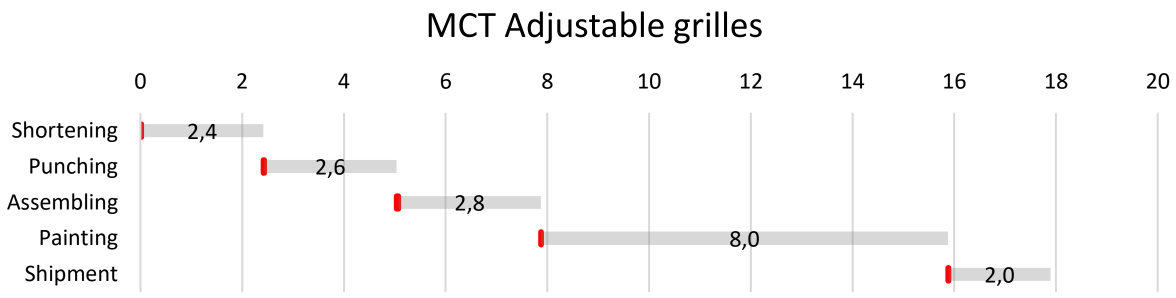
	Lead time			
Product	Mean	Median	Mode	Standard Deviation
1H	11	11	15	5
1RV	13	15	15	3
1V	8	6	5	4
2H	11	14	14	5
2RRTC	13	10	10	4
2RTC	12	14	15	4
2RV	11	12	15	4
2V	14	14	14	1
3H	11	10	8	5
ABM300	15	16	16	1
ABRS4	14	12	10	5
AC	2	2	2	1
ACG	7	7	7	1
ACGP	8	8	7[a]	1
ACV	7	7	7	.
AF	8	8	9	1
AFDEK	1	1	1	0
AKA	4	4	4	0
AKB	7	6	3[a]	4
AKC	7	7	6[a]	1
AL	12	13	15	5
AL2	12	14	14	3
ALC	7	8	8	3
ALC-Y	6	6	4	2
ALPC	9	9	5[a]	3
ALZ	9	8	8	4
ASR	8	8	8	0
AV	2	2	1	2
BERKVENS	10	10	2[a]	5
CR	1	1	1	1
CS	7	3	2	6
CSVZ	7	5	3[a]	5
CU	1	1	1	1
DF	3	3	2[a]	1
DSR	11	12	15	4
DT-2M	11	11	11	0
DT-2MG	8	8	7[a]	2

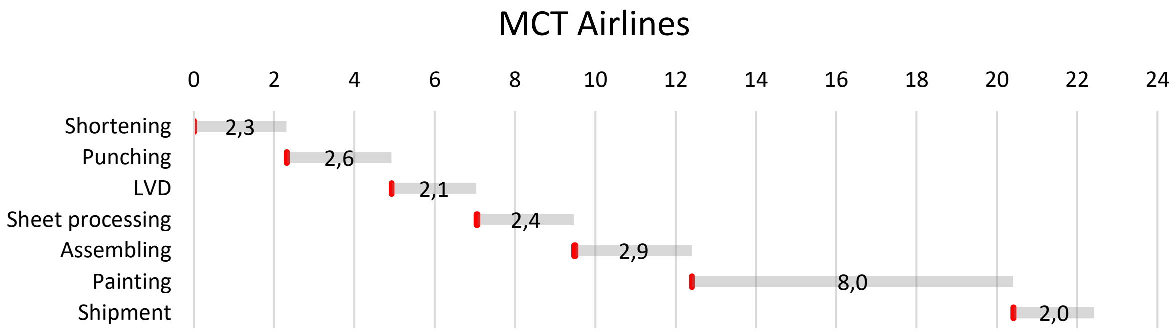
DV	10	9	8	4
FDC	4	5	6	2
GC5	11	12	12	4
GKR	4	4	4	1
GR	7	8	8	2
ISOPLENUM	6	6	5[a]	1
KV	3	3	2[a]	1
LBK	5	5	3	2
LBKKAP	4	4	2	2
LVV	11	14	14[a]	6
MKV	3	3	3	0
MWPD	13	13	13	0
MWVPD	5	5	2	3
NF-15	13	14	14	3
O	5	6	7	2
O-ALWA	17	17	10[a]	5
OBD	9	8	7[a]	3
OBD2	11	11	10	3
OBSSD	7	7	7	2
OCK	7	7	7	2
OLP	6	4	4	2
PANEEL	13	13	13	.
PER	14	14	14[a]	2
PER-G	15	15	15	.
PEROA	14	15	14[a]	3
PKIC	3	3	3	.
PKIR	3	3	3	0
PKIS	3	3	3	0
RRTC	9	9	4[a]	7
RTC	13	14	15	4
RTC-STUC	14	14	14	1
RTC-Y	11	12	12	3
RTCC	7	8	8[a]	2
RTCC-Y	13	15	15	4
RWA	10	11	11	3
RWH	16	16	16	.
RWI	2	2	2	1
RWK	6	4	3[a]	5
RWV	9	11	11	4
S	10	9	7	6
SAPZ	4	4	5	2
SC	1	1	1	0
SDV	7	7	7	3

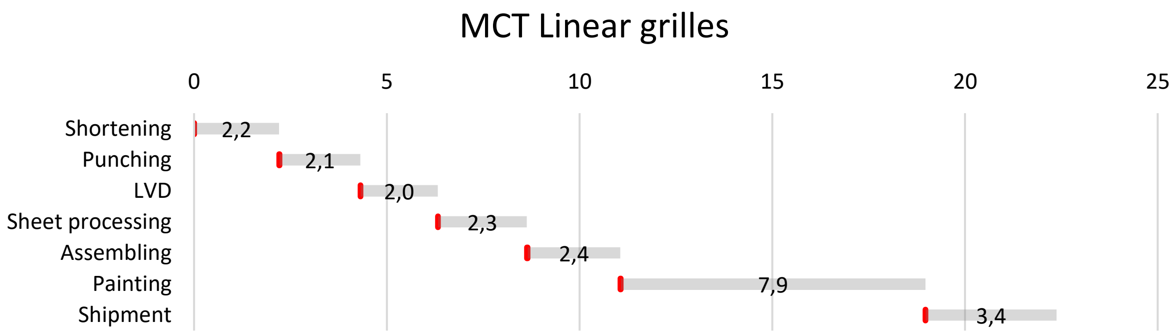
SI	4	3	2	2
SL	14	14	14	.
STCS	11	11	11	0
SUPAIR	5	5	5	0
SVEDEX	15	15	14[a]	2
TKV	3	3	2	2
UKV	5	3	3	2
VKT	12	12	13	2
VVB	1	1	1	0
WDD	7	8	8	2
WDJ	3	3	1[a]	2
WG	11	9	6	6
WG-HEERING	7	8	8	2
WGD	19	21	21	8
WGDDAK	7	8	8	3
WGK	18	18	18	.
WID	2	2	2	1
WID-FR	4	3	2	3
WISL	14	14	14	3
WKA	9	9	9	.
WKA-Y	5	5	5	0
WKV	4	3	3	2
WLMS	11	10	10	2
WPD	6	3	3	5
WRM	4	3	3	2
WRS	10	10	10	3
WRS-OD	14	14	14	.
WS	7	7	8	4
WSDSD	3	3	3	1
WSLU	3	3	3	.
WSRS	2	3	3	1
WTF	3	2	1	2
WVK2	1	1	1	0
YG	11	11	8	4
YGHF	17	17	16[a]	2
YGK	9	9	9	.
YGT	9	9	9	.

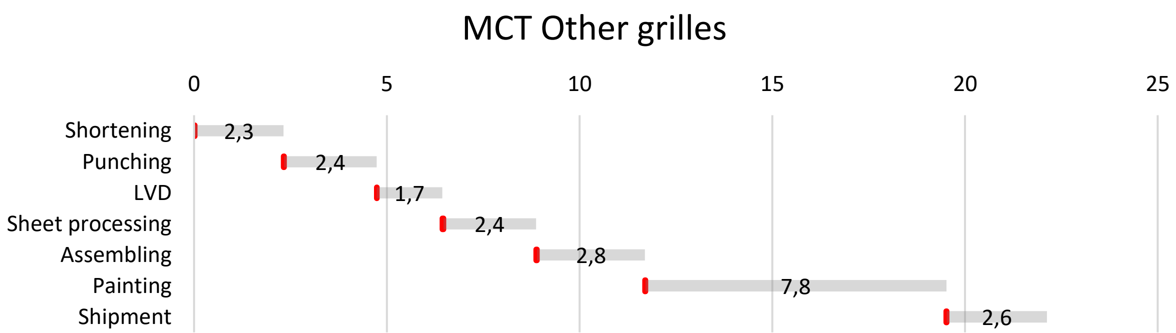
a Multiple modes exist, the lowest has been selected.

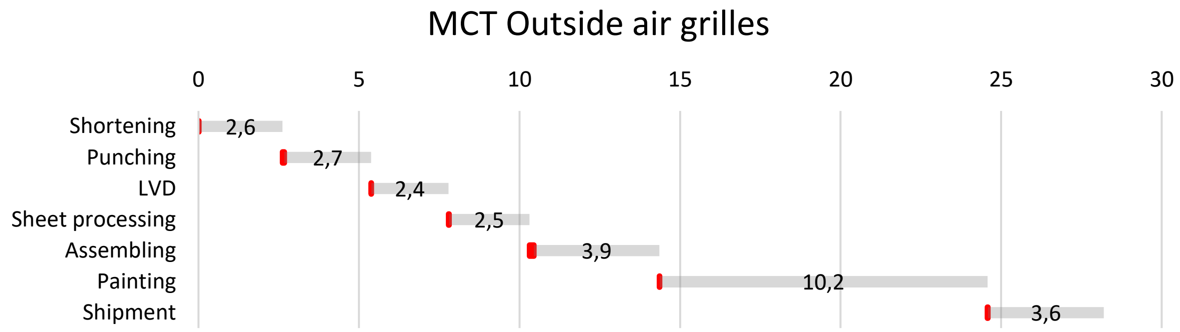
APPENDIX 12: MANUFACTURING CRITICAL PATH PER PRODUCT FAMILY

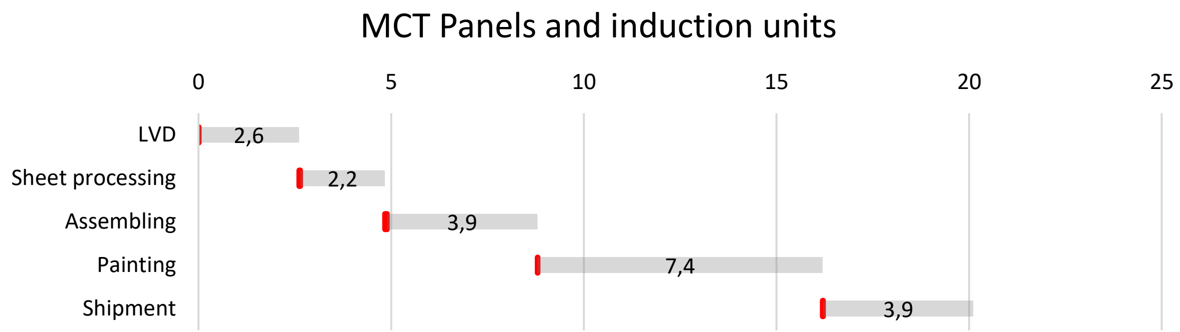


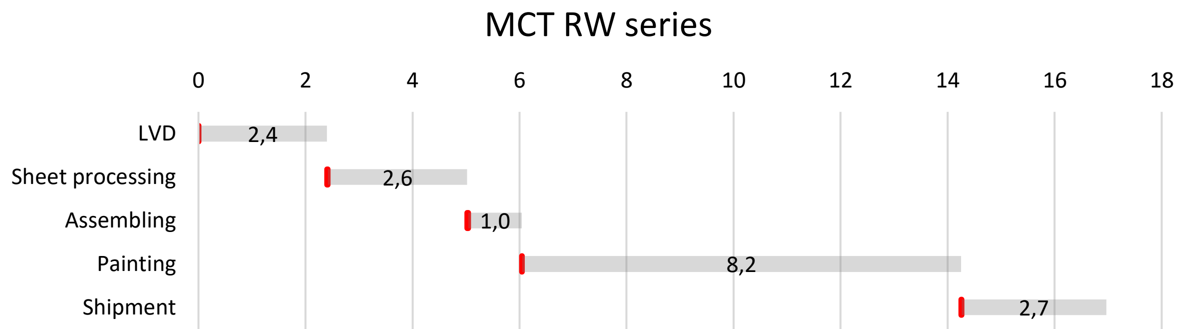


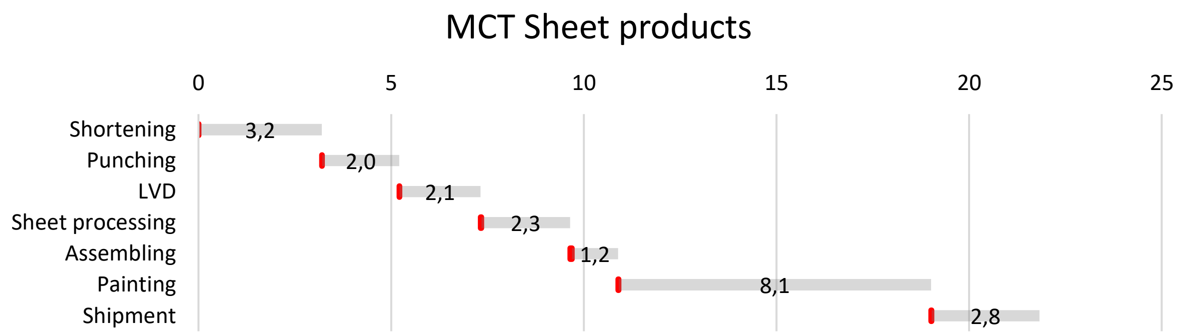




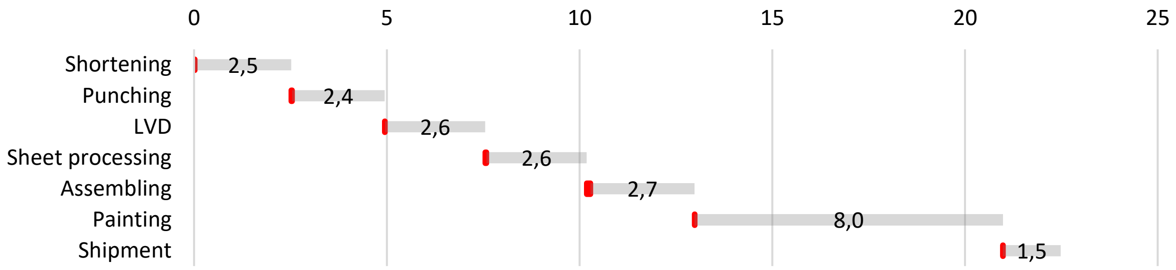

MCT Outside air grilles
0
5
10
15
20
25
30
Shortening
Punching
LVD
Sheet processing
Assembling
Painting
Shipment
2,6
2,7
2,4
2,5
3,9
10,2
3,6


MCT Panels and induction units
0
5
10
15
20
25
LVD
Sheet processing
Assembling
Painting
Shipment
2,6
2,2
3,9
7,4
3,9

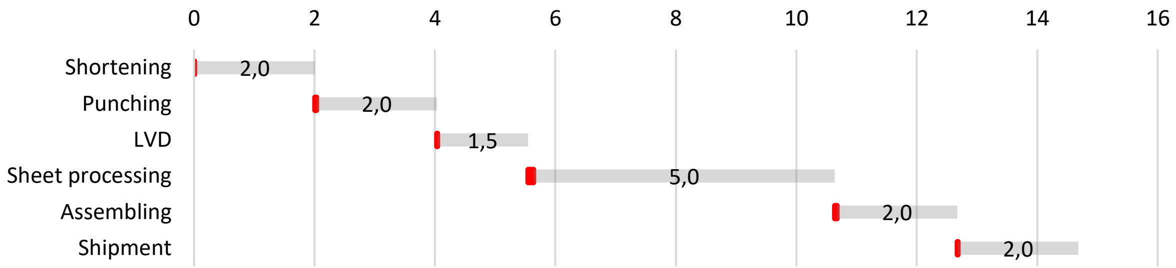

MCT RW series
0
2
4
6
8
10
12
14
16
18
LVD
Sheet processing
Assembling
Painting
Shipment
2,4
2,6
1,0
8,2
2,7


MCT Sheet products
0
5
10
15
20
25
Shortening
Punching
LVD
Sheet processing
Assembling
Painting
Shipment
3,2
2,0
2,1
2,3
1,2
8,1
2,8

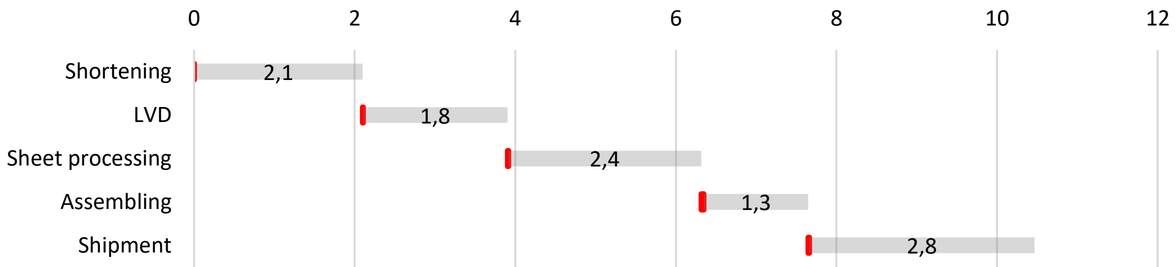
MCT Specials



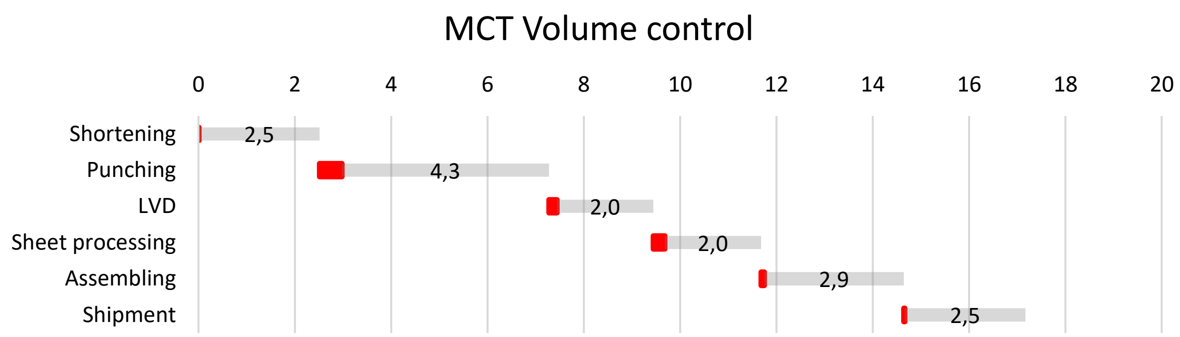
MCT Steel linear grilles

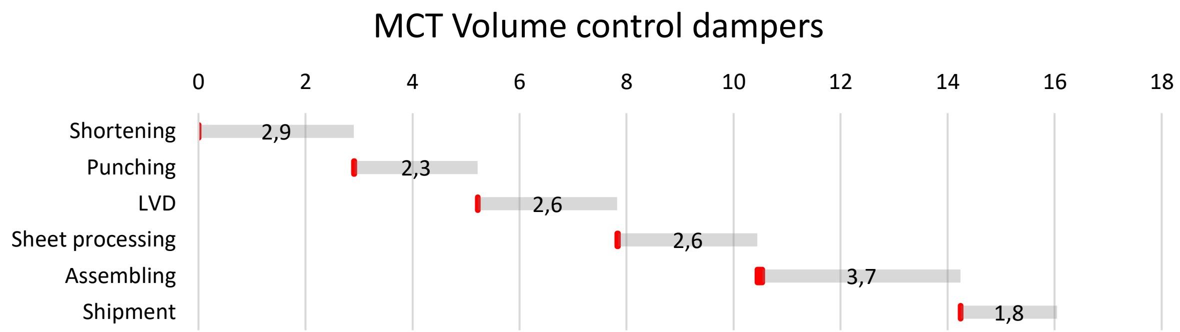


MCT Swirl diffusers



MCT Trade


MCT Volume control
0
2
4
6
8
10
12
14
16
18
20
Shortening
Punching
LVD
Sheet processing
Assembling
Shipment
2,5
4,3
2,0
2,0
2,9
2,5


MCT Volume control dampers
0
2
4
6
8
10
12
14
16
18
Shortening
Punching
LVD
Sheet processing
Assembling
Shipment
2,9
2,3
2,6
2,6
3,7
1,8