Redesigning a food assembly process at KLM Catering Services

On the short term and long term

Master thesis

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Management summary

Problem context

At the Intercontinental Airline (ICA Flow) department of KLM Catering Services (KCS), located at Schiphol Airport, all inflight catering is prepared for all intercontinental KLM-flights. At the ICA Flow, we study a work cell named VLAS (Vluchtgebonden Assemblage). At this work cell, employees stow main dishes, hot snacks and rolls (bread) into oven inserts and other carriers for every flight, depending on the number of passengers, the destination and the type of aircraft.

KCS presumes that there is potential for improvement in the VLAS-process, but does not exactly know where and how. Therefore, KCS wants to investigate the bottlenecks at VLAS, and explore the improvement potential. The goal of this research is to redesign the VLAS-process and realize an improvement in:

- productivity of employees
- number of on-time deliveries
- producing first time right
- ergonomics
- quality of output (temperatures of meals)

This paper reflects the findings from the research conducted at the VLAS-process. Following from the goals for this research, the following central research question was posed:

How can the VLAS-process for ICA Food at KLM Catering Services be redesigned, so that an improvement of on-time deliveries, first time right, productivity, ergonomics and quality can be realized?

Methods

The first step towards a new VLAS-process design, is to analyze the current situation. For that, the current work methods at VLAS have been studied and identified. Following, we assessed the current performance of the VLAS-process in general, and its individual work cells. Because the KPIs of KCS did not sufficiently cover the process performance, we introduced three new KPIs: meal productivity, throughput time and waste percentage. Using the performance indicators, we identified the bottlenecks and problems at VLAS.

Results

Bottlenecks and problems

Employees make use of high batch sizes, e.g. they put 20 trolleys on a lifting table and then stow these with meals one by one. This **use of batching** leads to:

- **a (high) throughput time** of approximately one hour. Employees put their batch of trolleys on a lifting table and start stowing products. After one hour, all trolleys are completed and put through to the finished products inventory.
- **mistakes**: employees pick one type of meal and visit all trolleys that should contain that meal. Employees can forget to stow trolleys or pick the wrong type of meal.

- **deliveries done too late:** through batching, the trolleys are either all too late, or all on-time.

The high throughput time is, next to the use of batching, also caused by:

- the **manual transportation of trolleys and meals**. Employees spend over a quarter of their time (15 minutes per cycle), transporting trolleys to VLAS and from VLAS to the gate. This activity is necessary, but non-value adding.
- The work pace of the two employees at a lifting table is **not synchronized**: if one employee finishes his batch before the other one does so, waiting time occurs.

Following up, the **high throughput time** as described leads to:

- A **high WIP:** this results in less overview in production progress and an increased risk of damaging equipment.
- **quality issues**: as meals are outside the cooling for about an hour (throughput time), product temperatures might rise above the maximum allowed temperature of 7 degrees Celsius.

The **ergonomic** working conditions at the work cells can be considered as tough:

- At silverware, a high health risk was found, since all containers are **built on the floor**.
- At M-class MND & HSN and C-class MND, employees are **lifting heavy totes** too often.
- At C-class juice & HSN, the drawers with champagne bottles require a lot of **heavy lifting**.

Finally, the probability of an employee making a mistake increases through the **similarity of the meal codes**. Employees can misread or misinterpret a meal code and stow the wrong (amount of) meals.

Solutions

To solve the bottlenecks and problems that are found in the analysis above, we conducted a brainwriting session with the stakeholders to generate ideas. The ideas from this session are mostly the quick wins that can be implemented soon and quite easily, or ideas that are adopted in the general layout design.

Quick wins

- For the silverware work cell, we designed a new layout to improve the very poor ergonomic circumstances. For this, a flow rack and roller conveyors are introduced, to enable the employees to work on a better working height. Furthermore, instead of that employees pick up the containers at the C-class trolley washing machine, containers are put through the silverware washing machine. This is done to make sure the employees can produce continuously and travel times are minimized.
- To prevent the manual lifting of totes with meals, a mobile lifting aid has been designed.
- At the C-class juice & HSN work cell, to prevent employees from lifting the heavy drawers with champagne bottles, a different method of supplying of the drawers is designed.
- To reduce the mistakes made by employees (e.g., by putting the wrong type of meal in the trolley), the content of a trolley can be visualized on a monitor. This visualization

should simply state the type and amount of meal, including a picture of the meal, to stimulate the employee's awareness.

- To reduce the waiting time that occurs at the C-class juice & HSN lifting table, a more even distribution of trolleys that are produced per employee is set-up, to create a better synchronization of the throughput times per employee.

Layout designs

In the literature review, we specified four layout types that are used in production processes. Each layout type has its own volume/variety characteristics. We determined that the VLAS-process has a low variety and high volume in terms of products. The layout types that go with these characteristics are a cell and a product layout. Therefore, using these two layout types, we created general layout designs for VLAS, while trying to incorporate solutions from the brainwriting for the posed bottlenecks.

We designed 8 different layout alternatives, varying between the layout type and production process. Next to this, the method of supply varies between supplying meals specifically per flight, or supplying the meals in bulk for one block. After a session with all stakeholders, we plotted the 8 layout alternatives in an Impact/Ease matrix, to categorize alternatives in terms of impact on the operation and ease of implementation. Three layouts were excluded, as they were categorized with a low impact and high difficulty of implementation. The five remaining layouts were then judged and ranked using the Analytical Hierarchy Process with all stakeholders. The alternatives were compared on ergonomics, quality, productivity, feasibility, costs and throughput time criteria.

After comparing the five alternatives, the assembly line was ranked first, with the (split-up) lifting tables second and third. These three alternatives are selected for further research, testing and implementation and are shortly described below. The alternative including Automated Guided Vehicles for transportation initially got a very high score, but was deemed infeasible by the stakeholders. Therefore, we omitted it from the ranking.

Layout 1: flight specific production

This layout does not require a physical modification in the process, so the four lifting tables are kept. However, in this layout alternative, production will be flight specific. This means that one employee produces one flight at a time, resulting in smaller batches and therefore a shorter throughput time and a productivity gain of one hour per day. Also, through the shorter throughput time the quality of the meals will improve, since they are outside the cooling area for a shorter period.

Layout 2: split-up lifting tables

A drawback of Layout 1 is that employees can still fall back on producing in high batches, as well as that when two employees are at one lifting table, they cause waiting time. To prevent this, we designed a layout in which the lifting tables are split-up or reduced in size. Through that, employees have to use the flight specific production. The work methods used here are identical to the ones at Layout 1.

Layout 5: assembly line
To automate the transportation of trolleys in the VLAS-process and at the same time strive to a single-piece flow, we designed a layout with an assembly line. Here, a main transportation conveyor belt will be used for the transport of trolleys. Small split-off belts then transport the trolleys to the individual work stations. This layout would result in a productivity gain of 14 hours, assuming that the supply of trolleys and meals is done automatically. Furthermore, it reduces the throughput time and improves the quality of the meals significantly.

Recommendations

In this research, we analyzed the current VLAS-process and designed and selected concepts for improvement. This leads to the following recommendations for KCS:

On the **short** term:

- Start implementing the quick wins as mentioned, to gain momentum for the other (bigger) projects.
- Start a pilot with flight specific production per work cell, according to the design of Layout 1.

On the **long** term:

- Split-up the lifting tables after Layout 1 has been implemented successfully, to further improve this process.
- Build a simulation model of the assembly line (Layout 5) to test several scenarios.
- If KCS moves to a different location, we recommend further research into adopting AGVs.

Preface

This master thesis is the final step in obtaining my degree in Industrial Engineering & Management at the University of Twente. I consider myself lucky to have gotten the opportunity to conduct my graduation assignment at KLM Catering Services at Schiphol, starting in April 2017.

I could never have performed this assignment without the help of my colleagues. There are countless people that have contributed and helped me with the analysis and the design of the layout alternatives. Therefore, I would like to take this opportunity to thank everyone at KCS that has been involved in the realization of this research. I am still learning a lot every day at KCS, which is accompanied by an incredible amount of fun.

In particular, I would like to thank Heidi Haveman for welcoming me in the incredible ICA Flow team and providing me with a lot of help, guidance and support. Even though your schedule is incredibly packed, you always managed to reserve time for my questions and struggles, which I value a lot. I also want to thank Lucas Kloek for helping me to push my thesis to a much higher level (and pointing out that the term 'airplane' is a no go). Finally, a word of thanks to Duncan Burger. Before (temporarily) leaving KCS, your advice and guidance brought my research further step by step.

Furthermore, I want to thank my supervisor Peter Schuur, first of all for helping me finding this challenging research assignment, but also for his personal involvement during my research assignment and for providing me with feedback and advice for further improving my research. Also, I want to thank Wieteke de Kogel for her constructive feedback. Her opinion, from a different (mechanical engineering) viewpoint, helped me in taking the last step for this master thesis.

I am very excited by having received the opportunity to implement the solutions that we designed in this research at KCS, after my graduation internship-period ended. I am proud to present the results of my graduation assignment and hope you will enjoy reading it.

Tom Snijders

Amsterdam, 2017

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List of abbreviations

Abbreviation	Meaning	First mentioned on page
AHP	Analytical Hierarchy Process	49
C-class	Business class	1
CC & ED	Customer complaints & Extra delivery runs	27
CTR	Container carrier	10
Flight specific supply	When supply is delivered in the exact number of products required by a flight	12
FGI	Finished Goods Inventory	2
GOC	Goederen Ontvangst Controle (Goods Receival Control)	3
HSN	Hot snack	10
ICA	Intercontinental Airline	1
KCS	KLM Catering Services	1
M-class	Economy class	1
MND	Main dish	10
NNVA	Necessary but Non-Value Adding	29
OIS	Oven Insert (oven rack)	13
PAM	Process Activity Mapping	42
ROA	Retour Ontvangst en Afwas (Returns Receival and Washing)	7
SQC/STC	Squared/Standard Container	17
T12-trolley	Half-sized trolley	8
UTR	Full-size trolley	8
UNVA	Unnecessary Non-Value Adding	29
VA	Value Adding	30
VLAS	Vluchtgebonden Assemblage (Flight specific Assembly)	2

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1. Introduction

In the framework of obtaining the Master of Science degree in Industrial Engineering & Management, we performed a graduation research project at KLM Catering Services into the VLAS-process. In this chapter, an introduction to this assignment will be given. Firstly, we describe the background of KLM Catering Services in section 1.1, before going into more detail about the context of the problem in 1.2. Then, the goal and scope of the research and the research questions will be explained in sections 1.3, 1.4 and 1.5. Finally, the deliverables are mentioned in 1.6.

1.1 Background

KLM Catering Services (KCS) has more than 80 years of inflight catering experience, but was officially founded as a 100% subsidiary company of KLM in 1982. Before that, the Dutch Civil Service for Aircraft Catering Provisioning provided meals to the planes. This, according to the KLM website (KLM Catering, 2015), was an umbrella term for various departments that jointly assembled the final product: a meal, sometimes adjusted for personal wishes, with dishes that suited the time of day, served on a clean tray. Of course, those were completely different times. In the very far past, there were cooks on board that provided the passengers with their meals, and even before that, passengers were required to eat in the airport restaurant. But in 1965, cooks on the ground created thousands of meals a day, not just for KLM, but also for other airlines: up to 10,000 trays were laid out each day.

Nowadays, with over 1300 employees, KCS is the biggest inflight caterer in the Netherlands and number 5 in Europe. Every day, KCS provides 55,000 meals, thousands of liters of drinks, as well as newspapers and magazines, to over 350 flights that depart from Schiphol Airport, Amsterdam. The production and assembly of all its deliverables is done between 6 AM and 11 PM, in an early and in a late shift. KCS is a 100% subsidiary company of KLM, so obviously, deliveries are done for KLM flights, but also to a few foreign airlines that depart from Schiphol, such as China Southern and Martinair.

At the Intercontinental (Inflight) Catering (ICA) Flow department the catering is prepared for all KLM-flights bound for countries outside of Europe. Slightly over 50 flights each day depart for an intercontinental destination. These flights have a much longer duration than flights within Europe. Therefore, the amount and type of meals provided on the flights differ a lot. For the ICA flights, a hot snack and a main dish is provided, whereas for European flights, only a small meal can be consumed. For these meals, there is a distinction for the type of passenger. As with every airline, there are economy (M-class) and business class (C-class) passengers. Within KCS, the flow of these two classes is separated if possible.

During the flight itself, passengers receive their meals in two stages. Depending on whether the flight departs in the evening or in the morning, the first served dish is determined. For example, passengers in an evening flight get their main dish (with a bottle of water, a salad and a dessert) first, and at the end of the flight (in the morning), they get their breakfast dish. For a morning flight, this is the other way around.

1.2 Problem context

Several work cells produce the complete catering package, divided into two departments each for the ICA (and Europa) Flow: Food and Non-Food & Beverages (NF&B). In this report, we will research a work cell at the ICA Food department named VLAS (Vluchtgebonden Assemblage). At the VLAS-work cell, employees put main dishes, hot snacks and rolls into oven racks and other types of carriers for every individual flight, depending on the number of passengers, the destination and the type of aircraft. There is a high diversity in the type of meals, resulting in differing throughput times and stock levels.

As human resources are used at the VLAS-process, mistakes are made easily. For example, it occurs that there are less main dishes put into the oven racks (see Appendix III for a more detailed explanation about the carriers) than that is specified, which results in a shortage of meals in the aircraft. Especially when the number of passengers in flights is rising, the workload and pressure within the production becomes high and mistakes occur more often. When these mistakes are noticed too late, an extra delivery run has to be made to the aircraft, which is expensive and wasteful. As KCS has been applying lean manufacturing widely in its processes, the elimination of waste is very important.

Next to these errors, KCS wishes to put the meals into trolleys as short as possible before the aircraft's departure, in order to make sure to put a very fresh product on board of the aircraft and to minimize the finished goods inventory (FGI). A lower FGI leads to lower costs, more storage capacity and less risk of loss of items. KCS uses several KPIs to measure its performance: these are criteria based on the quality of the products, number of on-time deliveries, number of extra delivery runs made due to mistakes, and human resources.

KCS presumes that there is potential for improvement in the VLAS-process, but does not exactly know where and how. Therefore, KCS wants to investigate the bottlenecks at VLAS, and explore the improvement potential. This initial step should be done to redesign and optimize the VLAS-process and realize an improvement in the number of on-time deliveries, productivity of employees, ergonomics and the quality of output. In this report, the VLAS-process will be investigated and opportunities for improvement will be determined. Then, we will design solutions for the found problems and/or bottlenecks, and finally, the best solutions will be selected and recommended for implementation.

1.3 Research goal

The goal of this research is to come up with a proposal for the improvement of the VLAS-process related to criteria regarding

- Productivity
- Extra delivery runs
- On-time deliveries
- Ergonomics
- Quality

In cooperation with KCS, we defined Key Performance Indicators, for example, regarding productivity of employees and the on-time deliveries to aircrafts. Therefore, the new work cell design should improve these KPIs. Hereby it should be noted that the quality of the products should be kept at a constant level as well.

This research will provide the new general design of the process, including some small, easy to implement wins to improve the work cells ("low hanging fruit"). Also, new work instructions for the workers will be provided, as well as an implementation plan. Vital to a successful implementation will be the creation of support of employees for the to be proposed alternative, as employees are the ones that are going to be working with it.

1.4 Research scope

In Figure 1-1, a general and simplified overview of the operations prior to and after the VLAS-process is shown. The meals and other products are firstly delivered to KCS from the warehouse. Simultaneously, trolleys and ovens are received from the landed aircrafts and washed within KCS. After that, both the meals and the trolleys and ovens are transported to VLAS, where the meals are stowed into the trolleys. After the assembly, the completed trolleys are sent to the distribution department, which makes sure that the trolleys are transported to the aircraft.

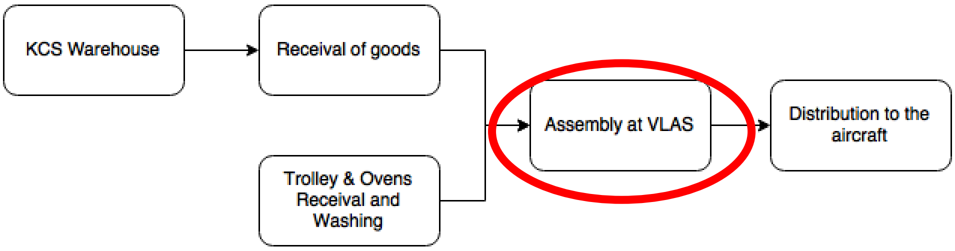

Figure 1-1 - Overall process

The process at the KCS Warehouse, receival of goods, washing of trolleys and the distribution to the aircraft are outside of the scope. Of course, these processes are of influence to the VLAS-process, as the correct type and number of products have to be delivered by the warehouse, and put through by GOC (Goods Receival Control). Also, the trolleys and ovens have to be delivered to the VLAS-process in time, as to not slow down the process. Including these processes would expand the research project significantly and would therefore mean that finishing the project within the specified time would be near to impossible. Therefore, we decided to focus this research solely on the VLAS-process.

1.5 Research questions

The described research goals and problem context led to the following central research question:

How can the VLAS-process for ICA Food at KLM Catering Services be redesigned, so that an improvement of on-time deliveries, first time right, productivity, ergonomics and quality can be realized?

In the literature, we found that the concept-generation approach fits best to this research. Therefore, following this approach, sub questions were posed to form a good answer to the central research question.

1. What is the current situation at the VLAS-process?
    a. What does the (material) flow at ICA Food look like?
    b. What are the current work methods?
    c. What is the current performance of the VLAS-process?
    d. Where lie the bottlenecks and problems in the process?

To answer Question 1, we will submerge into the ICA food facility, to map the entire (material) flow at the VLAS-process and figure out the work methods at each individual work cell. By creating flow charts and by interviewing production workers and their supervisors, the current situation will be mapped. Also, to experience working at the VLAS-process and to create a connection between us and the employees, we will be working in the process some shifts as well. The work process will be described in Chapter 2.

After that, to determine the current performance, the relevant KPIs will be selected, after consulting with the ICA Food managers. Then, with help of the data department, the KPIs can be calculated. Finally, the problems will be examined and bottlenecks of the process will be described, using information of the three aforementioned topics. In Chapter 3, we will explain this.

2. Which methods are suggested in literature for designing a new VLAS-process?

In Chapter 4, a literature study is described which is used to find the best method for designing the VLAS-process. Firstly, we will look for a framework for the redesign of a production progress, to base our methodology on. The next step is to analyze the current situation, using different Lean strategies, as KCS has implemented Lean manufacturing. Furthermore, for the general layout design of the work cells, we will look for literature with the idea to find a type of production process that fits the characteristics of VLAS best. Finally, we look for a method to asses and select the best alternative.

3. What are feasible alternatives for improving the work cell design of the VLAS-process?
    a. What are future requirements for the solution?

After the literature study and the analysis of the current situation at the VLAS-process, feasible alternatives for a new process design will be generated in Chapter 5. For this, firstly the future requirements for the solution will be set. Then, work cell designs will be made, using the information found in the first two sub questions, as well as with input from the different stakeholders in the process.

4. What are the advantages and disadvantages of each proposed alternative and which alternative should be selected?

The next logical step is to judge the generated alternatives using several criteria. This will be done in Chapter 6. We will use soft criteria (such as quality) and hard criteria (such as productivity) to evaluate the alternatives. Using these criteria, all alternatives will be categorized. A multi-criteria decision analysis will be done to rank the alternatives, and the best alternative will be selected.

5. How can the chosen alternative be implemented in the VLAS work cell?

The final step in this research will be the implementation of the selected best alternative. The basics of an implementation plan will be described in Chapter 7.

Figure 1-2 shows the structure of this report, as previously described. After introducing KCS and the subject of this thesis, the current situation will be assessed and the performance of each work cell will be measured. Supporting this, a literature study will be done. Using the outcomes of these two sub questions, solutions for the problems and bottlenecks will be generated and applied into work cell designs. After that, the performance of these designs will be analyzed. For the final solution, an implementation method will be described. Finally, conclusions are drawn and recommendations are made.

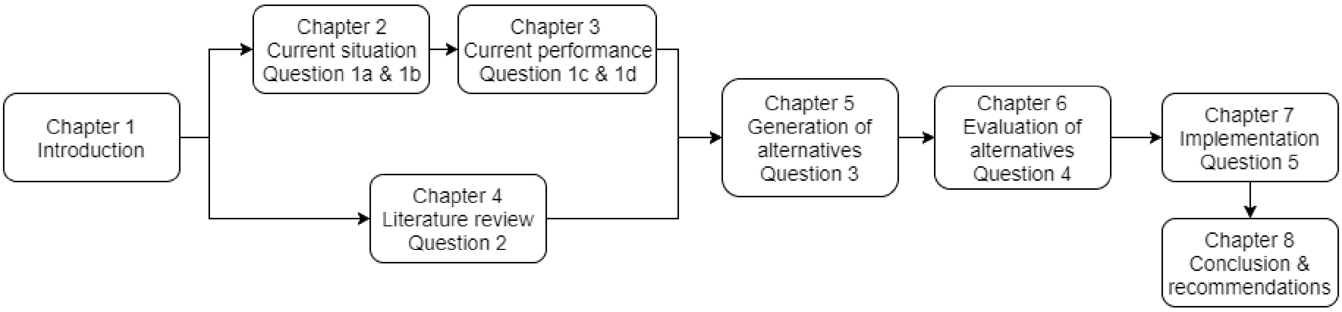

Figure 1-2 - Report structure

1.6 Research deliverables

- Process and data analysis that provide insight into the operations of VLAS.
- Quick improvement wins.
- Multiple scenarios with solutions.
- An implementation plan that describes the general steps to make the design operational.

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2. Current situation

In this chapter, the current situation will be described. Before going into detail about the VLAS-process, we first zoom out of this process and describe the preceding process at ICA Food. The overall process at KCS is explained in section 2.1. Following in 2.2, we elaborate on the work methods per work cell.

2.1 Overall process

At ICA Food, production starts at 6 AM and ends 11 PM, in a morning and a late shift. The total working time is divided in 12 production blocks, so 6 blocks per shift. Each block has a length of 85 minutes. For each block, a certain number and type of flights is planned for produced. These blocks are implemented to monitor the production progress for the day, to check whether production is on schedule. At different departments within KCS, the blocks are used to make the planning and purchasing processes easier. Employees first produce the flights that are planned in Block 1, continuing with Block 2, et cetera. The morning shift produces for the flights departing in the afternoon and evening, whereas the late shift does so for the flights that depart the morning after. Because of this, the pressure on the morning shift is higher, as they must finish the production for their flights (departing on the same day) on time, to not cause delay of a flight. In the late shift, there is less pressure, as their flights will depart the morning after anyway.

The process within ICA Food is divided in three main areas:

1. In the ROA (Returns Receival and Washing) area, the trolleys, filled with the remainder of the meals from the flight, and ovens are received, emptied and washed.
2. In the assembly area, the trolleys are set-up with ovens and trays, and are filled with food. The VLAS-process is located in this area.
3. In the distribution area, the trolleys are stored and sorted for transportation to the aircraft. This main process is visualized in Figure 2-1 below.

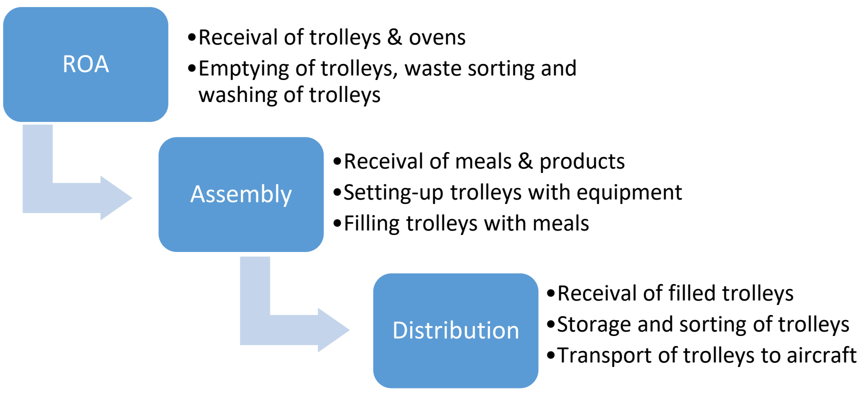

Figure 2-1 - Overall ICA Food process

To visualize the flow of the different types of meals and the several types of carriers (containers, ovens, trolleys), we constructed a Material Flow Map. This map shows the material flow to and from each work cell and gives an overview of where each cell is located. The map can be found in Appendix I.

ROA

After the arrival of an intercontinental flight at Schiphol, all trolleys are loaded off of the aircraft to the KCS trucks. These trucks are then driven to the ROA of the KCS facility and park at one of the slide doors (Location 1 in Appendix I). There, the trolleys are loaded off the trucks.

Figure 2-2 - T12 trolley

Figure 2-3 - Oven insert (OIS)

Figure 2-5 – MUTR-trolley

Figure 2-4 - Transport trolley

Several types of trolleys are used to transport the meals from the KCS facility into the aircraft. There is a distinction between types of trolleys:

- T12-trolley: half size trolley (Figure 2-2). Can contain two oven inserts (Figure 2-3)
- MUTR-trolley or UTR-trolley: normal size trolleys (Figure 2-5). Can contain 4 oven inserts. These two types of trolleys are the same size, but the MUTR-trolley is used in C-class, the UTR-trolley in M-class.
- Transport trolley (Figure 2-4). Can contain 4 oven inserts. This trolley transports the oven inserts within KCS and to the aircraft. At the aircraft, the oven inserts are taken out of the trolley and loaded into the aircraft, but the transport trolleys themselves, go back to KCS. In the flow of the process however, this distinction can be ignored.

All different types of trolleys, containers and oven inserts are shown in Appendix III.

As mentioned before, within KCS there is a distinction between the quality and type of meals served to passengers. Likewise to the different types of passengers in the aircraft, there is a distinction between C- and M-class products:

- C-class meals are served to the business class passengers, on a China plate (therefore the letter C).
- M-class meals are served to the economy class passengers. This is done using a small plastic/carton box of the material melamine (the letter M).

Because of the distinction in M- and C-class, there are different locations for the assembly of C- and M-class meals.

This distinction is also made at ROA. There, after receiving the waste-loaded trolleys, the employees sort the C- and M-class trolleys and push them to their specified locations (2a and 2b in Appendix I respectively). The waste is removed from the trolleys and is thrown away.

The oven inserts that come back from the aircraft are also emptied at location 2a. The empty trolleys are then put into their respective empty trolley storage area (3a and 3b). These trolleys are then batch-wisely put into the trolley washing machines at 4a and 4b.

Assembly (pre-VLAS)

When coming out of the washing-machine, the trolleys enter the Assembly part of the facility. Then, the trolleys are set-up with equipment for the C- and M-class at locations 5a and 5c (shown in Appendix I). According to the loading diagram, that is linked to a trolley, the right amount of oven inserts, and trays are placed in the trolley. Then, a production card (Figure 2-6 and explained in Appendix III) is assigned to every trolley. On such a production card, the amount and type of meals that should be stowed in a trolley is shown.

Figure 2-6 - Production card

C-class trolleys have a high variety in loading diagrams: they can be filled with oven inserts, trays to place the meals upon, empty drawers to put types of juice or crackers into, or drawers that contain glasses for inflight beverages.

M-class trolleys have not such a variety in loading diagrams. These trolleys are, depending on whether it is a T12 or a UTR trolley, filled with, respectively, two or four oven inserts. Depending on the type of plane, a different brand of oven insert is used. Such an oven insert consists of seven or eight skids. On these skids, the main dishes and hot snack will be stowed.

The trolleys for the C-class juice work cell at VLAS are prepared at 5b: over there, after being assigned a production card, the right number of trays and empty drawers are put in the trolley. The juice trolleys are also stored at that location. The other trolleys are stored at locations 6a and 6b, after they have been set-up. At that stage, the trolleys are fully prepared for the VLAS-process. As mentioned before, VLAS is the area in which the trolleys are filled with main dishes, hot snacks, rolls and juices. Of course, these will have to be supplied to the VLAS-section, too.

There are two storage areas for food: the Goods Receival Control (GOC) and the cooling area. GOC provides the VLAS of its rolls and stores the main dishes, hot snacks and juices in the cooling area at 7b. Here, the C-class main dish, hot snack, juices and the M-class main dish and hot snack are separated by a small fence. These products are delivered in totes and stacked for one complete block, as shown in Figure 2-7.

Figure 2-7 - Totes with meals in a cooling area

To sum up, in the process before VLAS, “dirty” trolleys that arrive from the plane are emptied, washed and set-up in a buffer in the assembly area. Next to this, the meals and juices that will be stowed in trolleys at the VLAS-process, are stored in the cooling area. We will now describe the VLAS-process: there, depending on the flight destination and number of passengers, main dishes, hot snacks and juices for the C- and M-class are stowed in trolleys.

VLAS

As mentioned, for the VLAS-process two types of supply are required: the set-up trolleys and a supply of food in the cooling area. Per block, the meals are stored in the cooling area.

There is a certain variety in meals:

- Depending on the destination, the main dish and hot snack are determined: for example, on flights to India, a curry main dish is served. This leads to some variety in type of meals, as there is a large range of destinations.
- Furthermore, there are meals for people with special needs. For example, a special meal without meat can be provided for a vegetarian. These meals are provided separately from the normal meals. Lastly, for every flight, rolls are provided.

The VLAS-process consists of five work cells, with each work cell being dedicated to a certain type of final product. There are separate work cells for the following types of products:

1. C-class main dish (C-MND)
2. C-class juice & hot snack (C-JUI & HSN)
3. M-class main dish & hot snack (M-MND & HSN)
4. CTR
5. Silverware (cutlery, coffee/teapots etc.)

For the production at work cells 1 until 4, lifting tables are used. Employees put the trolleys and CTRs on such a lifting table, to be able to produce on a better working height (Figure 2-8). There is no lifting table at Silverware: here the stowing of Silverware containers is done on the floor (Figure 2-9).

Figure 2-8 - Trolleys on a lifting table

Figure 2-9 - Silverware containers built on the floor

In Figure 2-10, a simplified Material Flow map for VLAS in the ICA Food Assembly is constructed. The processes for other types of products within the assembly have been excluded from the map. The process starts at washing machines 1, 2 and 3. Here, the C- and M-class trolleys and CTRs are washed, whereas the items for silverware are washed at machine 2. The trolleys are then transported to their specified lifting table. There, the retrieved hot snacks, main dishes, rolls and juices are stowed into the trolleys. Finally, the trolleys and CTRs are pushed to the gate to distribution.

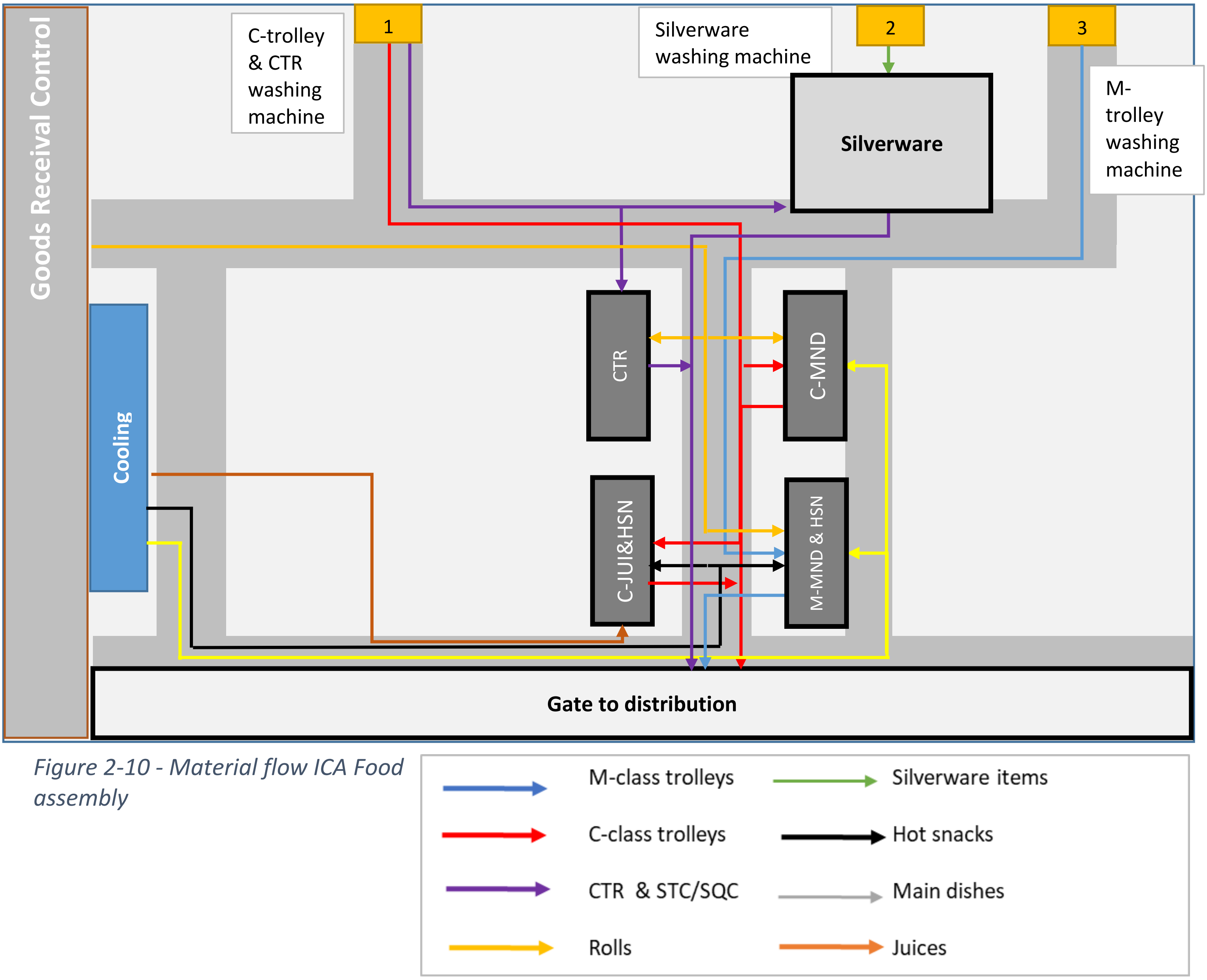

Figure 2-10 - Material flow ICA Food assembly

The five work cells as mentioned will be the analyzed in this report, using the following steps:

1. Per work cell the work method and characteristics are described.
2. The current performance for each individual cell will be measured.
3. The bottlenecks and problems will be examined.

2.2 Work methods

In this section, we describe the work methods for each work cell. In Table 2-1, specifications for each work cell are given:

- the type of equipment, in which the different types of products are stowed.
- the number of employees that are working at the work cells
- the way of supply of the products

In Appendix III, a more precise description is given about the trolley types, cooling and production cards.

The main difference between the supply of the work cells is that all the meals and juices are supplied in bulk for an entire production block, except for the main dishes for the M-class. These are supplied specifically for each flight, meaning that the exact number of meals that should be stowed in the trolley for a flight is delivered.

Table 2-1 - Work cell specifications

Work cell	Equipment	Type of products	# Employees per shift/day	Supply
1. C-class main dish	OIS T12	C B MND C MND- C ROLLS CREWOFLOW	1 per shift 2 per day	Bulk
2. C-class juice & hot snack	T12	C CHEESE C DESS C C-SNACK C H-SNACK/DESS C JUICE	2 per shift (1 juice, 1 hot snack) 4 per day	Bulk
3. M-class main dish & hot snack	OIS STC T12 UTR	M B MND M H MND M H SNACK M MND- M ROLLS	2 per shift 4 per day	Main dish: flight specific Hot snack: bulk
4. CTR	SQC STC T12	C B ROLLS/CROISS M B ROLLS M BOX M I-CREAM M ROLLS	1 per shift 2 per day	Bulk
5. Silverware	SQC STC	C SILVERWARE M SILVERWARE COFFEEPAD/JUGS C/W SOUP M COFFEE/TEAPOT MUG/COFF.TR/PLATE	2 per shift 4 per day	Bulk

2.2.1 C-class main dish

The C-class main dish is stowed in the trolleys by one VLAS-employee. Here, the skids in the oven inserts (OIS) are filled with the main dishes, as well as the rolls for the C-class. In Figure 2-11, the layout of this work cell is shown. The grey rectangle represents the lifting table, on which the trolleys (blue) are placed. The employee is in the process of stowing meals (small orange rectangles) in a C-MND trolley. Behind him, there are two stacks of different meals. The other three lifting tables (C-class juice & hot snack, M-class main dish & hot snack and CTR) use the same method of working on a lifting table, albeit that they have different trolley contents.

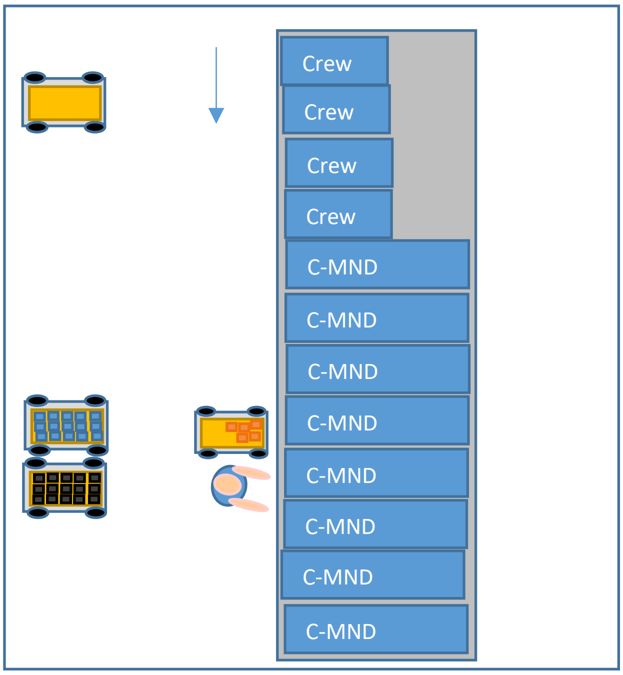

Figure 2-11 - C-class main dish work cell

At C-class main dish, the employee first retrieves the set-up C-class trolleys and puts them on a lifting table (capacity of 24 T12-trolleys), in the way that is shown in Figure 2-11. These are the trolleys that are scheduled for a block and are sorted on the lifting table per flight. To reduce the number of times the employee must transport the trolleys to the lifting table or to the gate, batch sizes varying between 8 and 13 UTRs are used.

Firstly, for the Crewoverflow trolleys, empty trays are placed in the trolleys according to the loading diagram. The loading diagram indicates how much empty trays and other small items should be placed in the trolley.

The next step is then to retrieve the totes with main dishes from the cooling area. The main dishes are delivered in bulk for two blocks and are not specifically sorted per flight. After retrieving the totes, the employee stows the main dishes in the trolleys, according to the numbers on the production card that is assigned to the trolley (pre-VLAS). According to the instructed work method, firstly one trolley with its different types and amounts of meals should be completed, before going on the next one. However, in practice, the method that is used is to pick a certain meal that is supplied and visit every trolley that should contain the meals: a way of batching. This is also shown in Figure 2-11: the employee is using one stack of meals and visits the trolleys with this.

Figure 2-12 - C-class main dish trolley

As the tote should contain the exact number of meals for an entire block, there should be no meals left after finishing with stowing the trolleys for a block. However, if meals are left over, the amount of already stowed dishes is counted. If this number is correct, the left-over dishes are sent back to the cooling area. There is also a possibility that there are not enough meals provided in the totes. If, after counting the stowed dishes again, the amount does not comply with the production card, a flow coordinator orders extra main dishes, which are stowed in the trolley later on.

When all trolleys are stowed correctly, their production card barcodes are scanned to notify that the trolleys are completed. According to the flight number, the completed trolleys are pushed to the specified gate to distribution.

Next to this process, the work space must be tidied up as well. Every employee has a different work method for this. One clears the empty totes after completing stowing the products in the trolleys, the other one does this during that process.

The entire process for the C-class main dish is captured in Figure 2-13.

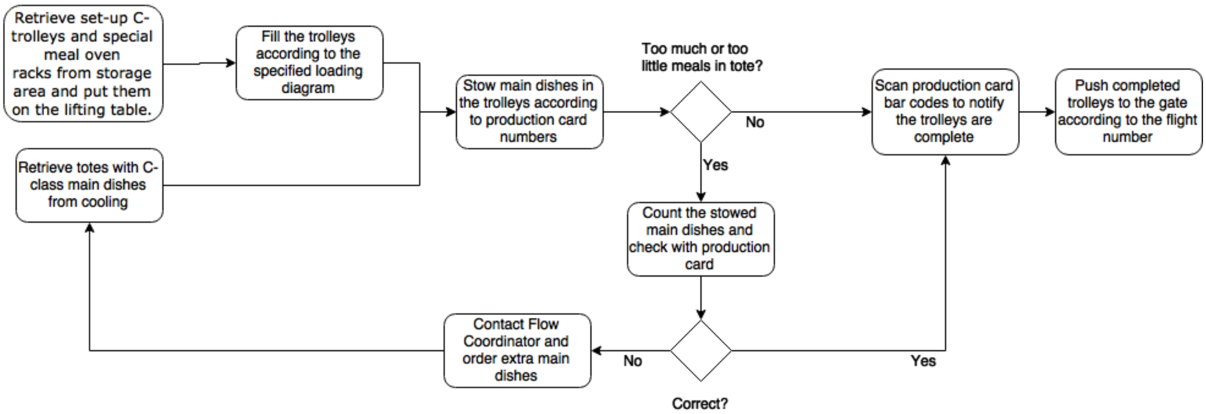

Figure 2-13 - Flow chart C-class main dish

2.2.2 C-class juice & hot snack

The juice and the hot snack for the C-class are stowed in trolleys by two employees: one fills the juice-, the other the hot snack trolleys. The juice-trolley is filled with tomato and orange juices, water bottles and champagne, but also cheeses and small bags of nuts. In the hot-snack trolley, rolls and, obviously, hot snacks are stowed. In the C-class MND work cell, rolls for the first service are stowed, whereas in the C-class hot-snack area, rolls for the second service are provided.

Again, the first step is to retrieve the prepared trolleys for the C-class juice and hot snack. The supply of meals here is pushed: the totes that are retrieved from the cooling area are provided in bulk for two production blocks.

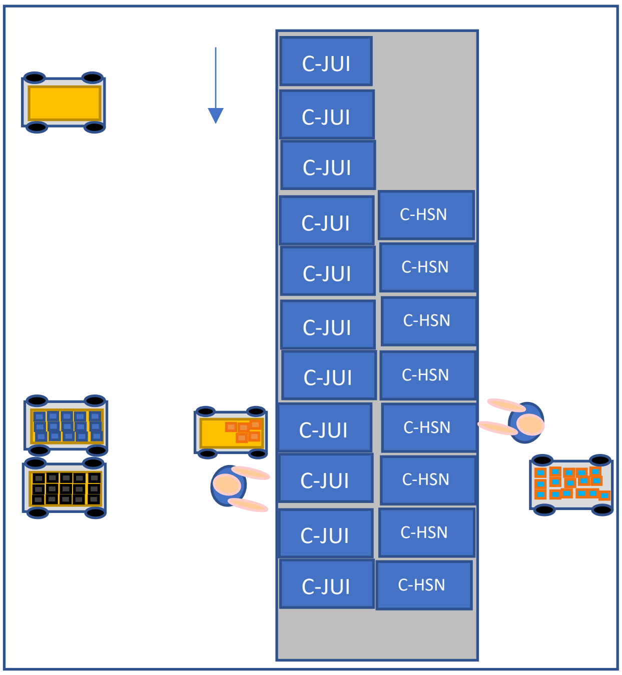

Figure 2-14 - Layout C-class juice & hot snack

The trolleys are then placed on the lifting table, but are split up based on their categories. The juice trolleys are located on the one side of the table, the hot snack trolleys on the other (Figure 2-14). In this work cell, the full capacity of the lifting table is used, so its area is fully obtained by trolleys. This batch size (12 UTRs fit on a table) is used to reduce the number of times that the employee has to transport the trolleys.

The juice trolleys are firstly filled with equipment, according to the specified loading diagram. Then, the employee stows the orange juice, tomato juice, champagne, bags of crisps in the trolleys, according to the production card. His work method here is to pick a tote with a specific product and stow this product in the trolley if it is specified on the card. If he is finished stowing that product, he picks a tote with a different one and visits all trolleys again, and so on.

Figure 2-15 - C-class juice trolley

For the hot snack trolley, the same work method is used: the employee picks a stack/tote with a certain product, and visit all trolleys that require that product. There is one additional requirement here, that is to calculate the required number of PSU (Pre-Set-Up) plates and stow these in the trolley. PSU plates are empty China plates and are provided when the outbound flight is not fully booked. Meals on China plates are only provided for the number of passengers in that flight. There is a probability that the return flight contains more passengers. Therefore, to make sure there are enough plates and dishes for the return flight, PSU plates are taken on the outbound flight. In the current situation, the calculation is quite devious: on the production card, the total number of plates is specified through a code of the plates (e.g. *PSU0010H* specifies that in total 10 plates, full or empty, have to go in the trolley). The number of PSU plates is then calculated by subtracting the number of meals that are stowed from the total number of plates.

After having completed stowing the products in the trolleys, all barcodes are scanned and the trolleys are pushed to the gates. Then or during the process, the work space is tidied up. The process is captured in Figure 2-16.

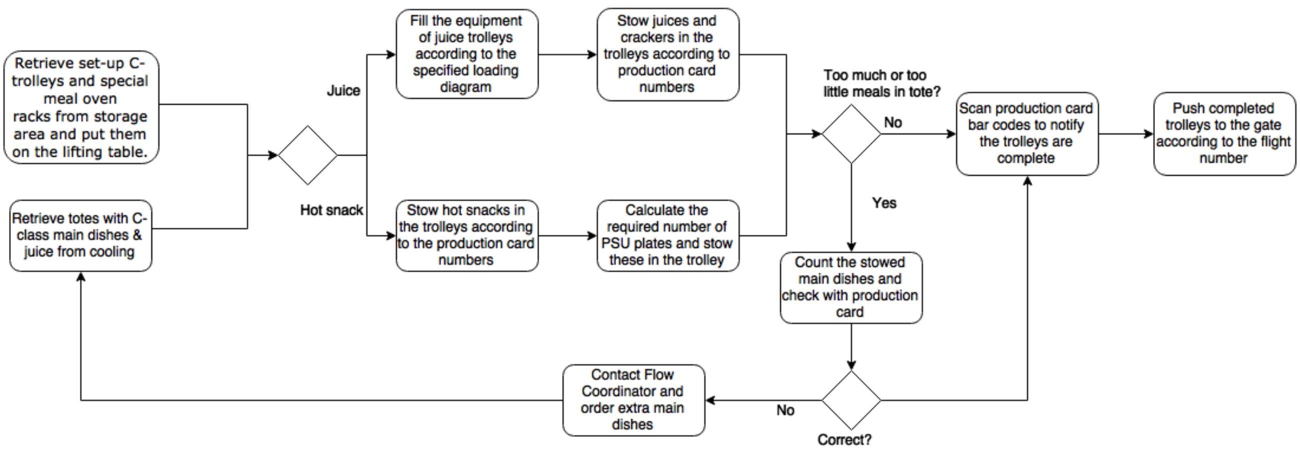

Figure 2-16 - Flow chart C-class juice & hot snack

2.2.3 M-class main dish & hot snack

The M-class main dish and hot snack are assembled on one lifting table by two employees. One employee stows the main dishes and the rolls for the first provision during the flight, the other the hot snacks. For this, the same division of trolleys between categories on the lifting table has been used as shown in Figure 2-14.

The set-up trolleys are retrieved from the storage area, the totes with main dishes and hot snacks from the cooling area, whereas the rolls are retrieved from the GOC. Here as well, the entire capacity of the lifting table is used for the trolleys. Next to this however, it occurs that the employee retrieves some additional trolleys that will be stowed on the ground.

Figure 2-17 - Hot snacks in an OIS

The totes with main dishes are put into the cooling area for two production blocks and are delivered flight specific. So for each flight, the exact number of main dishes needed are put in the totes. The hot snacks for all flights are supplied in bulk, containing the meals for two blocks. Next to the normal meals, there could be special meals involved as well, e.g. for vegetarians. For these special meals, there are dedicated oven racks, stacked in a small storage area. The employee then checks this special storage whether there is an oven insert linked to the flight he is assembling. If this is the case, he gathers the oven rack with the other trolleys.

Figure 2-18 - Main dish

In accordance with the production card numbers, the main dishes and hot snacks are stowed in the trolleys. Likewise to the process at the C-class main dish, the amount of meals in the totes per flight should be exactly equal to the amount stated on the production card. If this is not the case, the same steps are undertaken at the M-class assembly. Again, when the trolleys are completed, barcodes are scanned and the trolleys are pushed to the gates and the work space is tidied up. The process is captured in Figure 2-19.

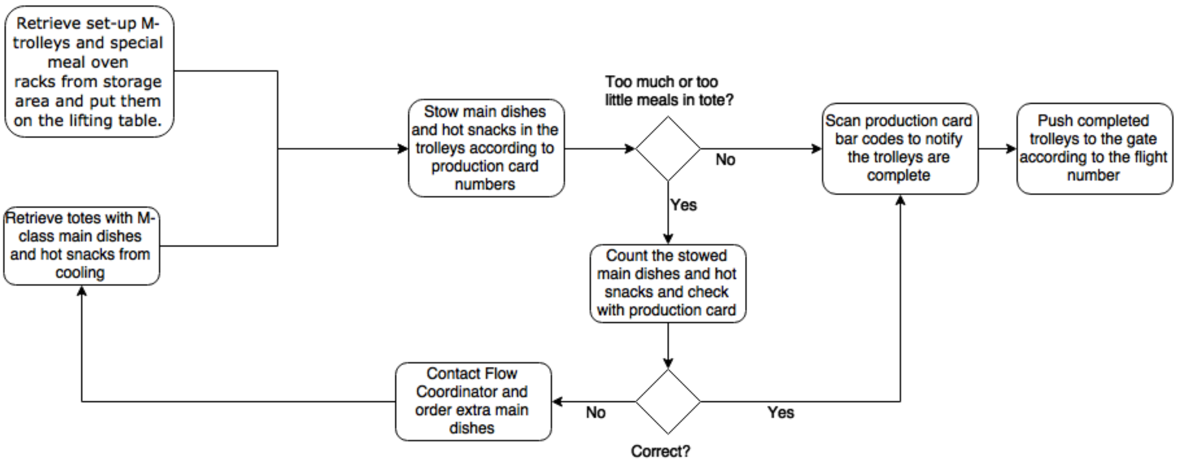

Figure 2-19 - Flow chart M-class main dish & hot snack

2.2.4 CTR

At the CTR lifting table the croissants and rolls (for the second provision during the flight) for respectively the C- and M-class, as well as the boxes and ice-cream for the M-class are stowed in the STC and SQC containers (as shown in Appendix III). According to the production card that is linked to the type of container, the right amount and type of meals are stowed. One employee per shift makes sure that all CTR trolleys are produced.

Figure 2-20 - CTR

The first step is to retrieve the set-up CTR-trolleys, as well as the STC and SQC-type containers from the storage area. In total, all CTR-trolleys for one entire production block are retrieved. The CTR-trolleys can be set-up with the two types containers. Next to this, a bulk supply of rolls, boxes and ice-cream cups is retrieved from either GOC or the cooling area.

Figure 2-21- Standard Container (STC)

The next step is then to stow the products corresponding to the production cards. This is done by picking a tote that contains a certain meal, and stowing that meals in the right containers. Employees have been instructed to stow the rolls first in the containers. After that, the boxes and ice cream cups can be done. The ice cream cups are put into Styrofoam boxes, for isolation. Then, a layer of dry ice bags is used, before adding the next ice cream cups. These filled Styrofoam boxes are then stowed into the container, corresponding to the production card. Finally, bar codes are scanned and the CTRs are pushed to the gates and the work space is cleared.

In Figure 2-22, the flow chart for the CTR work cell is shown.

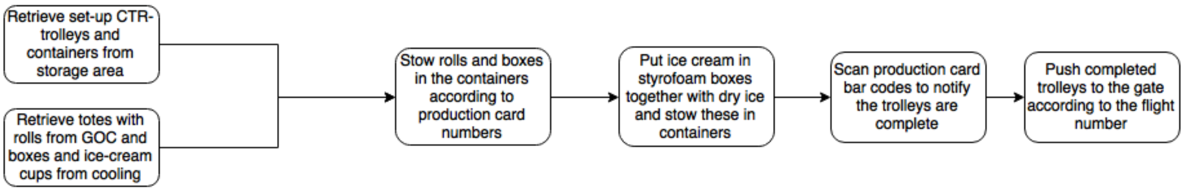

Figure 2-22 - Flow chart CTR

2.2.5 Silverware

At silverware, the containers are both set-up and assembled. The layout of the work cell is shown in Figure 2-24. Bread baskets, serving trays, silverware and tea(pots) and coffee(pots) are put into either the SQC or STC containers. Three employees are working at this work cell: one employee (Employee 1) fetches all the items from the washing machine at the silverware cell and puts these in totes specified for the items. Another one (Emp. 2) is occupied with building a supply of equipment that will be stowed in the container, such as the bread baskets, drawers and serving trays. The third employee (Emp. 3) stows the built equipment in the container. The content of the containers at this work cell is independent of the number of passengers that will go on the flight. So for every flight, there is a standard number of equipment that will be stowed into the trolleys.

Figure 2-23 - Silverware CTR with SQCs and STCs

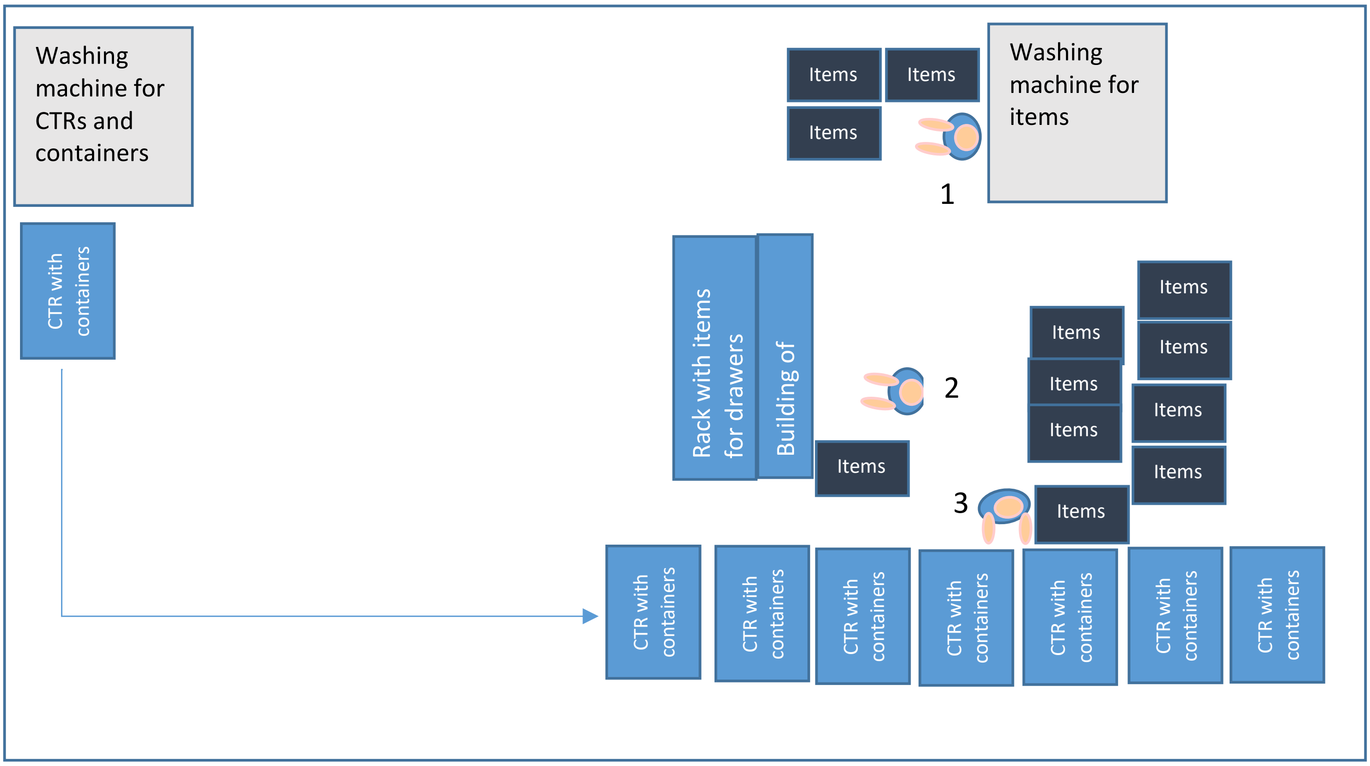

Figure 2-24 - Current silverware layout

Firstly, employee 3 retrieves the CTR-trolleys and containers that are scheduled for an entire block from the storage area. This storage area is at another washing machine (at 4a), which is quite far from the silverware work cell. After transporting the CTRs and containers to the work cell, the containers are sorted by the employee. The rule of sorting is to put the containers that will be put in a certain galley in the aircraft on one CTR.

Employee 1 continuously fetches the items from the washing machine at the work cell and puts these in totes. As there are a lot of different individual items, there are as many different stacks of totes with these items, as can be seen in the figure. This results in that the work cell looks rather messy. Employee 2 uses the individual items, so that he can keep on building a stock of drawers and trays. The built-up stock is used by Employee 3, to stow the required drawers, items and trays in the containers, according to the production card. Finally, the bar codes are scanned and the completed CTRs are pushed to the gates and the work space is cleared.

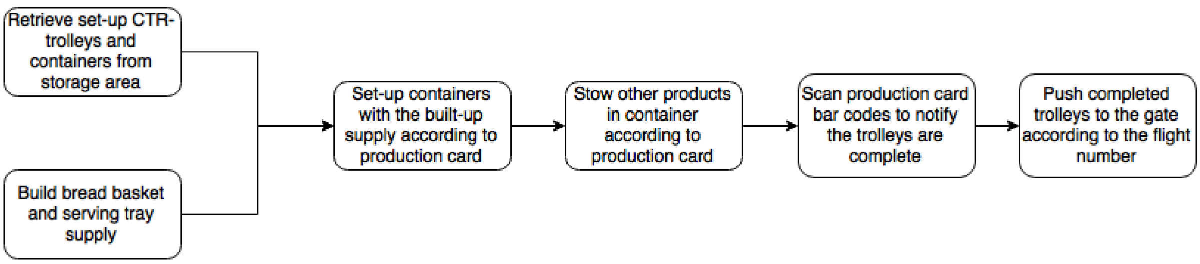

Figure 2-25 – Flow chart silverware

2.2.6 After VLAS

The final location in the assembly is the gate. On a large flyer in the facility is stated which trolley, destined for a specific flight, should be pushed to what gate. In the gate, which is a cooled area, the trolleys are sorted per flight and are arranged in a line. According to the time schedule of the flights, the trolleys are put through to distribution. This department makes sure the trolleys are put on a KCS truck, that transports the trolleys to the aircraft.

Figure 2-26 - Assembled tray. Main dish or hot snack is placed on the tray in the plane

At a different location within the ICA Food department, an automated production line is established, that assembles a tray containing a bottle of water, a salad and a dessert and puts it in a trolley (Figure 2-26). As mentioned, at the VLAS-process, the main dishes and hot snacks are stowed in the oven inserts. During the flight, the cabin crew puts the main dishes and hot snacks in the ovens. When these are warmed up, the cabin crew puts either the main dish or the hot snack on the tray (in the figure in the open space below left), that has been assembled at the production line.

2.3 Conclusion

In this chapter, we described the overall process at KCS, before zooming in on the work methods of the five individual VLAS-work cells. Generally, the process at the work cells to produce the trolleys is similar: first, the trolleys and the meals are retrieved, then the meals are stowed in the trolleys. Finally, the barcodes are scanned and the trolleys are pushed to the gate.

There is a difference in the method of supply however: for the M-class MND & HSN work cell, the main dishes are delivered flight specifically, whereas the meals for the other work cells are delivered in bulk for two production blocks. In the following chapter, we will measure and assess the current performance of the VLAS-process and its individual work cells.

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3. Current performance

After describing the work methods for each work cell, we will now measure and assess the performance of the work cells, and the VLAS-process in general. For this, we firstly determine the KPIs in section 3.1 and measure the performance in 3.2. In 3.3 we describe the several bottlenecks and problems that are found.

3.1 Key Performance Indicators

After describing the material flow in the ICA Food facility and zooming in on current work methods that are used within the different VLAS-work cells, we will measure the current performance. Firstly, measuring the current performance might give a good insight in where possible potential of improvement is. Secondly, for the comparison of the current design and future solutions, the current performance will be used as benchmark.

To measure the performance, KCS has distinguished its Key Performance Indicators (KPIs) into four different categories:

- customer
- human
- quality
- process.

The KPIs for the first three categories describe the current performance in their regards appropriately. However, for the process category, these KPIs are not sufficient. Therefore, we augmented the current KPIs with three indicators, which will be described in the corresponding section.

Customer related KPIs

The KPI for the category customer is the amount of complaints that are sent from KLM, the ‘customer’ of KCS. These complaints can, for example, be about the wrong type or incorrect amount of meals sent on the plane, damages to equipment or quality and taste of the meals. These mistakes are found out after take-off, so these cannot be corrected by KCS. Complaints taken into account are only the ones that can be traced directly to the VLAS-process, such as meal shortages.

Human related KPIs

KPIs in this category are of course about the KCS employees, the human resources. Typical HR KPIs are formed to measure its performance, such as non-attendance and illness, that can give an indication about the motivation of the employees and the ergonomic circumstances that they have to work in. A low non-attendance would indicate a high motivation and/or a good working environment. Lastly, there is the training KPI, which indicates the number of employees that follow training courses to further develop themselves. These KPIs are interesting for the management of KCS, but these are not directly relatable to VLAS, as the cause of e.g. an employee’s illness cannot be traced back to VLAS.

However, it is one of the goals of this research is to improve the ergonomics of the VLAS-process and therefore improve working conditions for the human resources. For measuring the ergonomics of the entire department, we cooperated with a physiotherapist who conducted a research of the ergonomic situation of each individual process. Using quick scan methods as proposed by the German public institution for work health and safety, a risk classification for lifting and pushing/pulling per work process is done. For a classification for repetitive motions, the OCRA (Occupational Repetitive Action) ergonomic tool is used. These classifications indicate the health risk for employees.

Quality related KPIs
The KPIs in this category are about the quality of the process. KCS is registered at several hygiene quality check consultancies, such as HACCP (risk-analysis for food). This consultancy checks the meals and juices on temperature. Each product has a maximum temperature restriction for it to be allowed to be filled in a trolley. For example, a main dish must have a temperature below 7 degrees Celsius. Random sample tests are done at KCS to measure the temperature of a product. HACCP provides a monthly report on this quality KPI. A goal of this research is not per se to improve this KPI, but a new solution must at least meet the current HACCP score.

Secondly, to measure the safety of the work cell, the number of incidents that have occurred at VLAS is identified, to get a good indication of the quality of the work instructions and devices, e.g. whether they are safe to work with.

Process related KPIs
The process KPIs consist of indicators that measure the in- and output of KCS. The on-time deliveries KPI specifies the number of deliveries done from ICA Food to the gate. For example, whether a trolley is scheduled for block 6 and is actually put into the gate to distribution before the end of block 6.

Furthermore, when the onboard crew at the aircraft finds out that a certain product is missing before take-off, or the wrong product is stowed, extra delivery runs to the aircraft have to be made to correct the mistake by delivering extra or the right type of meals. This is expensive and time consuming, therefore wasteful, so the lower the amount of extra deliveries, the better.

KCS uses two KPIs to measure employee productivity: one is the number of passengers 'produced' per employee, the other one is the amount of flights produced per employee. Of these two KPIs, the flights per employee KPI is the most constant, as the number of flights does not fluctuate a lot, but only the number of employees needed does. The number of passengers however, fluctuates heavily per day and per month. These KPIs are used by the management to measure the overall KCS performance per department, but are not suitable indicators for measuring the individual VLAS-performance. However, the KPIs can be used as describing factors of the process, e.g. in the different work tempos per work cell.

<u>New Process related KPIs</u>
The process KPIs, as mentioned above, do not sufficiently provide insight in the performance of the VLAS-process. The productivity KPIs can be used as describing factors, but not as performance indicators for VLAS. The ED runs and on-time deliveries however, are very suitable indicators for measuring the output of VLAS. Next to these indicators, we will introduce new KPIs to assess the process within VLAS.

A new indicator is to calculate the amount of meals stowed into trolleys per employee, at a work cell. This is not a key performance indicator, but likewise to the flight and passenger productivities, a describing factor. It will give a good insight in the work load and work pace per work cell. For example, it could show that during a certain time period, far more M-class main dishes than C-class main dishes are stowed per employee. The cause of this could be that the M-class main dishes are in plastic boxes, whereas for the C-class there are China plates involved, which needs more carefulness when stowing.

Furthermore, to identify the value adding and non-value adding activities of a work cell, the Lean rate will be calculated. This is the time that an employee is adding value to the product, relative to the total available time. The percentage should obviously be as high as possible. To determine the time spent on these activities, Process Activity Mapping will be used. This method will be further explained in section 4.3.

Finally, per work cell, the throughput time for a trolley for each work cell will be determined. The throughput time here will be the total time that the trolley spends in the VLAS-process. So, from when the employee picks up the trolley at the storage until the trolleys is pushed to the gate. Currently, KCS has no indication whatsoever about the time that is taken for a trolley, which means that there is less insight in the process. Furthermore, in order to create efficiency and more flexibility, the throughput time should be minimized.

Concluding the above, in Table 3-1, the KPIs that are going to be used to measure performance, are sorted per category.

Table 3-1 - Key Performance Indicators

Category	KPI	Measurement unit	Target
Customer	Customer complaints	# of customer complaints	Minimize
Human	Ergonomics	Health risk factor	Max/min
Quality	Temperatures of meals	HACCP test score	Maximize
	Safety	# of incidents	Minimize
Process	On-time deliveries	% of deliveries made on time	Maximize
Existing KPIs	Extra delivery trips	# of extra delivery trips done	Minimize
	Passenger productivity *(describing factor)*	# of passengers served per employee	Maximize
	Flight productivity *(describing factor)*	# of flights served per employee	Maximize
New KPIs	Meal productivity *(describing factor)*	# of meals served per employee	Maximize
	Waste time	Non-value-added time compared to total available time	Minimize
	Throughput time	Process time per trolley	Minimize

As mentioned, the calculation of these KPIs is only done in general for the separate departments in general: meaning that the performance is measured, e.g., for ICA Food and for ICA NF&B separately. So, the performance is not measured per work cell. Therefore, there is no clear overview of the actual performance of a separate work cell, which could possibly mean that there is one work cell that compensates for flaws in the process at other work cells, as the average overall performance of the department is measured anyway. In this research, it is essential to look at the individual performance of each work cell within the VLAS-process. Therefore, the KPIs will be determined per work cell.

The KPIs mentioned will be retrieved from the data department or (if not available) be calculated per work cell using the following formulas:

Passenger productivity: $$\frac{number\ of\ passengers\ served}{number\ of\ employees}$$

Flight productivity: $$\frac{number\ of\ flights\ served}{number\ of\ employees}$$

Meal productivity: $$\frac{number\ of\ meals\ stowed}{number\ of\ employees}$$

Lean rate: $$\frac{value\ added\ time}{total\ available\ time}$$

Throughput time: $$wait\ to\ move\ time + move\ time + wait\ for\ parts\ time + set\ up\ time + production\ time + queue\ time$$

Whereas, applied to KCS context:

Wait to move time: time the trolleys are waiting upon transportation to the next stage in the process

Move time: retrieving the trolleys and meals

Wait for parts time: time employees are waiting for equipment or meals.

Set up time: setting-up the trolley with equipment at C-class MND

Production time: time spent stowing meals in the trolley

Queue time: time a trolley spends waiting to be filled with equipment or meals or waits for transportation to the gate

3.2 Performance

After we described the several KPIs that will be used, we can now move on to calculate and measure them, starting with the overall VLAS-performance.

Restriction

There is no data warehouse at KCS, data is saved every day on an FTP server. However, to keep memory available on the server, the IT-department removes these data files after one or three days. This means that there is no data accessible about production numbers and on-time deliveries over e.g. the past year. Also, when data is available, it is very time consuming to cleanse the data for it to be used for analysis. Because of this fact, in combination with the limited available time for this research project, we decided to use data of a certain number of weeks to determine performance on several KPIs. For this, data was used from week 10 until week 19 in 2017 (during the first weeks of this research assignment). According to KCS, these weeks are a good representation of the performance over a certain time.

Flight, meal and passenger productivity

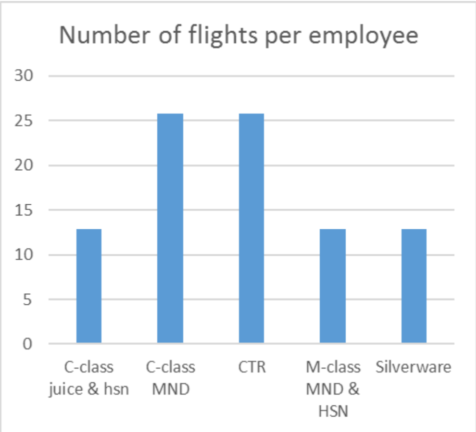

Figure 3-1 - Flight productivity

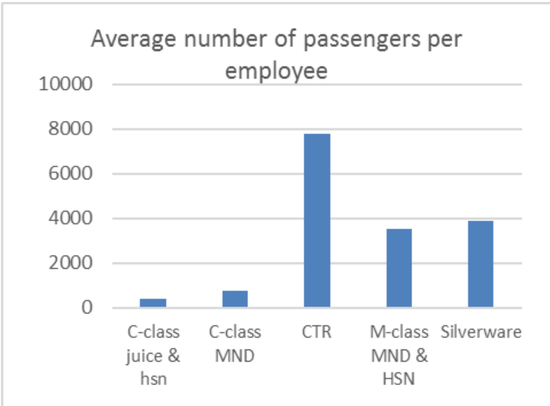

Figure 3-2 - Passenger productivity

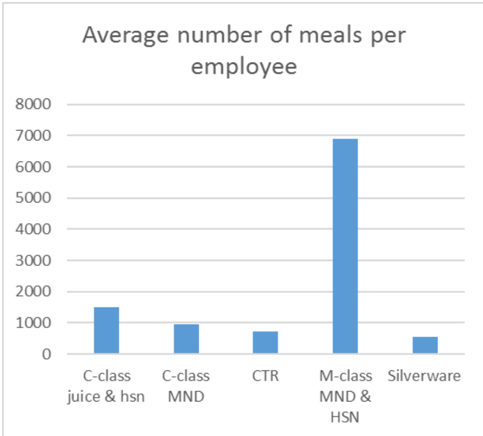

Figure 3-3 - Meal productivity

As each work cell assembles trolleys and containers for the same amount of flights, the only difference in the average number of flights per employee is caused by a difference in number of employees that work at a work cell. In the C-class MND and CTR work cells, one employee works an early and a late shift, so the amount of flights per employee is higher there (Figure 3-3).

The real discrepancies can be observed in the average number of passengers served (Figure 3-2) and meals assembled per employee. It is clear that the highest number is produced at the CTR work cell, followed by the silverware. This is due to that these work cells produce trolleys for both the C- and the M-class, whereas CTR produces more passengers per employee, because at CTR only one FTE is used. After these two is the M-class MND & HSN work cell. This number is also very high, regarding that this work cell only produces for M-class passengers (around 15,000 per day).

As per the average number of meals per employee (Figure 3-1), the M-class MND & HSN reaches the highest amount. This is again due to the 15,000 M-class passengers per day, but also through that both a main dish and a hot snack are provided at the same work cell, whereas the main dishes and hot snacks for the C-class are provided at two different work cells. The work tempo of the M-class MND and C-class MND cells is also very different. Whereas the M-class dishes (with its plastic cups) are stowed into the oven racks at a high speed, the C-class main dishes (on porcelain plates) are put into the oven racks slower and more carefully. To conclude, the throughput and speed at M-class MND & HSN is by far the highest, compared to the both C-class work cells.

The lowest number of items flow through the CTR and Silverware work cells. However, at these work cells, the variation of the trolley content here used is significantly higher, especially with keeping the low number of products in mind. At the CTR work cell, on average 285 standard or squared containers are used. For Silverware this number rises to 560 containers. Compared to the 240 for both C-class work cells and 870 for the M-class work cell (with its two employees), this Silverware number is very high. This would indicate that a high percentage of their time is spent on retrieving the containers from the storage, and transporting them to the gate.

Customer complaints & extra delivery runs

In Figure 3-4, the number of customer complaints (CC) and extra delivery (ED) runs are visualized. The data concerning these two topics has been filtered on whether the complaints or runs can be directly traced back to one of the five VLAS work cells. Reasons for complaints or extra delivery runs are shortages of meals or because the wrong meals are stowed into the trolleys. The M-class work cell reaches the highest amount. This is due to the high amount of meals that is stowed in that work cell, as shown in Figure 3-4, so that the chance on a mistake is higher. However, the silverware work cell also has a poor performance, especially regarding the lower number of products that is stowed there. The same applies to the CTR and C-class juice work cells, albeit that their performance on complaints and runs is better than Silverware. One of the main causes for mistakes in stowing the products, is that the codes of meals look very much alike. For example, 99311A53 is the code for a chicken meal, whereas 99311A63 is the code for a pasta. There is just one number separating the two codes, which increases the probability of making a mistake.

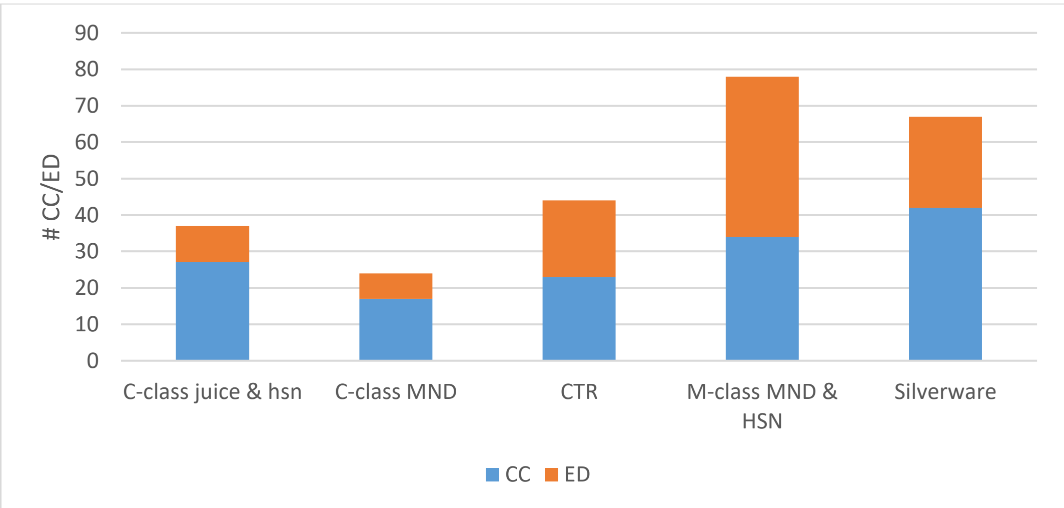

Figure 3-4 - Customer complaints (CC) and extra delivery (ED) runs per work cell over 9 weeks

According to Smith (2005), the human error rate for interpreting words that look similar is 0.03, for example for the previously mentioned case of the chicken and pasta meals. Meaning, for every 100 times a code is read, 3 are read wrongly. The error rate for physical operations varies between the 0.01 and 0.02. Figure 3-5 gives an indication of the number of mistakes made, regarding the number of positions that are produced. The total amount of customer complaints and ED runs is divided by the total amount of positions per work cell. By comparing the human error rate to the relative number of CCs and EDs, it becomes adamant that the CTR work cell is performing poorly, as 1% of all its positions include an incorrectly stowed trolley. Compared to Figure 3-4 and the human error rate, it shows that the M-class MND & HSN is performing relatively well, due to the very high amount of positions that flow through this work cell. However, every mistake that is made is one too many and is preventable, as the content of the trolleys is quite easy.

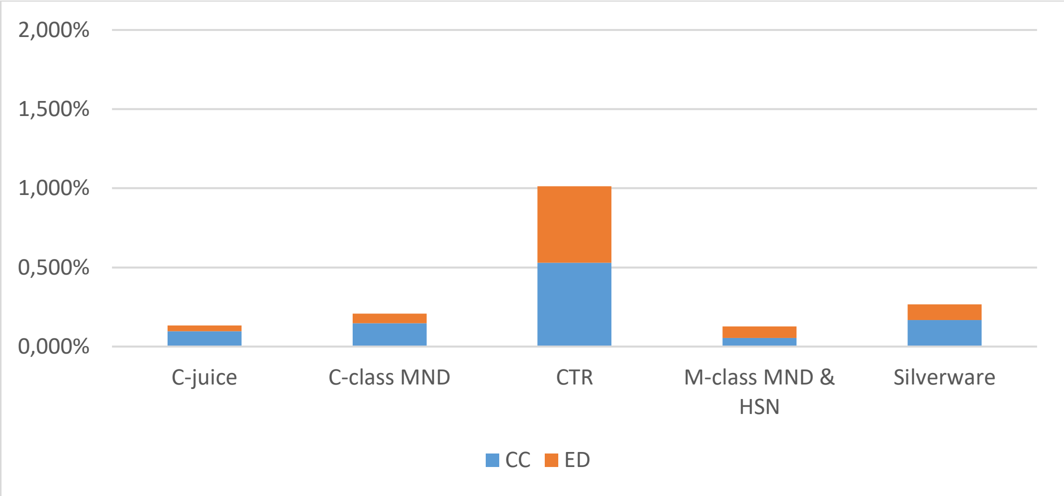

Figure 3-5 - Relative number of CC and ED per work cell

Figure 3-6 visualizes the CCs and EDs for the CTR work cell. Compared to the amount of meals and containers that are produced over here, there are a lot of mistakes made here. Most complaints and runs are caused by shortages of rolls, this is a problem that has occurred at KCS for a longer while now, resulting in several problem-solving projects to reduce the number of mistakes here. One of the main causes of shortages of rolls is that sometimes not all bags of rolls fit in the container, so the employee considers the container to be completed. Next to this, some ice-cream boxes tend to be forgotten to be stowed in the containers by employees, as well as the bags of dry ice.

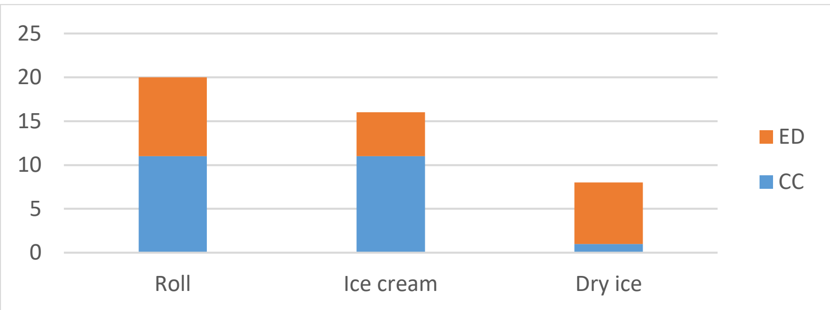

Figure 3-6 - CC and ED CTR

For the M-class lifting table, surprisingly, the amount of complaints and ED runs are equal for the hot snacks and main dishes, as shown in Figure 3-7. This is unexpected, as the main dishes are supplied to VLAS specific for each flight, whereas for the hot snacks everything is delivered in bulk. This could be caused by GOC delivering the wrong amounts of meals, whereas the employee assumes that the right amount of meals is delivered. Next to that, the employee has to count the stowing of the dishes by heart, so a miscount can be made easily when he loses his focus suddenly, e.g. after searching for equipment or meals and returning to the lifting table. This is interesting, but as there are no data available about the completeness of deliveries and this process is outside the scope of this research, this will not be looked into in further detail. However, this should be kept in mind when possibly recommending to supply all meals flight specifically.

Within the 66 mistakes, there is a surprisingly high amount of complaints and EDs in which more than twenty meals are short or missing in a trolley: 29 times. In these cases, either an oven rack or a container had been forgotten to be transported to the plane, or an employee had skipped a certain oven rack per accident. This can be caused because batching is used for filling the trolleys. Through this, a trolley or oven rack can be easily overlooked.

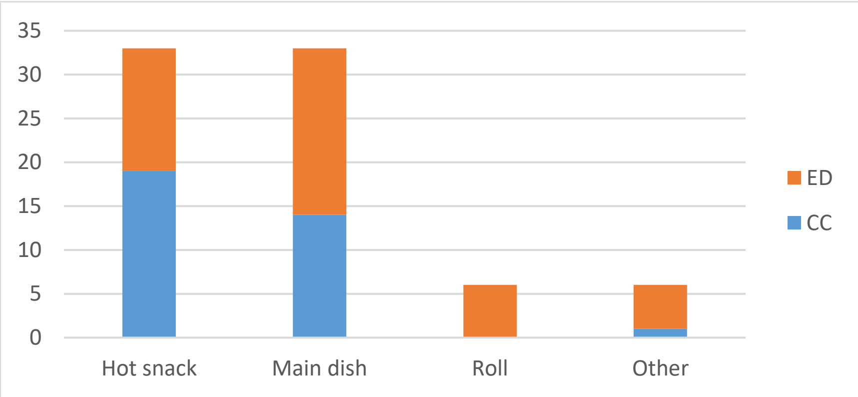

Figure 3-7 - CC and ED M-class main dish & hot snack

On-time deliveries

In Table 3-2, the percentage of on-time deliveries from the VLAS-process to the gate is shown. As mentioned, there is no data warehouse at KCS and gathering data is time intensive. Therefore, for over fourteen random, but representative days, data was gathered regarding the time of delivery to the gate. To determine whether a position was delivered on time, the scheduled completion time was compared to the time of scanning (i.e. actual completion time).

Next to this, data cleansing was necessary in order to make a reliable analysis. For example, the ice-cream trolleys for the CTR work cell can be scheduled for production on a certain evening at 10 PM and would be delivered to the plane the morning after. In practice however, the ice-cream trolley would be produced on the day of flight, as early in the day as possible. Through this, the trolley wouldn't have to be in the gate for the entire night and would ensure that the ice-cream does not melt. Therefore, for the ice-cream trolleys, there was a modification for the on-time determination. This was done for some other types of trolleys as well.

As can be seen in the table, the Silverware and CTR work cells have a poor performance on the on-time deliveries KPI. Approximately 15% of all their deliveries to the gate is too late. Furthermore, the standard deviation indicates a wide spread in the performance, meaning that there are several days on which the performance was extremely bad (or good). For the

C-class juice & HSN and M-class MND & HSN work cells, the performance target is almost maintained with 92% on-time deliveries. The C-class MND performs by far the best, with almost 96% on-time deliveries. For these three work cells, the spread is quite low, which indicates a constant performance on this KPI.

Table 3-2 - On-time deliveries per work cell

Work cell	On-time	Standard deviation
C-class juice & HSN	92.1 %	4.8 %
C-class MND	95.8 %	4.9 %
M-class MND & HSN	91.9 %	3.8 %
CTR	85.8 %	13.1 %
Silverware	85.5 %	13.5 %

So, the Silverware and CTR work cells are bad performers on the on-time deliveries KPI. Approximately, only 86% of all its deliveries to the gate are on time, which is way below the target of 92%.

The large batch size that employees use to build the Silverware and CTR is the main cause of this performance. Through this, the sorting process of the different containers relatively takes up more time, as the number of containers to be filled is higher. Also, through the large batch size, a huge number of trolleys are either all on time or they are all too late.

Furthermore, there is a big difference between the morning and late shifts here: as many as 82% of all too-late deliveries occur in the morning shift. This is due to the start-up time of both work cells, but Silverware is very dependent on the input of equipment of the incoming flights. It takes some time to get the flow of items from the plane to KCS going. Furthermore, the items that come back, need to be washed first, which costs even more time. It takes approximately three production blocks to catch up with the production schedule.

Lean rate
Using the activities described in the flowcharts in section 2.2, Process Activity Mapping was used to measure the percentage of time in which value actually is added to the product: the Lean rate. As mentioned in Chapter 4, every activity is assigned one of the five categories of flow, to identify the type of activity. Following, it is assessed whether the activity is a Necessary (NNVA), Unnecessary Non-Value Adding (UNVA) or a Value Adding (VA) activity. For the two NVA-activities, waste types were identified.

The following step is the timing of the activities. In order to make sure the timing is done in a statistically correct way, the structure of Pollux (2016) was used. Firstly, an estimation was made about the percentage of time spent on each activity. After consultation with KCS, the standard deviation of the outcome in percentages (at 95%-confidence) was set at 15%, as this method remains a tool to identify waste and does not need to be pin-point accurate. The maximum sample size turned out to be 11. So, for each activity, if possible, 11 time-measurements were done. See, for more detailed calculations for this statistical verification, Appendix IV.

To measure the time of the activities per work cell, GoPro cameras were used. By going through the pictures made by the camera every 5 seconds (such as Figure 3-8), the start and ending of each activity could be timed by using the time the picture had been made. For all 5 work cells, the same procedure was undertaken. Of course, employees were informed about this, to ensure no privacy violations were harmed. After having measured the durations of all activities per work cell, the value-adding and non-value adding times could be calculated and the lean rate could be computed.

Figure 3-8 - GoPro picture

In Table 3-3, the average VA and NVA-times measured over the 11 measurements and the lean rate are shown. The C-class MND performs best on this, with a Lean rate of 65%. This means that 35% of the time is non-value adding, and 65% is value adding. Silverware is performing the worst on this criterion. The Lean rate is based on the activities in each process, so the lunch breaks are not included. If we would have included these, the Lean rate would have been lower.

Table 3-3 - Lean rate per work cell

Work cell	VA time	NVA time	Lean rate
C-class MND	00:52:18	00:28:16	65%
C-class juice & HSN	00:42:26	00:27:08	61%
M-class MND & HSN	00:30:38	00:24:41	55%
CTR	00:36:28	00:28:09	56%
Silverware	00:35:02	00:31:47	52%

To illustrate the calculation of the Lean rate, the Process Activity Map of the M-class main dish & hot snack work cell is shown in Table 3-4. The only activity that actually adds value for the customer is the stowing of main dishes and hot snacks in the trolleys. The remaining activities are necessary to the process, but do not add value for the customer. In the entire process at this work cell, as much as 31% is spent on the transportation of trolleys and meals, which is high. This percentage is very similar to the ones at the other work cells.

Table 3-4 - Process Activity Map M-class main dish & hot snack

	Activity	Flow	NVA/VA	Waste type	Average time	% of time
1	Retrieve set-up M-trolleys from storage area and put them on the lifting table. Gather oven racks for special meals.	T	NNVA	Transport. Waiting. Inventory.	00:09:30	18%
2	Retrieve totes with M-class main dishes & hot snacks from cooling	T	NNVA	Transport. Motion.	00:03:14	6%
3	Stow main dishes and hot snacks in trolleys	O	VA	-	00:30:38	55%
4	Scan production card bar codes to notify the trolleys are complete	C	NNVA	Motion	00:03:43	7%
5	Push completed trolleys to the distribution gates	T	NNVA	Transport. Waiting.	00:04:20	8%
6	Other waste: cleaning work space, searching for equipment, etc.	O	NNVA	Transport. Motion. Waiting.	00:03:54	7%
				Total	00:55:19	100%

Throughput time & WIP
Using the Process Activity Map analysis, the throughput time and WIP were measured and calculated for each work cell individually. Firstly, the throughput time for one trolley was measured and the arrival rate of trolleys per hour was calculated. Following from that, the different Work in Progress-inventories were determined.

In Table 3-5, the throughput time per trolley for each work cell is shown. Recall from section 3.1 that this is a summation of production time, set-up time, move time, queue time and wait for parts and move time. In practice however, we were not able to measure each individual activity, as multiple employees are working at the same lifting table, and therefore make the process for measuring more indistinct. Therefore, we measured the throughput times as follows: the time starting when a trolley is retrieved from the set-up trolley storage, to the point where the trolley is delivered to the gate. As can be seen from the table, the throughput time for the C-class MND and C-class juice & hot snack are the highest. This is maybe what could be expected, due to the high variety and the use of China plates that slows down the speed.

Table 3-5 - Throughput time per work cell

Work cell	Throughput time
C-class MND	01:06:08
C-class juice & HSN	01:04:36
M-class MND & HSN	00:41:26
CTR	00:57:05
Silverware	00:57:15

However, in general, the throughput time of approximately one hour for a trolley seems very high, compared to the production time for one trolley being around two to four minutes. The high throughput time is due to the use of batching. The batch quantities that are used for each work cell seem very high. For example, for the Silverware work cell, 30 to 40 containers are gathered together to be stowed. The employee then starts stowing a certain product in all the containers that require the item, before moving on to the next item that is required. This results in a very high waiting time for each container. For example, it could occur that the first container is completed within a few minutes. However, because the employee then continues stowing all the other 30 containers, the container is waiting to be transported until all other containers are completed.

The use of batching and the use of high batch quantities are also applicable to the other four work cells, which are the main reasons for the high throughput times.

Besides that, the cycle times of building a C-class juice trolley and a C-class hot snack trolley differ significantly. This is problematic, as these two types of trolleys are placed on the same working table, where one employee builds the juice trolley and the other one the hot snack trolley. That leads to, for example, the juice trolleys being completed faster than the hot snack trolleys.

Figure 3-9 - Juice trolleys are completed and transported to the gate, whereas the hot snack trolleys are not completed yet.

What occurs then is that, when the juice trolleys are completed, even if the hot snack trolleys are not, the lifting table goes down, the employee lifts the juice trolleys from the ground and pushes these finished trolleys to the gate. The lifting table then goes up again, the other employee proceeds with the hot snack trolleys and the "juice employee" retrieves new trolleys. The lifting table then goes down again, the new juice trolleys are put on the lifting table again, which goes up. After a while, the hot snack trolleys are completed and the whole cycle is repeated again, this time for the hot snack trolleys.

After calculating the cycle times, the Work in Progress-inventory for each work cell can be determined using Little's formula (4.1). The lambda has been calculated by dividing the average amount of trolleys per day that flow through the work cells, by the total available hours per day. The WIP is shown in Table 3-6. The calculation for this can be found in Appendix VI.

Table 3-6 - Work in Progress per work cell

WIP per cycle	T12	UTR	Containers
C-class MND	6.0	6.2	-
C-class juice & hot snack	20.5	8.2	-
M-class MND & HSN	10.2	9.7	-
CTR	6.8	-	19.8
Silverware	-	-	30.7

As can be seen from Table 3-6, the WIP per work cell is quite high, compared to the amount of trolleys that are used for each flight. This WIP is also what could be expected, regarding the high batch size that the different work cells maintain. On average, the trolleys for 4 or 5 flights are placed in the WIP. In all work cells, the capacity of the lifting tables is used to the limit. Next to that, a very high batch of containers is used for the Silverware and CTR work cell.

Quality

In the Figure 3-10 below, the HACCP test scores are shown. For the M-class and the C-class separately, temperature tests are done. The temperature of the meals should be below 7 degrees Celsius. In the months June until October 2016, KCS struggled with these temperatures. After that period, a project was started to deal with that poor performance. The impact of that project can be seen immediately, as the scores went up to 95% and even 100%. The scores tend to stay above the target of 92%. Therefore, there is no current issue regarding the HACCP score. So, for a potential new design, the current performance has to be maintained at the same level.

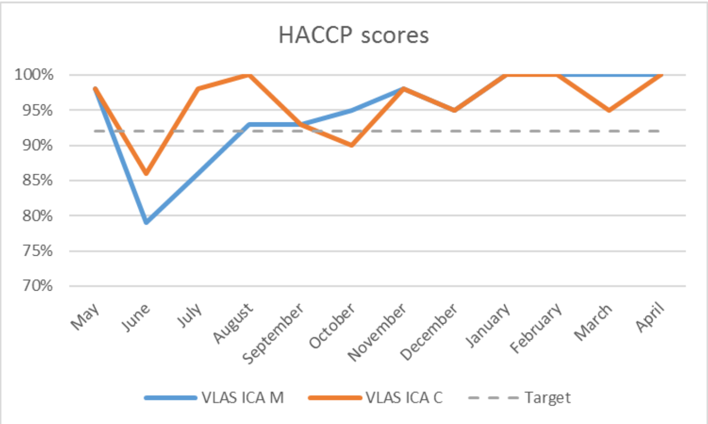

Figure 3-10 - HACCP scores per month

Ergonomics

In Table 3-7 an overview of the performance of each individual work cell on the ergonomic criteria is shown. Ergonomic studies make use of traffic lights to indicate the level of health risk, in the study that was performed at KCS, quantitative measurements were done to indicate this level. To visualize the health risk, colors can vary from green (no risk) to red (very high risk). Measuring each category individually indicates the area for improvement. In the first row, the scale is shown for each separate criterion. In the individual sections of these work cells, the ergonomic performance of each work cell is described. Overall, Table 3-7 shows that the VLAS-work cells are physically tough places to work. Especially the C-class juice & HSN, M-class MND & HSN and Silverware work cells stand out in a negative way. The individual work cell sections will elaborate on the ergonomic performance. In Appendix V, the calculations to determine the ergonomic factors can be found.

Table 3-7 - Ergonomic performance per work cell

	Weights		**Repetitive motion**	
	Pushing-Pulling	**Lifting**	**Shoulder**	**Upper body**
Scale	*0 – 50*	*0 - 50*	*0 – 22.5*	*Low – very high*
C-class MND	16	20	14.5	-
C-class juice & HSN	14	30	15.5	-
M-class MND & HSN	32	24	16.5	-
CTR	16	0	13	Medium
Silverware	16	12	12.5	Very high

By far the poorest ergonomical circumstances are measured at the silverware work cell. There is a very high risk on the upper body repetitive motion. The silverware CTRs are stowed on the floor, so not on a lifting table. Therefore, employees must bend over forward to stow the items in the containers with a high frequency. Especially when the employee is quite tall the movements ask a lot of his body.

At C-class juice & hot snack, a high health risk was observed for the lifting criterion. The products that are lifted here are above 3 kilograms, such as the drawers containing champagne bottles or orange juice packs, or trays that contain water bottles. These items are lifted very frequently, and are picked up from a very low position, which can be very hurting for the backs of employees. Next to that, the previously described inefficiency regarding the different throughput times of the juice and hot snack trolleys, leads to employees having to lift full, heavy juice or hot snack trolleys, which is ergonomically poor. This all results in a very poor performance on the lifting criterion.

At M-class main dish & hot snack, the lifting score is poor. To be able to pick the meals from a better working height, employees use two empty creates as a basis, to put the full totes with meals upon. These full totes are lifted from a big stack, and are placed on the empty crates. The disadvantage of this, is that the weight of the totes is above 10 kilograms, which is quite heavy to be lifting all day long. This lifting occurs frequently, which is why the score on this criterion is poor. The same goes for the C-class main dish work cell, but due to the slightly lower frequency, the score is a bit better.

Furthermore, at M-MND & HSN, a very poor score on the pushing/pulling-criterion was measured. The weight of the trolleys is similar to the other work cells, but the frequency of transporting the trolleys is higher, which results in a higher transporting distance and therefore a worse score.

Lastly, the frequency of movements at this work cell is the highest, compared to the others. This is because of the high amount of meals that are stowed in the trolleys. These meals are stowed in a very high tempo over a long time in a day, which results in a poor score on the repetitive motions criterion.

Safety
Lastly, the work cells can be regarded as very safe. Over the last three years, only one (minor) incident happened at VLAS. However, it must be kept in mind that not all (near-)incidents are registered, so the actual number of (near-)incidents would turn out a bit higher. But overall, there are no issues regarding the safety of VLAS.

This section only showed the most important outcomes of the work cell performance analysis. In Appendix II, for each work cell all KPIs have been calculated and analyzed.

3.3 Bottlenecks and problems

After determining the performance of VLAS and of each individual work cell, the bottlenecks, problems and potential for improvement can be identified. After consulting the shift leaders, production employees and management staff, a definitive problem identification was established. These aspects will serve as basis for the generation of designs for improvement. The found bottlenecks are described using the analysis of several KPIs.

Throughput time
The throughput time per trolley is considered as high. For all five work cells, the throughput time for one trolley or container is approximately one hour. This high throughput time leads to a higher WIP for every work cell, resulting in long waiting times for trolleys to be finished, as well as a higher risk of damages and a less clear overview in the process. Furthermore, recall that meals have to stay below 7 degrees Celsius. Because of the high throughput time, meals are waiting outside of the cooling area for a longer time, which results in a higher probability that the temperatures of meals rise above the maximum.

The cause of the high cycle time and high WIP is the use of the batch sizes that are used in each work cell. As mentioned, either the entire capacity of the lifting table is used to put trolleys on, or all containers for one or two blocks are gathered to be stowed.

Next to this, the cycle times for a C-class juice trolley and for a C-class hot snack trolley differ significantly. This is problematic, as these two types of trolleys are placed on the same working table. Each employee is responsible for one type of trolley. This results in an inefficient process with a lot of waste and waiting time, and a higher throughput time for both types of trolleys.

On-time deliveries
For the Silverware and CTR work cell, the on-time deliveries percentage is far below target, with approximately 85%. The main cause of this is that the batch sizes are very high, this results in that either all trolleys in the batch are on time, or all are too late. Furthermore, a cause for the late deliveries is that it usually takes a while in the morning shift before the first equipment has been processed through the washing machines, due to the arrival of the first flights in the morning. This results in more too late deliveries in the first production block.

Related to the on-time deliveries are the data gathered through the scanning process. These data are inconsistent, as the scanning of a bar code is done on different times in the process. Sometimes, the employee scans the bar code before starting a trolley, sometimes during the stowing of trolleys and often after having completed all the trolleys. Batching is also used for the scanning process. Therefore, due to this inconsistency, the scan data are unreliable.

Waste/lean rate
The lean rate for the five work cells ranges between 52 and 65%, which are positive estimations, due to the assumption was made that whenever the employee starts stowing, he does not perform other activities. Also, (lunch) breaks have not been included. However, still around 50 percent in each process is categorized as waste. At each work cell, over 25% is spent on the transportation of trolleys and meals, due to the long distances that are travelled each time and the searching for the right trolleys and meals.

Next to this, there is no standardized work method at each work cell for the employees. This results in a lot of waste, as employees (and managers) lose overview of the process and start mixing up activities. Conform Morgan and Liker (2006), a standardized process leads to more efficiency. Furthermore, employees need time to interpret the production cards, with all the meal and equipment codes.

Finally, at the Silverware work cell, a lot of time is taken up to sort the containers after retrieving them. These trolleys are sorted according to their size or content. The total process of one block takes approximately one hour, in which employees have spent at least 15 minutes to sort all the containers, which is non-value adding.

Customer complaints & extra delivery trips
Compared to the number of positions produced, the CTR and Silverware work cells stand out in a negative way. At the CTR work cell, the rolls are the main cause for mistakes: these are miscounted very often. At Silverware, breadbaskets and thermos cans are the cause for mistakes, due to that these positions are built on the floor, so that a visual check is difficult.

Next to these individual reasons, a main cause for mistakes is the use of batching. When stowing meals, employees pick a stack containing a certain meal and visit the trolleys that require that meal, before moving on to a different type of meal. However, if an employee accidentally skips one trolley or picks the wrong meal to be stowed in the trolley, the same mistake could be made for all the trolleys in the batch and would be difficult to trace back.

Furthermore, the number of products that is stowed in the trolleys is done by heart, which makes the process vulnerable. When an employee loses focus for a second and miscounts the products, it costs a lot of time to correct the mistake. Finally, the meal codes look very much alike. This causes probability that the employee interprets the code wrongly therefore and picks the wrong meal. The interpretation time is a factor here as well.

Ergonomics
The ergonomic circumstances of the work cells are generally below standard level. Especially at Silverware the performance on the repetitive motions for the back is very poor. This is due to the building of containers on the floor. There, employees have to bend over to put the items in the containers all day long, which makes it a very tough place to work.

At the C-class juice & HSN work cell, the performance on the lifting criterion is bad, due to the lifting of drawers with champagne bottles. These are lifted from a low position to the trolley that is on the lifting table, and are heavy. The same goes for the juice bottles, albeit that these are of less weight than the champagne bottles.

Finally, at the M-class MND & HSN and C-class MND there is a below average performance on the lifting of totes containing meals. Employees use three empty crates as a 'foundation' to put the full totes upon and be able to pick meals from a normal working height. However, these full totes have to be lifted on those three empty crates and are heavy (above OHS standards). Therefore, this could be damaging to the employees' health.

3.4 Conclusion

In this chapter, we assessed the current performance of the VLAS-process in general, and its individual work cells. For this, the KPIs of KCS do not sufficiently cover the process performance. Therefore, we introduced three new KPIs. Using the performance indicators, we identified the bottlenecks and problems at VLAS.

- The high batch sizes that are used at every work cell, cause a high throughput time (compared to the production time of an individual trolley) and a high Work in Progress.
- The on-time deliveries percentage suffers from the batch size, as these trolleys are either all too late, or on-time.
- A high percentage of waste (over 50%) is measured at each work cell, this is caused by the manual transportation of trolleys and meals (25%).
- The working conditions at the work cells can be considered as tough. A very poor ergonomic performance was measured at Silverware, as all containers are built on the floor. Next to that, at M-class MND & HSN and C-class MND, employees are manually lifting heavy totes too often, and at C-class juice & HSN the champagne bottles require a lot of the employees.

In the following chapter, we search for literature to find answers for the research questions as posed in 1.5.

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4. Literature

In this chapter, we describe the literature review, in order to come up with answers for the posed research questions. Recall that these research questions were linked to reviewing the current situation and current performance, and designing and evaluating several solutions. Firstly, a general approach for this research will be described in section 4.1. From thereon, theories will be linked to the different steps in this approach. For the analysis of the problem, the 5 Lean principles are explained in 4.2, different types of Lean waste will be described in 4.3, before mentioning the different layout types for designing a solution in 4.4 and the necessity of reducing throughput time in 4.5. Finally, in 4.6 design evaluation criteria and the selection method will be explained.

4.1 Approach

In this research, an improvement for the current situation at VLAS will be suggested. In order to obtain good results, a logical and structural approach should be used. Therefore, we searched the literature for methodologies for designing solutions for the to be found problems and bottlenecks. Through this, the research methodology was designed, as described in Chapter 1.

Säfsten (2002) describes three different approaches from the perspective of the manufacturer. In the *concept-generating* approach, the design process follows all the steps prescribed in the general design process. However, when the conceptual design phase is skipped and the actors work towards a preferred concept that was given from the beginning of the design phase, the process is *concept driven* (Engström et al. 1998). The third approach is described as *supplier-driven*, in which suppliers come up with a 'standard solution' for the problem.

According to Hicks (2004) a problem-solving or decision-making approach generally runs through a number of the same steps. He identified these steps and linked them together in the general problem-solving model, which is shown in Figure 4-1.

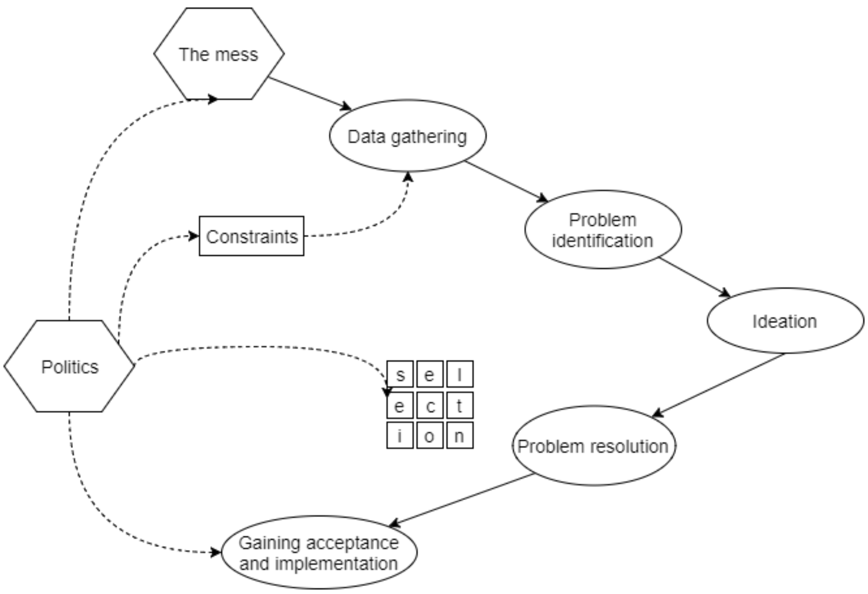

Figure 4-1 – Hicks' General Problem Solving model

It is essential that divergent and convergent thinking are balanced, while doing a creative problem solving (Osborn, 1953). Divergent thinking means generating lots of options, while convergent thinking is about evaluating options or making decisions. Therefore, in different steps within the general problem-solving model of Hicks, different types of thinking are needed. It will show that there is an alternation of convergent and divergent thinking with each step.

1. **The “mess”**. In this step, there is the realization that problems (or opportunities) exist. The temptation to ‘rush in to things’ must be resisted, so there is the need to spend time to firstly identify the things that are needed to be addressed and prioritized. In other words: create a structure in the project.
2. **Data gathering**. In this stage, it is necessary to find facts. Objective data (the who, what, where, when and how of the problem situation, subjective data (opinions, attitudes, feelings and beliefs) and details of any constraints that exist are gathered, that provide a basis for the next step. This stage requires divergent thinking.
3. **Problem identification**. Or ‘problem redefinition’. The found problems from Stage 1 are reexamined. Additionally, it might occur that problems are defined in a too general way, so that these problems have to be broken into sub problems. This is a crucial stage in the problem-solving process, as this is what the entire solving will be based on. Over here, convergent thinking is needed.
4. **Ideation**. In this stage, solutions or designs for the problem described in the previous stage are generated. As this is a ‘brainstorming’ stage, the solution should not be evaluated to soon. Divergent thinking is needed, because many innovative and creative ideas should be generated.
5. **Problem resolution**. In this stage, the generated ideas from the previous stage are evaluated. The most promising solutions are further developed to their final designs. Following, appropriate criteria are selected in order to compare the solutions. In the end, the best solution(s) are selected for implementation. Obviously, this stage requires convergent thinking.
6. **Gaining acceptance and implementation**. This is the final stage of the process. Here, an implementation plan is made in order to put the solutions into practice successfully. The brilliance of a solution alone is rarely sufficient to guarantee its implementation. Gaining acceptance among employees is therefore vital. This step might involve ‘politics’ as well, as it is necessary to involve the right employees at the right organizational level.

Almgren (1999) mentions three types of changes to production systems: an *existing* system is when no changes are made. The system is *modified* when there is some technical redesign and a minor change in comparison with a new design. Finally, there is a *new* production system, when there is a major technical redesign (new equipment, layout and flows). Van Gigch (1991) describes a process as either a *system improvement*, when a change is implemented that brings a system closer to standard or normal operating conditions set by the original design. *System design* is a more creative process, moving outwards from the system and creating an entirely new design.

4.2 Lean principles

For the analysis of the current situation and the design of the future solutions, the five Lean principles should be kept in mind. These are stated in Womack and Jones' book (1996).

1. Determine the added **value** of a product through the eyes of the customer. Here, added value is a service or product that the customer is willing to pay for or wait for.
2. Determine the **value stream**. For this, all activities in the production process need to be mapped, to determine which of these activities are value adding or not. The non-value added activities are waste (*muda* in Lean terms) and should be eliminated. We elaborate on these activities in 4.3.
3. Create **flow** in the production process. In this step, the activities that are qualified as waste should be removed. The remaining activities should be set-up so that the product can "flow" towards the customer: with the specified quality and without loss of time. Ideally, within Lean: this is a single-piece flow (not a batch-and-queue) where in-between stock is reduced to a minimum and process mistakes are not put through to the next station. However, in practice, a mix between batch and single-piece flow is often used. According to the book, a continuous flow can be justified when the production quantities are high and when there is a high sense of standardization.
4. **Pull** the product: doing what is necessary, only when it is necessary. So for example, only start production when the customer triggers the system with an order.
5. **Perfection**. For this, the Plan-Do-Check-Act cycle (Figure 4-2) is used in the Lean philosophy. This is used when the previous steps have been implemented and are secured. Then, there should be a strive for perfection through continuously improving the production process.

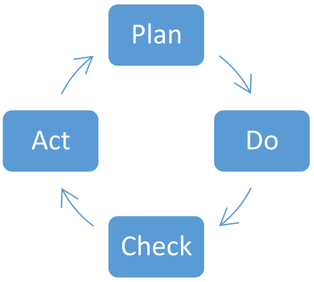

Figure 4-2 - PDCA Cycle

4.3 Types of Lean waste

Step 2 and 3 in the problem-solving model of Hicks are about gathering data and identifying the problem. For this, among other KPIs, the waste in the process can be defined. Before measuring the waste, firstly the several types of waste are described.

Womack and Jones (1996) state that one of the main goals of lean production is the elimination of everything that does not add value to the product or service. In other words: the elimination of waste. Waste uses resources but does not add value to the product (Search Manufacturing, 2000). In the lean philosophy, there are two categories of non-value adding activities:

- **Type I**: necessary non-value adding activities, these do not add value to the process, but are necessary for the system to function and are unavoidable with current technologies.
- **Type II**: unnecessary non-value adding activities. These do not add value to the process and are not necessary for the system to function and are avoidable. These should be eliminated first.

Hereby, non-value adding (NVA) activities are defined as activities that do not change the product or assembly. Only an activity that physically changes the shape or character of the product can add value (Ohno, 1988).

For these two categories, 7 types of waste have been defined by Taiichi Ohno (1988), the 'inventor of the Toyota Production System':

- **Transport**: the unnecessary movement of materials from one location to another. Movement adds nothing to the value of the process.
- **Inventory**: when materials are standing still in the inventory. No value is added while keeping finished materials (unnecessarily) in inventory.
- **Motion**: unnecessary movements by employees, such as searching for misplaced items, poor ergonomics, excessive travelling between locations. These motions cost time and cause stress on employees and machinery.
- **Waiting time**: any idle time when two interdependent processes are not completely synchronized. Waiting for the previous step in the process to complete.
- **Overproduction**: when more or faster than required is produced. The worst of all wastes. This results in a poor flow of information and high inventory levels.
- **Overprocessing**: performing any activity that is not necessary to produce a product or service. In other words, activities are performed that are not specifically required.
- **Defects**: frequent errors in paperwork, product quality issues and rework. Having to repair is a waste, but of course investing too much in repairing is also a waste.

Often, an eighth type of waste is mentioned: **non-utilized talent**. The waste of failing to make use of the maximum of the human resources in your organization.

To identify these types of waste, the Value Stream Mapping (VSM) technique can be used. Through VSM, an entire production process, representing material and information flow, can be visualized (Rother & Shook, 1999). This visualization creates the ability to see where, when and how information and product flows through the organization (Sullivan, McDonald, & van Aken, 2002). VSM consists of two basic components. Firstly, a big picture map is made, to get a good overview of the key features of that entire process. This map provides information about the product types and the amount of products that is done, as well as information flows within the process. After that, a detailed map is made. This is to identify waste in any system. To create this type of map, there are several VSM tools. Taylor et al. (2000) give an overview of these seven tools with the key categories of waste targeted per tool.

The most appropriate tool for this type of research is 'Process Activity Mapping' (PAM), which already has been applied in Chapter 3. This tool "classifies different processes as operations, transports, inspections, delays, storages and where communications occur". It targets the waiting, transportations, overproduction, motion and inventory types of waste. PAM undergoes the following steps:

1. Record all activities: measure where and how often they occur, how much time they take and the number of people involved.
2. Assign flows to activities. Five types of flows are identified: operation, transport, inspection, delay and communications.
3. Analyze. The found data are analyzed and major problems or concerns are identified, understood and countermeasures are developed.

Before undertaking the first step of PAM, the sample size must be determined, in order to analyze processes in a statistically correct way. According to Pollux (2016), the allowable standard deviation of the mean is dependent of the goal of the time-measurement. The goal of PAM in this research will be to get an indication of the amount of time on the different activities. Therefore, a large standard deviation is acceptable. After consulting with KCS, a standard deviation or accuracy of 15% has been set.

To determine the needed sample size, firstly an estimation of the percentage of time spent on each activity is made. After deciding on the allowable standard deviation needed to get a correct indication, the sample size can be determined using the following formula.

$$n = \frac{4p\ (100-p)}{(2s)\hat{}2} \qquad (4.1)$$

Hereby is *n* the sample size, *p* the estimated time-percentage spent and *s* the standard deviation (or accuracy of the measurement).

After timing the different activities and assigning the activities one of the two types of non-value adding activities and value-adding activities, the lean rate can be calculated. Lean rate is the relation between value-added time and the time the product spends in the plant from when it enters until it leaves (Domingo, Alvarez, Pena, & Calvo, 2007).

4.4 Different layout types

After having analyzed the value stream of the current process, the focus can shift to designing solutions for the to be found issues in the process maps. This is the “ideation” phase of the problem-solving model.

After considering with KCS, we determined various solution directions, such as changing the method of planning and a different method of supplying the meals. However, we determined that these directions are impossible to pursue, due to that the supply of meals (by an external supplier) and the planning of flights (done by KLM) is fixed. Therefore, we determined that a solution must lie in changing the work methods of the VLAS-area. This can be done by looking at different basic layout types: these can form a basis for the design of a final solution. So, in this section, the different process types are described and the theory behind choosing a layout type for an operation is explained.

General approaches for designing and managing processes are called process types. The differences between these process types are largely explained by the different volume-variety positions of these types. Slack et al. (2010) identify five different process types.

Project processes
Highly customizable products are usually dealt with by project processes. The production time for this type of product is relatively long. This process is characterized by having products with a high variety (highly customizable) and a low volume. For example, in shipbuilding: a ship has a high variety of components, and is built in a low volume. A lot of the company’s (human and financial) resources are then spent on building one certain ship: a project.

Jobbing processes
Jobbing process are quite similar to project processes, however, in jobbing processes each product shares the operation's resources with many others, whereas project processes have resources that are more or less exclusively dedicated to a certain job. Jobbing processes are likewise characterized by high variety and low volume. Within this type of process, the volume is slightly higher due to the fact that the items are usually a lot smaller in size, but the degree of repetition is low. Many jobs are probably 'one-offs'. For example, a craftsperson uses a general-purpose wood-cutting machine for the production of a product for an individual customer. The next product that is made on that machine will be different, possibly for a different customer.

Batch processes
Batch processes are very similar to jobbing processes, but the degree of variety is much lower. In this process, a batch of products is produced each time a production order is executed. Batch sizes can be very small, just two or three, but could also be large and fairly repetitive. This is why this type of process can be found over a wide range of variety and volume levels. For example, in a restaurant kitchen, food is prepared in dishes. All batches go through the same production steps, but each batch is a different dish.

Mass processes
In mass processes, goods are produced in high volume with a relatively small variety. Here, each product is almost the same, but with the possibility of different variants of goods, and is made in large quantities. Activities in mass processes are repetitive and largely predictable. The best example is an automobile plant, here, an enormous number of variants of cars can be produced. Despite this variety, it yet is a mass process, because the variety does not affect the basic steps of production: the cars are still produced in very high quantities.

Continuous processes
Continuous processes go one step further than mass processes: these produce an even higher amount of goods, with often an even lower variety and operate usually for longer periods of time. The process is sometimes literally continuous, when the goods are produced in an endless flow. A characteristic of this process is often a rather inflexible production process with a very predictable flow. For example, the water treatment process almost never stops and performs a narrow range of tasks.

The five processes as described above, are visualized in Figure 4-3. This figure shows the different volume-variety characteristics for each process (Slack, Chambers, & Johnston, 2010). For example, it is easy to see for continuous processes, with its low variety and high volume, that it has a highly repetitive process and, of course, a continuous flow.

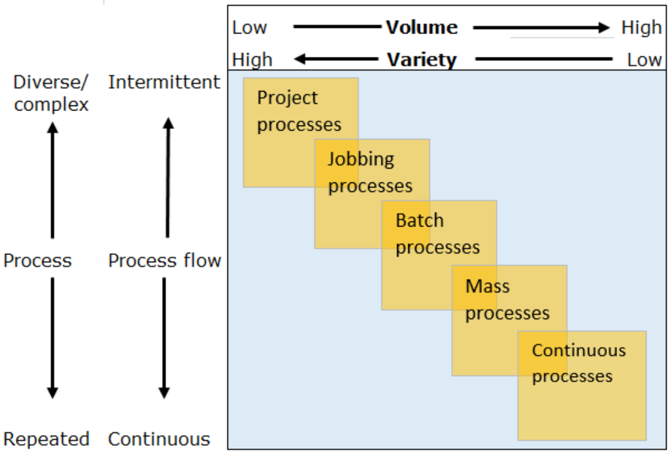

Figure 4-3 - Volume-variety characteristics

To analyze the relationship between the process and the product structure, the product-process matrix can be used (Hayes & Wheelwright, 1979). This matrix gives an indication of the interaction between both structures and provides a basis to choose a type of process to employ. This choice will have impact on the operation, specifically in terms of cost and flexibility.

On the Y-axis in Figure 4-4, the previously mentioned process types are represented. On the X-axis, the variation between volume and variety is shown. Most operations follow the diagonal of the matrix, few are found in the corners of the matrix (Slack, Chambers, & Johnston, 2010). Obviously, there can be an overlap in process types. Then, the operation moves slightly away of the diagonal: if it moves to the right top corner, more process flexibility is needed (so a higher cost). If it moves to the bottom left corner, less process flexibility is required.

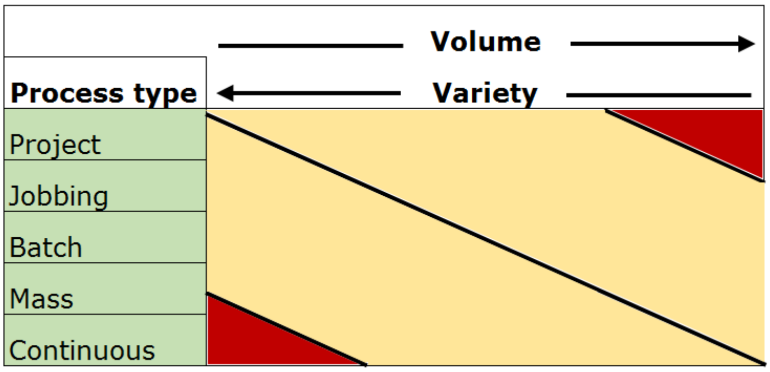

Figure 4-4 - Process types per volume/variety

After the identification of the relevant process type, the layout type can be chosen. A layout is the physical manifestation and design of a process type. Four basic layout types are identified in Slack (2010).

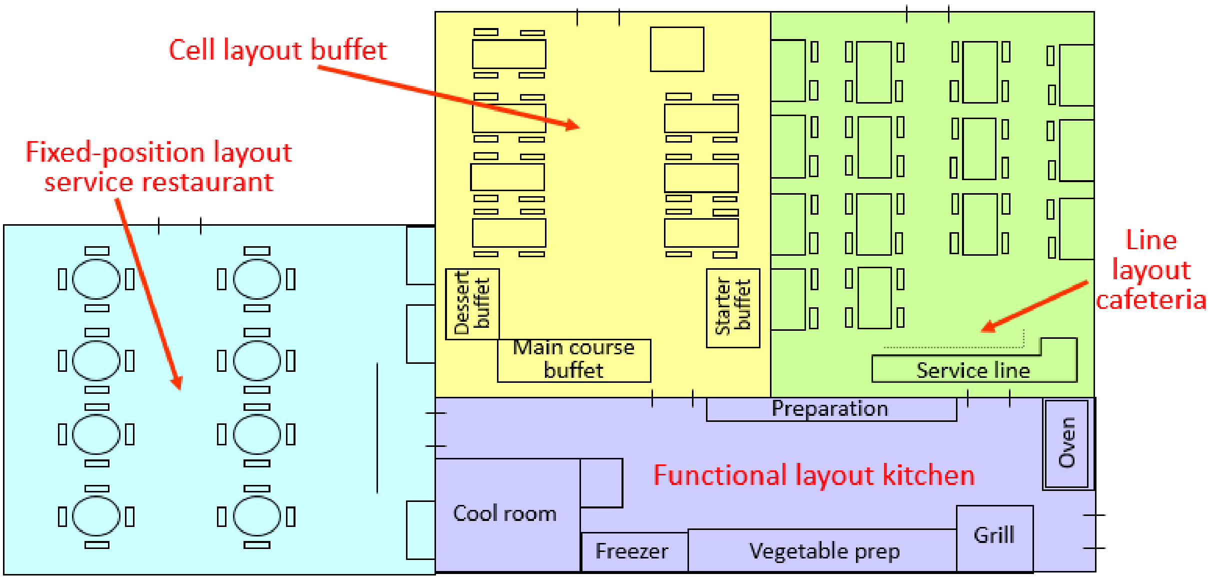

Figure 4-5 - Four layout types in a restaurant complex (Slack)

- A **fixed position layout** is used when the product is physically large, awkward to move and has a low demand. In this layout, the position of the product is fixed and all resources are required move around the product. In Figure 4-5, the customers at the tables are at a fixed position, whereas the waiters (resources) move around the customer.
- In a **functional layout**, resources or processes are grouped together by the function of the process. This could be because it is efficient to group them together or to raise the utilization of a process to a higher level. In such a layout, the route of materials is determined according to their needs. In the kitchen of restaurant in Figure 4-5, a functional layout is used. There, for example, there is a section for the preparation function.
- In a **cell layout**, production work stations and machines are grouped by the products or parts they produce. In this work cell, their immediate processing needs are located. For example, in the restaurant, the different types of courses are grouped together.
- In a **product/line layout**, each product follows a route in which the sequence of activities that is required is the same as the order of location of the different processes. All products made in this layout have the same processing requirements. For example, in the restaurant, a service line buffet is used: each customer follows the same sequence of (in this case) meals, to put together the dish that he requires.

In Slack (2010), the theoretical layout type possibilities for the five described process types are shown. In Figure 4-6, this is combined with the volume/variety characteristics. This figure visualizes the relationships between the manufacturing process types, basic layout types and the characteristics of the products. It is clear that there are different overlaps of layout types for certain processes. E.g., both fixed position and functional layouts can be used for jobbing processes.

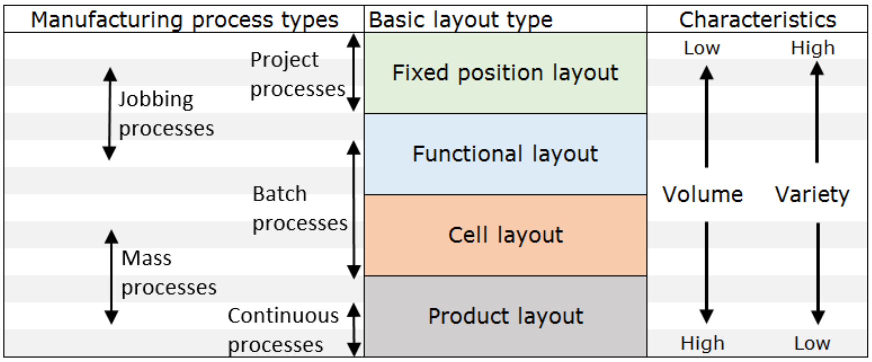

Figure 4-6 - Layout types

After deciding on a type of layout, the specifics must be filled in. For example, the type of material handling systems, the material flow within the design and the several activities the employees must undertake. Within these activities, it is very important to consider the ergonomic circumstances of the work place. According to Genaidy et al. (2007), companies should incorporate the ergonomic approach in a production or assembly system. In both the long and short term this would be profitable, through the reduction of employees' discomfort, pain and fatigue. This would then lead to a better speed of performance and less production errors. Battini et al. (2011) state that integrating a methodological model regarding ergonomic improvements led to improvement in line flow, flexibility and productivity.

In line with this, according to Morgan and Liker (2006), standardization is the basis for continuous improvement. Therefore, in order to reduce variation, the production process should be standardized with the result of a higher flexibility and efficiency, and more predictable outcomes. In addition to this, when the process has a high degree of standardization, it makes it easier for the company to identify and eliminate waste, and continuously improve the process.

As KCS has adopted lean thinking, the tenets as posed by Womack and Jones (1996) (described in section 4.2) can be used as a basis for setting future requirements. They posed five principles for Lean production:

- *Stopping the line* prevents the release of defective work downstream the pipeline. The production line is stopped as soon as a mistake is found out, in order to assure that no defectives are released downstream (Howell & Ballard, 1998).
- *Pulling products* means that a good or service should only be produced when the customer downstream asks for it. Using a pull-based system reduces the WIP that is present in the system, as there are no intermediate stocks.
- *One piece flow* is the logical result of pulling products, it focuses on completing the production of one unit at a time, from start to finish, before starting a different piece for production.
- *Synchronize and align* is a principle about synchronizing the sequence of delivery with the rate of the installation. If this is not done, large on-site material inventories and installation inefficiency are created.
- *Transparency* is about the visibility of the state of the system for the people making decisions throughout the production system.

4.5 Throughput time reduction

One of the goals in lean manufacturing is reducing throughput time of products. According to Hopp et al (1990), this has a positive influence on the company's performance in many ways. Orders can be delivered to the customer in a shorter time and less forecasts about future demand will be done. Reducing throughput time leads to a higher flexibility in the production, through having more opportunities for a change over. Subsequently, costs of inventory carrying and material management may fall and faster feedback will reduce the amount of scrap and rework as well as the need for safety stock in the FG inventory (Lieberman & Demeester, 1999).

The throughput time is calculated through the following formula:

$$throughput\ time = wait\ to\ move\ time + move\ time + wait\ for\ parts\ time + set\ up\ time + production\ time + queue\ time$$

Whereas, applied to KCS context:

Wait to move time: time the trolleys are waiting upon transportation to the next stage in the process

Move time: retrieving the trolleys and meals

Wait for parts time: time employees are waiting for equipment or meals.

Set up time: setting-up the trolley with equipment at C-class MND

Production time: time spent stowing meals in the trolley

Queue time: time a trolley spends waiting to be filled with equipment or meals

A high throughput time leads automatically to the existence of long queues and therefore a longer waiting or queueing time. This has a result of a higher Work in Progress inventory, which can be calculated using Little's law:

$$N = \lambda * T \qquad (4.2)$$

Whereas

N = number of products in the system
λ = average number of products entering the system in a certain time period
T = average throughput time

As can be concluded from Little's law, there is a vice versa influence of WIP on the average throughput time. Reducing the WIP can lead to a shorter lead time and increased labor productivity (Lieberman & Demeester, 1999).

Next to reducing throughput time and therefore the WIP, it is vital that the work load for employees is well spread. For that, the concept of Heijunka can be used. This Lean term is defined as 'the distribution of production volume and mix evenly over time'. This can be useful when e.g. implementing an assembly line: Heijunka creates more predictable manufacturing processes and therefore brings stability to a manufacturing process (Dennis, 2007).

4.6 Analytical Hierarchy Process

In the final phases of the problem-solving model, the concepts generated in the ideation stage (using the layout types and Lean principles) are evaluated, improved and selected. For this, the Analytical Hierarchy Process (AHP) can be used. This is a theory that uses pairwise comparisons to give priorities to criteria and alternatives.

Saaty (2008) composes the AHP into the following four steps:

1. Define the problem and determine what kind of knowledge is sought.
2. Structure the decision hierarchy top-down with the decision goal to the criteria, to the lowest level (the alternatives).
3. Construct the pairwise comparison matrices to compare the different criteria that are set and set priorities between them.
4. Using the constructed matrices, prioritize the different alternatives and continue this process of comparing until all priorities of alternatives are obtained.

To simplify the above: firstly, the criteria to judge the alternatives on must be set-up and agreed upon with all participants in the AHP. Then, using the pairwise comparisons, the criteria are compared against each other and priorities (weighing factors) are given to each criterion. The next step is then to compare the alternatives against each other per individual criterion. By then multiplying the weighing factors of the criteria against the scores of the alternatives, the final score per alternative is calculated.

Saaty (1980) described the fundamental scale of absolute numbers, that can be assigned to comparing the criteria or alternatives, as shown in Table 4-1.

Table 4-1 - Fundamental scale of absolute numbers

Intensity of importance of (a_{ij})	Definition
1	Objectives *i* and *j* are of equal importance
3	Objective *i* is weakly more important than objective *j*
5	Objective *i* is strongly more important than objective *j*
7	Objective *i* is very strongly or demonstrably more important than objective *j*
9	Objective *i* is absolutely more important than objective *j*
2, 4, 6, 8	Intermediate values

Because of the many pairwise comparisons, inconsistencies can arise. For example, when criterion 3 is considered strongly more important than criterion 2, criterion 2 is more important than criterion 1, but criterion 1 is more important than criterion 3, an inconsistent comparison has been made. Therefore, in AHP, a consistency check has been incorporated.

The Consistency Index (CI) can be computed by calculating the average of the elements of the different vectors in the matrix and subtracting the number of criteria:

$$CI = \frac{x-n}{n-1} \qquad (4.3)$$

When the comparisons are done completely consistent, the CI would be 0. However, a small value of inconsistency is tolerated. The to be tolerated value is when:

$$\frac{CI}{RI} < 0.1 \qquad (4.4)$$

Whereas RI is a Random Index, dependent on the number of criteria or alternatives that are compared against each other.

Table 4-2 - Random indices

n	2	3	4	5	6	7
RI	0	0.58	0.9	1.12	1.24	1.32

In the end, when all pairwise comparisons have been done consistently, the weight of each criterion can be multiplied with the value of an alternative on that criterion. The result of this would be a score for each different alternative, where the alternative with the highest score is considered to be the best.

4.7 Conclusion

In this chapter, we used literature to answer the research questions.

- We found a framework in the Hicks problem-solving model, which first regards the mess and finds a solution after performing several steps. Using this problem-solving model as a basis, for each step, literature is searched.
- To identify the amount of waste in the process, different types of lean waste are specified and a way to measure it is proposed.
- For the next step, designing concepts as a solution, different layout types are described, to create a good link between a theoretical layout and the characteristics of VLAS.
- For the measurement and selection of the to be proposed solutions, the Analytical Hierarchy Process is described.

5. Alternatives

In this chapter, we reach the ideation phase of Hicks problem-solving model. Before moving to the designing stage, we determine the future requirements for the solution in 5.1. In order to get to the design of concepts for solving the found bottlenecks, we perform a brain writing session with all stakeholders, as mentioned in 5.2. In combination with this, we generate concepts using literature, i.e., the type of process that theoretically is linked to VLAS. For the individual problems at several work cells, we design quick, easy to implement wins, as described in 5.3. After that, for the entire layout at VLAS, designs are described in 5.4.

5.1 Future requirements

Before starting the process of generating alternatives as a solution to the previously found problems, future requirements must be set. These requirements, in combination with the found core problems, will provide a solid basis in order to come up with solutions of good quality. The requirements will also serve as criteria to judge the future solutions upon, as there probably will not be a solution that ticks all the requirement-boxes. The following requirements for the solutions are set:

- The demand of the customer, KLM, must be met. This means that the amount of trolleys, meals and passengers that are scheduled for production, according to the demand of KLM, can be produced within a certain specified time period. In other words: the minimal production capacity of **52 flights per day** must be reached.
- Following up on this, it would be ideal to keep the future growth in demand of KLM in mind. The number of passengers that fly KLM will probably grow in the future, so the capacity of KCS should grow accordingly. Therefore, a growth in productivity of **4%** should be reached, which is the target for KCS in general.
- The Work in Progress inventory (WIP) should be reduced to the **trolleys of one flight**, to reduce the chance that (the contents of) containers or trolleys are damaged or go missing. Next to that, a lower WIP will lead to a clearer overview in the process and will free up some necessary floor area.
- The lean rate of approximately 55% should **increase to 65%.** This means that relatively more value-added time will be used. This will lead to a more efficient process and savings of time and money.
- The chance that mistakes occur should be minimized. This means that the number of ED-runs and CCs should approach **zero**.
- KCS wants to complete the production of a flight as short as possible before the flight takes off. Therefore, the throughput time per flight should be **less than 30 minutes**.
- The on-time deliveries percentage should be **above the target of 92%** for all work cells.
- The moment of scanning a production card should be done at the **right moment** in the process. This will lead to a more constant communication stream to the distribution department, as well as more insight in the trolley completion data for analysis.
- Work cells should **no** longer have a **high ergonomic health risk**.
- The quality of the products, regarding the HACCP temperature checks, should be kept at **98%.**

5.2 Brainwriting session

In Chapter 3, potential for improvement for each work cell is described. These are either bottlenecks or problems that are applicable to all work cells or aspects that are specific for a work cell. In a brainwriting session with all stakeholders of the operation, for each problem and situation, solutions were generated. In this session, we firstly looked at the individual problems at the work cells. These solutions, i.e., quick wins, can be implemented anyhow, regardless of the eventual general layout, and could be done quickly. After that, we looked at the overall VLAS-process, and designed solutions to further improve the performance.

In the brainwriting session, ideas were generated regarding the following topics:

- Reducing batch size
- Reducing transportation time
- Reducing time spent on scanning and ensuring uniform scan data
- Minimizing rework
- Reducing throughput times
- Improving ergonomics for each work cell
- Reducing time spent on sorting containers at silverware

Figure 5-1 – Brainwriting session

After the brainwriting session, a total of 77 ideas were formed, as shown in Appendix VII. As described in the literature, the process of diverging and converging in a such a session is vital. Therefore, after diverging in the generation phase, all ideas were all judged on their individual impact on the performance of the operation and the ease of implementation. After considering the other stakeholders in the operation, several concepts were selected from the brain writing session, to be designed in further detail. These concepts are described in the following sections.

Next to (small) concepts for improving VLAS, generated in the brainwriting session, several layout designs are created to improve the general VLAS-process. For the design of these layouts, the layout and process types, the future requirements (as described in section 5.1) and the Lean principles as posed by Womack and Jones (1996), described in the theoretical framework are kept in mind.

5.3 Quick wins

Firstly, we describe the quick/small wins. These wins are ready for implementation right away and most of these are applicable to any future layout design.

5.3.1 Silverware flow rack

As mentioned before, the throughput time and batch size in the silverware work cell are high. The silverware employee first spends 25% of his time on retrieving and sorting the containers on each CTR. Next to that, the number of mistakes made here is relatively high. Finally, the most important aspect that has to be improved in this work cell are the ergonomics here. We knew that, in order to realize an improvement, employees must be able to stow the products in the containers at a normal working height, and not on the floor.

In the brainwriting session, we thought about ways to produce at a more ergonomic height: for example, through a conveyor belt or a lifting table. Furthermore, to reduce the throughput (and waste) time, several ideas were generated. Through combining ideas from these two categories, we designed a solution to create a better flow in the work cell.

Figure 5-2 - Squared Container (SQC)

Figure 5-3 - Standard Container (STC)

Figure 5-4 - CTR

Recall from 2.2.5 that in the current situation, CTRs and containers (shown in the figures above) go through a washing machine quite far from the silverware work cell, whereas the items and drawers go through the washing machine located at the silverware work cell. The transportation of the CTRs from the washing machine to the silverware work cell takes up a lot of time that does not add value, which offers potential for improvement. Furthermore, we mentioned that one employee continuously fetches items from the washing machine at the work cell and puts these into totes. Another employee builds a stack of drawers and items, whereas the third employee picks up the CTRs and transports them to the silverware work cell and stows the drawers and items into the containers.

As mentioned, we tried to use the potential for improvement by minimizing transportation distances. Therefore, in the new layout, instead of washing the CTRs and containers at the washing machine that is far away, we will wash the containers at the silverware washing machine, together with the other items. The CTRs will go through the trolley washing machine, next to the silverware work cell (location 4b in Appendix I). Doing this, employees will not have to walk the long distances to the other washing machine anymore. Furthermore, we examined the hygiene quality of a container in a laboratory after putting it through the silverware washing machine. It appeared that the container is significantly cleaner, compared to putting the container through a trolley washing machine.

In Figure 5-5, the newly designed silverware layout is shown (with the current layout visualized in Figure 2-24.

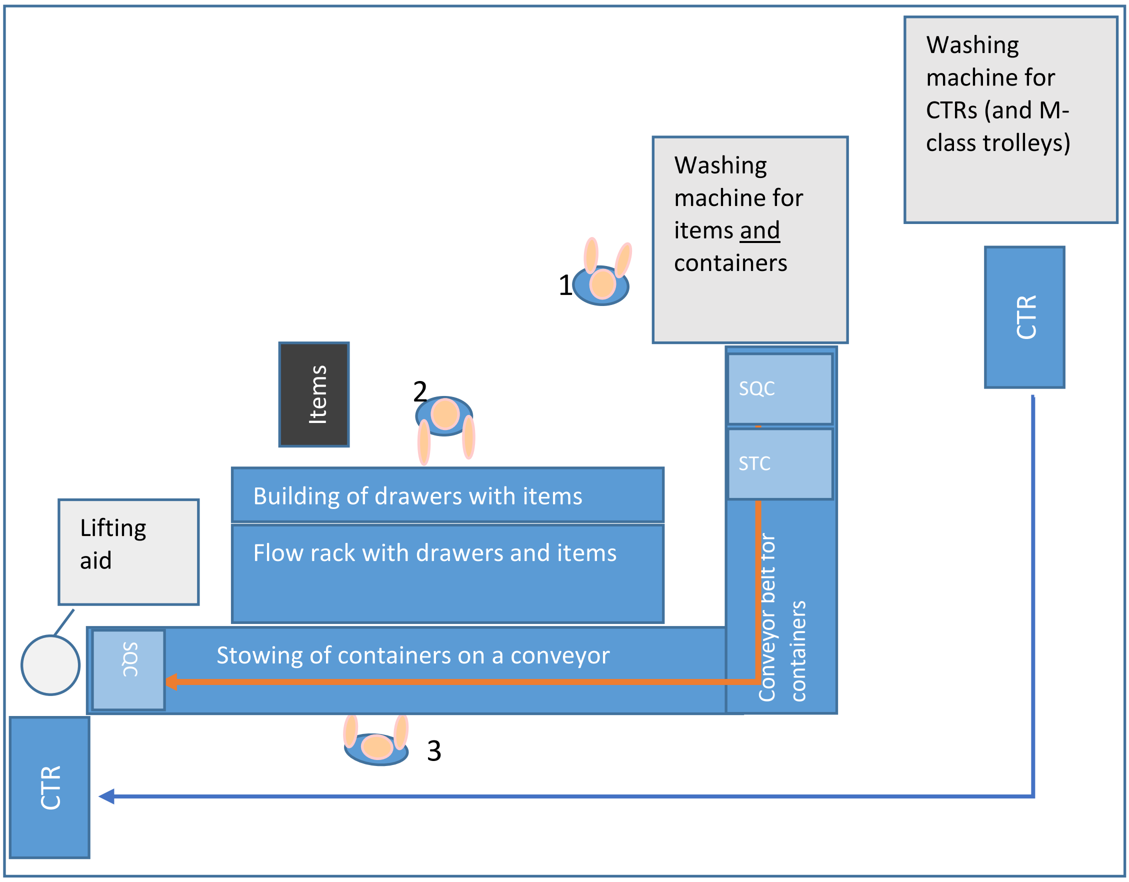

Figure 5-5 - New silverware layout

In the new layout, a flow rack for drawers and items will be set-up, as well as conveyor belts for the transportation of containers to the flow rack. The concept for this is that the flow rack contains set-up drawers that can be put into a container directly, next to the individual items. The drawers and items in the flow rack must be used frequently. Less frequently used items will be placed outside of the flow rack. Employee 3 then fetches a container from the conveyor belt, and during his passing of the flow rack, he can stow the drawers and items in the container. This results in a big ergonomic improvement, as all work activities are performed on a better working height, and not anymore on the floor.

The CTR, on which the completed containers will be put, is fetched from the trolley washing machine near the silverware work cell and will be placed on the floor at the end of the conveyor belt. The completed containers will weigh over 10 kilograms, which is too heavy to lift manually. Therefore, a lifting aid is placed at that location, to lift the containers from the conveyor belt on the CTR.

The use of a conveyor belt (which will be longer than the flow rack for a small buffer for finished containers) and a lifting aid, results in a reduction of the amount of time spent on sorting the containers per CTR and therefore a shorter throughput time. This reduction can be achieved by completing all containers that should be placed on one certain CTR, and buffer these at the end of the conveyor belt. Using the lifting aid, the container that should be on the bottom of the CTR can be placed first, and so on. For example, a CTR needs four containers with different contents. Employee 3 then builds the four containers, and buffers them at the end of the belt. Using the lifting aid, he can sort the containers easily.

In this new layout, there are still three employees at the work cell (as per the numbers in the figure). Employee 1 is still continuously fetching items from the washing machine and puts these into totes, but he also puts the containers that come through the machine on a conveyor belt for containers. This conveyor belt transports the containers to Employee 3, who stows the drawers and items in the container. These containers are then placed on a CTR. Furthermore, Employee 2 has the responsibility to continuously fill the flow rack, to supply Employee 3 with items and drawers that are needed.

With this new silverware work cell design, there will be a better flow of containers and items. Through this and because of the reduction of the batch size from 15 CTRs to a batch size of the CTRs for one flight (between 4 and 6 CTRs), the throughput time will be reduced. Also, the sorting time and transportation time are reduced significantly. Most importantly, the performance on ergonomics regarding the repetitive movements for the upper body will improve heavily, because all activities can be done at a good working height.

5.3.2 C-class juice & hot snack division

As mentioned in section 3.2, the pace of two employees in the C-class juice & hot snack is not aligned very well. It occurs very often that one employee finishes his batch quicker than the other one, which causes waiting time. In order to prevent this waiting time, it is necessary to create a better synchronization of production time for both employees. To realize this, we thought of methods to create a more even work load for the two employees. For example, it is possible that the employee helps the other employee, when he finishes earlier. This, however, will require more interpretation time from the other employee, to recognize the meal codes. The solution we thought of, was to even out the amount of trolleys of each type between the two employees. This is, the solution as shown in Figure 5-6, with two variants of the division of trolleys on a lifting table.

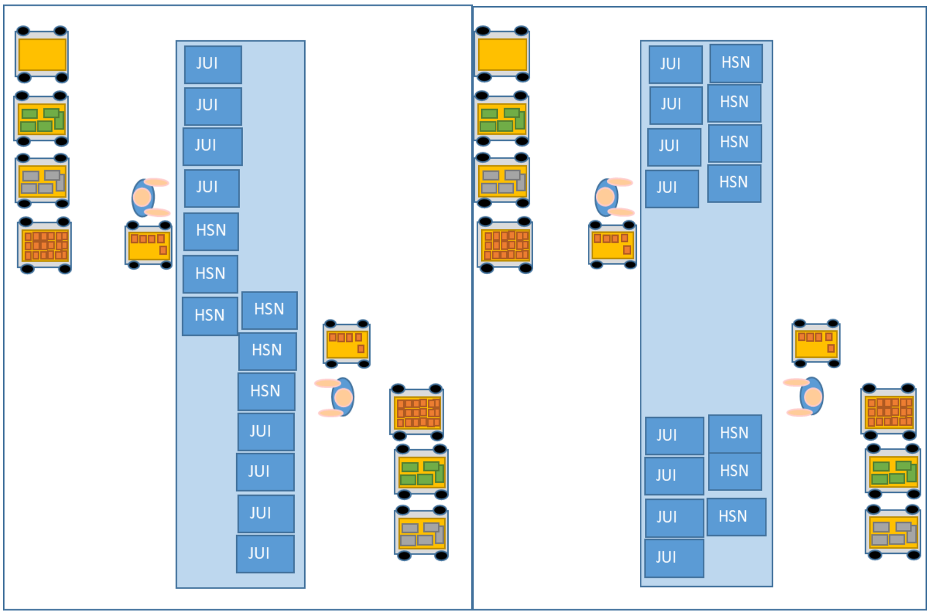

Figure 5-6 - Division A *Division B*

In both variants, each employee produces one flight at the time, on the same lifting table. In Division A, one employee is responsible for the trolleys on the left or right side of the table. At Division B, the trolleys are placed in a different way: the employee is responsible for the trolleys on the upper or the down side of the table in the figure. Averagely speaking, this would result in both employees producing the same amount of trolleys on a day and therefore lead to a better alignment of the time spent on a batch per employee. If there is a better balance of this work time on a batch, it would lead to shorter or no waiting time for an employee.

There is a small difference in principle between the two variants. In variant A, all trolleys for a flight are placed on either the left or right side of the table. This results in shorter walking times from the supply of juices and hot snacks to the trolleys, but would require a different way of supplying by GOC. In the current situation, the supply of juices and hot snacks is on one side of the table, but in variant A, the supply should be on both sides.

In variant B, there would be no change in the method of supply, as the hot snack supply remains on one side and the juice supply on the other. However, this way the travel distances for the employee to reach both types of trolleys would be higher, because he has to walk round the table. Also, longer distances will occur, to travel to and from the supply of products.

If it is possible for GOC to implement the change of supply for the juice and hot snack trolleys, variant A would be preferred over variant B, due to the shorter travel times. This variant would lead to shorter waiting times, and, also because the batch sizes are reduced significantly, the throughput time would be much lower than originally.

5.3.3 Ergonomics at M-class main dish & hot snack

Recall that an ergonomic study showed that the ergonomics at the M-class main dish & hot snack work cell are poor, due to lifting two or three totes containing meals on two empty crates, to make sure that the employees can pick the meals from a good operating height. These totes weigh over 10 kilograms, so it is physically tough to do this every time. To deal with this, we thought of ways to prevent the employees from lifting the totes manually. Therefore, a mobile lifting aid (Figure 5-7) is designed, using the idea of a lowerator.

Figure 5-7 - Mobile lifting aid

The totes are placed on a small wheeled chassis, which is used for the transportation of the trolleys. This chassis, with the stack of totes, will be placed on an automatic lifting aid (as shown in the figure). This lifting aid brings the totes on a preferable operating height, so that the employee can pick the meals from the tote easily. When the upper tote is empty, it is removed from the stack and placed on a different empty wheeled chassis, that will be brought back to GOC. The lifting aid then lifts the stack of totes back to the operating height, and the employee can proceed with stowing the meals.

The lifting aid improves the ergonomic circumstances of the work cell, because the employees do not have to lift heavy totes and put them on an empty crate. It might even reduce the throughput time, as the automatic lifting saves the employee time. If the lifting aid is received positively by the employees at the M-class work cell, it could also be applied to the other work cells.

5.3.4 Visualization

Production progress

As we stated in 3.3, shift leaders have no good overview of the production progress over the day. The only way employees can regard their progress is checking whether the block number on the production card, placed on the trolley they are working on, corresponds with the block number they are in at that time. But even then, they do not know exactly the amount of trolleys that are still coming up in that block. For this, we looked at existing and quick to implement methods (possibly at other companies) to visualize the progress.

We propose two options. The first is to place a monitor that visualizes the production progress over the day. For example, the number of flights that are scheduled for a certain block, and whether these have been completed can be shown. An easier and quicker way is to introduce a (physical) planning board, which contains the production cards for each flight in each block. If an employee starts producing a specific flight, he picks the production cards for that flight from the board, and starts filling the trolleys, and so on. This way, it is very easy for the employee to see the amount of flights that are left for a certain block, and whether they are on schedule for the day.

Trolley contents

Furthermore, we stated in 3.3 that mistakes are made because of wrongly interpreting the meal codes. It firstly takes time to interpret the meal codes, but these codes also look very much alike. According to KLM, it is not possible to use meal codes that distinguish themselves more and therefore are easier to read. Therefore, we thought of different ways to reduce the probability of making a mistake because of misreading the codes.

A method for this, is to place monitors above a lifting table that show the type and number of meals that should be stowed into a trolley. So, before the employee starts with a certain trolley or with a flight, the production card should be scanned for the system to know which trolley the employee is working on. It is then shown on the screen that, for example, 10 pizzas and 18 hamburgers should be put into the trolley. This visualization type can be applicable to any work cell and would reduce the number of mistakes significantly. Also, the interpretation time for each card would be reduced, as the employee does not have to memorize every article code.

5.3.5 Champagne bottles

At the C-class juice & hot snack work cell, the ergonomic circumstances regarding the lifting aspect are poor. This is mainly due to the lifting of drawers with bottles of champagne, which are heavy. These drawers are built at NF&B, and are placed on a roll container which is then transported to ICA Food. For the employees, this is tough, as those drawers have to be lifted from a very low height, which is very demanding of their backs.

To improve the ergonomic performance on this aspect, we looked at ways to prevent this heavy lifting of drawers with the bottles. Our solution is to not deliver the drawers containing champagne bottles, but to supply the champagne bottles and the drawers separately. The champagne bottles should be delivered in their original boxes, so that employees can pick the bottles separately. The empty drawer will be placed in the C-juice container, after which the employees stows the champagne bottles in the drawer one by one. This reduces the toughness of the lifting and results in improved ergonomics at this work cell significantly.

5.4 Layout designs

In the previous section, we described the quick wins, that are (generally) applicable to any future layout that is designed. For the design of these layouts, the different Lean principles and future requirements are kept in mind, next to the manufacturing process- and layout types that have been described in Chapter 3.3.

To determine the process and layout types that are applicable to the VLAS-process, the volume/variety characteristics must be regarded. The volume that flows through VLAS, i.e. the number of main dishes, hot snacks, rolls and juices, can be regarded as high. For example, the M-class work cell can serve meals for as much as 25.000 passengers a day.

Trolleys can have a lot of different contents: the type of meals and the number of meals can vary. However, the process for the employee is always the same: the employee only has to put the meals in the trolley that are delivered to the work cell. Therefore, the variety hereby is relatively low.

According to the theory, the basic layout types that go with a low variety and high volume are a cell and a product layout. Then, looking at the process types, a batch process and a mass process can be selected. A continuous layout does not fit to VLAS, due to the varying contents of the trolleys. Therefore, designs were created using a cell- and a product layout, with varying processes in them. Furthermore, there are two different methods of transportation in the design of a work cell. One is with the principle of bringing the meals and juices to the trolleys (in cell), whereas the other is to pull the trolley to that supply (in product).

Using all these process and layout types, lean principles, future requirements and transport principles, we designed 8 different layout alternatives. In Table 5-1, the layouts and their characteristics are described. In the following sections, we will explain each layout in further detail.

Table 5-1 - Layouts with characteristics

Layout	Layout type	Process type	Supply	Transport principle
1: Flight specific production without a physical modification	Cell	Batch	Flight specific	Meals to trolleys
2: Flight specific production and split-up lifting tables	Cell	Batch	Flight specific	Meals to trolleys
3: Added cooling area to layout 2	Cell	Batch	Flight specific	Meals to trolleys
4: Individual work cells	Cell	Batch	Flight specific	Meals to trolleys
5: Assembly line	Product	Mass	Bulk per block	Trolleys to meals
6: Assembly line with additional cooling area	Product	Mass	Bulk per block	Trolleys to meals
7: Automated Guided Vehicles	Product	Mass	Bulk per block	Trolleys to meals
8: Supermarket	Cell	Batch	Bulk per block	Trolleys to meals

When designing the different layouts, there must be enough capacity to produce the number of trolleys that are produced every day. As there are many different types of trolleys, this number is converted to the T12-size trolleys. For this, the assumption was made that one UTR-trolley consists of two T12 trolleys, two OIS fit in one T12-trolley, and so on. In Table 5-2 the converted average number of T12-trolleys per day and per flight is shown.

Table 5-2 - Converted T12s per day or flight

	T12	
Product	**Per day**	**Per flight**
C MND	168	3.4
C HSN	69	1.8
C DESS	216	4
C PRES	23.5	0.5
C JUI	178	5.9
M MND	287.5	3.4
M HSN	299	5.5
CTR	147	4

Layouts 1 until 4 are designed with the principle of bringing the meals to the trolleys. So, the trolleys are placed on a lifting table and the meals are transported to and around the lifting table. The layout types are work cells using batch processes.

5.4.1 Layout 1: flight specific production

The first layout we designed is one without a physical modification, so that it can be implemented almost immediately. For this layout, we had the goal to reduce the throughput time and the batch sizes. So, the current work cell layout in combination with batch processes will be used. We will still use batching, due to the lifting tables, but will try to reduce the size of the batch. The size of the batch will be the trolleys for one flight: flight specific production. Therefore, the only aspect that will be changed is the control and division of the lifting tables.

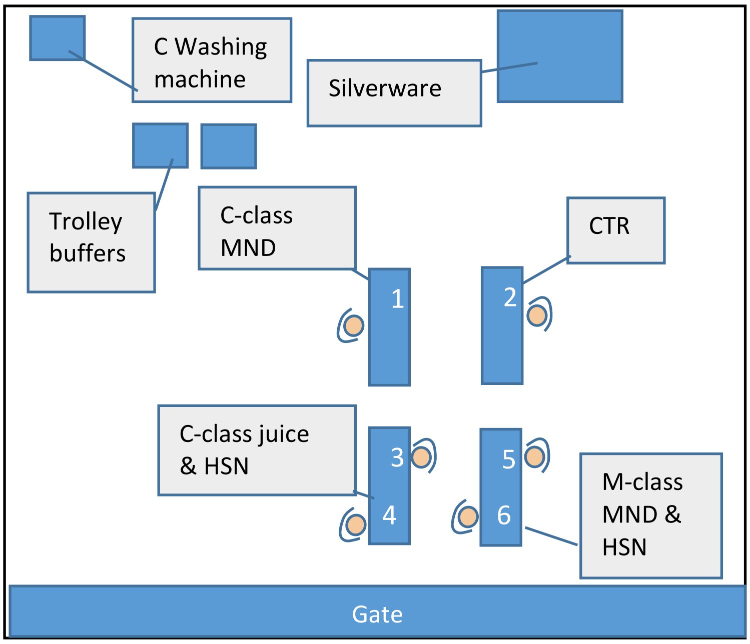

Figure 5-8 - Layout 1

Recall that in the current situation, several flights are produced at the same time on a lifting table. In this proposed configuration, one flight per employee will be produced at a time. So, looking at e.g. the M-class MND & HSN lifting table, there are two em ployees (number 5 and number 6), where each employee produces one entire flight. For this, we will use the same process as it currently is:

1. Each employee retrieves the trolleys for one certain flight and places these on the lifting table
2. He then retrieves the totes containing the meals for that flight
3. And stows these in the trolleys.
4. When the trolleys for the flight are completed, they are scanned and pushed to the gate.

The same goes for the other employees working at the lifting tables. Each employee is assigned to produce a specific flight, so that the employee will be and feel more responsible to produce that flight efficiently and without mistakes. Also, when a mistake has been found, the mistake can be traced back to the employee. This can be used to instruct and improve the employee in his work methods so that the mistake is prevented next time.

- Producing in smaller batch sizes leads to a lower Work in Progress, which means a better overview in the production progress for the day.
- Smaller batch sizes lead to shorter throughput times. It would mean more runs to the cooling area and more trolley pick up runs. However, the time spent on such a run is much shorter. All the meals and trolleys must be searched and picked together, but as the batch size of trolleys (and therefore meals) is smaller, this searching and picking takes up less time. There are more change overs, but change-over times are shorter.
- Using smaller batch sizes results in a quality improvement. As only the meals for the flight that is produced will be picked up on a run, these meals will spend less time outside the cooling area. Therefore, the temperatures will stay below their maximum temperatures more easily.

- A smaller batch size will lead to an ergonomic improvement, due to that employees have to push less trolleys per run.

Looking to the benefits of smaller batch sizes outside of the scope of the VLAS-process, the work load for the employee working at the washing machine and for the employee in the gate to distribution would be more evenly spread. Currently, there are high peaks and lows in their work load. For example, the employee in the gate is waiting for new trolleys. Then, at a certain moment 30 trolleys are transported to the gate, meaning that he has to work very hard to process those numbers, after which he waits for the next arrival of trolleys again. With smaller batch sizes, the employee will be able to work at a more constant tempo.

Drawbacks of this layout are:

- Employees will still have the tendency to keep using the batch sizes that are currently used, because the lifting tables provide the capacity.
- Employees 3 and 4, and 5 and 6 are dependent on each other's processes, as they are working at the same lifting table. This is problematic when one of the two employees at a lifting table finishes his process before the other employee does. He then has to wait until the other process is finished too. This waiting time is a waste.
- The walking distance for employees would increase, as they would have to walk to the cooling area or the trolley storage area more often.
- Regarding the quick wins, it could be difficult to visualize the content of the trolley. To accommodate this, the production card has to be manually scanned each time, before showing the content on a monitor. This extra action costs time and would likely be skipped by employees, as employees tend to memorize every meal code anyway.

The throughput time for this layout is calculated using estimations of the time needed per activity. For this, we simplified the process into five steps:

1. Retrieve trolleys
2. Retrieve meals from the cooling area
3. Stowing the meals in the trolleys
4. Scanning the production cards of the trolleys
5. Pushing the trolleys to the gate

For each type of product, we measured the stowing time per trolley. Using this, and the batch size of trolleys per lifting table employee, we calculated the total time per batch (a batch being the trolleys for one flight). Using this time per batch, the total time necessary per day is calculated, for the different layout options.

Firstly, per different lifting table, we estimated the time per activity. Using these times, the throughput time per lifting table for a batch is calculated, as is shown in Table 5-3.

Table 5-3 - Throughput time estimation per batch

Lifting table		Batch size	Retrieve trolleys	Retrieve meals	Stow meals	Scan	Trolleys to gate	Total mins
1	C MND & HSN	5.2	1.25	1	13	0.5	1	16.8
2	CTR & C PRES	4.6	1	1	12.9	1	2	17.9
3	C JUI & C DESS	7.4	1.25	1	19.2	1	2	24.5
4	C JUI & C DESS	7.4	1.25	1	19.2	1	2	24.5
5	M MND & M HSN	11.4	1.25	1	24.0	1	1.5	28.7
6	M MND & M HSN	11.4	1.25	1	24.0	1	1.5	28.7

Using the time needed per batch, the total time necessary to produce all batches in a day could be calculated. For this, we determined the number of batches needed, by dividing the total amount of trolleys by the batch sizes. By then multiplying the throughput time with the number of batches, the total time necessary per day is estimated, as shown in Table 5-4.

After calculating the throughput times, takt times were calculated. The takt time is the rate at which a batch must be completed: so, the maximum time available to produce a batch. The takt time is calculated by dividing the total available worktime on a day (13 hours), by the number of batches on a day. The estimated throughput times per batch were then compared to the takt times, to check whether production targets could be achieved: throughput time must "beat" takt time.

The throughput time of each batch has been reduced significantly, going from approximately one hour in the current situation, to 17 or 28 minutes. This results in the total time spent per employee on a lifting table, as shown in Table 5-4.

Comparing the sum of the total time spent by employees in this layout (71:37:18) to the total time spent in the current situation (70:06:05), a productivity gain of slightly over 1 hour and 30 minutes can be reached.

Table 5-4 - Output Layout 1

Lifting table	Product	WIP (T12)	# of batches	Takt time	Throughput time	Total time spent
1	C MND & HSN	5.2	45.6	0:16:57	0:16:45	12:43:25
2	CTR & C Preserv	4.6	37.1	0:20:49	0:17:53	11:02:44
3	C juice & C dessert	7.4	26.6	0:29:18	0:24:29	10:51:58
4	C juice & C dessert	7.4	26.6	0:29:18	0:24:29	10:51:58
5	M MND & M HSN	11.4	25.7	0:30:11	0:28:41	12:18:01
6	M MND & M HSN	11.4	25.7	0:30:11	0:28:41	12:18:01
					Total time	**70:06:05**

5.4.2 Layout 2: flight specific production and split-up lifting tables

As mentioned in 5.4.1, due to the size of the current lifting tables, employees could fall back in the pattern of producing trolleys using large batch sizes. Furthermore, having two employees at one lifting table dependent of each other creates waiting time. Therefore, to 'force' employees into producing one flight at a time per lifting table, we designed a layout in which the lifting tables will either be split-up into two or reduced in size. So, for the C-class MND and CTR categories, the lifting table will be reduced in area, whereas for the C-class juice & HSN and M-class MND & HSN, the lifting table will be split up into two. This will also result in a reduction of the throughput time, as employees are not dependent on each other anymore (i.e. no waiting times).

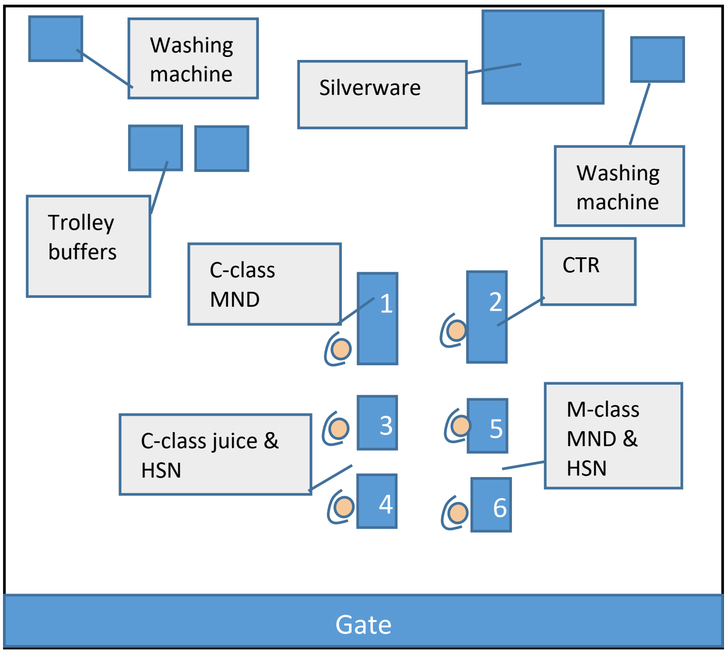

Figure 5-9 - Layout 2

The control for this option is the same as the control at Layout 1: per lifting table, one flight at a time will be produced. This means that the supply from GOC should also be delivered specifically for each flight. In Figure 5-9, the map for Layout 2 is shown.

Ideally, the travel time of the employee will be be reduced as well. Using smaller lifting tables would reduce the distance that the employee must walk, but he would still have to walk around the table very often each day. Therefore, there is a possibility of using a lifting table that can be rotated. In practice, this would mean that the employee first finishes the trolleys on e.g. the left side of the table, then rotates the table and starts on the trolleys that are on the other side.

The performance of this layout would, in a general sense, be very comparable to Layout 1. However, the throughput time will be shorter, through the fact that the two lifting tables of a category would no longer be dependent on each other and the fact that travel times would be reduced through the rotatable lifting table. It is difficult to quantify the time that would be gained through this, so no further calculations are made.

5.4.3 Layout 3: additional cooling area

When looking for ways to further improve Layout 2, we targeted the time spent on the transportation of meals, as this meal run is done very frequently. For this, we added a cooling area to the VLAS-process, as shown in Figure 5-10. Hereby, the same control and layout will be used as in Layout 2. By placing an extra cooling area close to the VLAS-process, travel times of picking up meals from the main cooling will be reduced significantly, as employees won't have to walk all the way to the main cooling as often as currently.

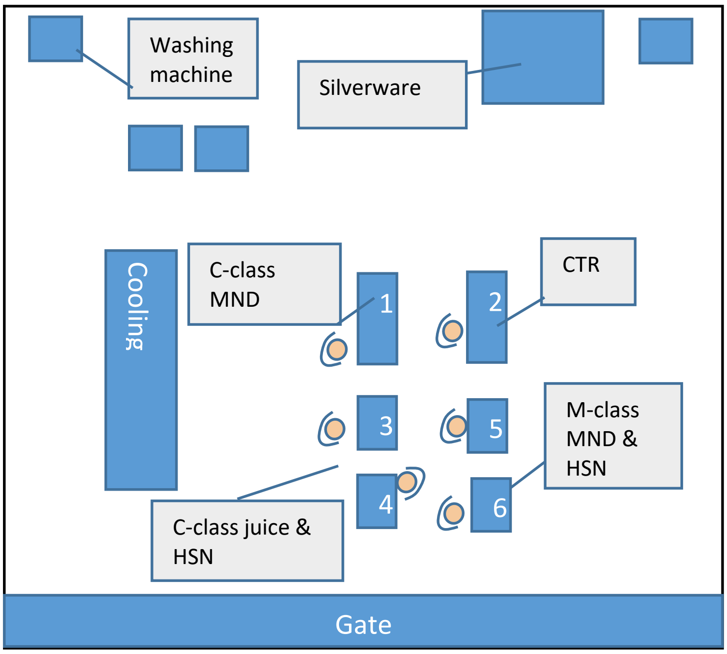

Figure 5-10 - Layout 3

Next to the benefit of the travel distances, the quality performance could be improved. As the cooling is much closer to the lifting tables, it is more beneficial for the employees to place meals, that are not used at that moment, provisionally in that cooling area. This would make sure that the meals would stay below the maximum temperature more often.

Two options are proposed for the type and amount of meals that will be placed in the cooling:

1. Place meals in the cooling that are frequently used in every production block and maintain a Kanban supply method. I.e., these meals are available at all times.
2. Meals are placed in the cooling according to the order of the flight production. These meals must be delivered flight-specifically in totes.

For this, Option 2 would likely be the most appropriate for this layout, as at the different lifting tables the production is also done per flight.

The downside of using an extra cooling area is that it takes up a lot of space, physically and visually, and that it could be quite expensive to implement.

5.4.4 Layout 4: individual work cells

Layout 4 is based on the same idea as the previous three layouts: a work cell is used with a batch process. However, we decided to change the types of products per lifting table. For each product type, an individual work cell is created. The idea is that when an employee focuses on one type of product in the entire shift, the chance of a mistake could be lower. Hereby, the C-class MND & HSN are combined because of the low amount of HSN trolleys that is produced each day. In Figure 5-11, the layout is shown.

The concept for the supply of meals is the same as the other layouts: GOC has to deliver the supplies for each flight specifically, and on each lifting table one flight is produced by one employee.

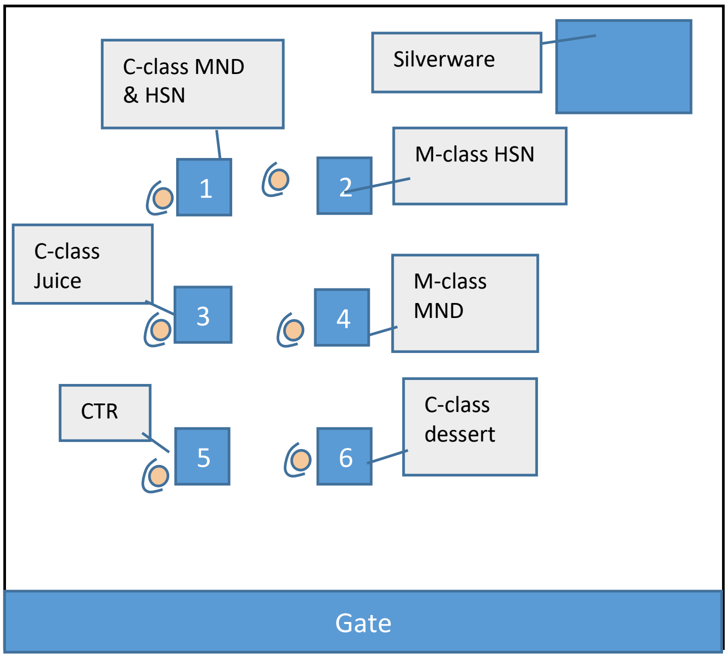

Figure 5-11 - Layout 4

This layout leads to a significant reduction in throughput times, as this is reduced to approximately 15 minutes per work cell, as shown in Table 5-5 (detailed calculations in Appendix VIII). However, when comparing the throughput times to the takt times, it shows that the takt time cannot be reached for three of the six work cells. The reason for this is that the batch size is slightly too small. Through that, the number of batches is higher, so the amount of runs to pick up trolleys and meals is also higher. This way, the higher transportation time cannot be well spread over the low amount of trolleys per batch. Therefore, the production goals cannot be reached, so this layout is not feasible.

Table 5-5 - Output Layout 4

Lifting table	Product	WIP (T12)	# batches	Takt time	Throughput time	Total time
1	C MND & C HSN	5.2	46.0	00:16:57	00:16:30	13:03:45
2	M HSN	5.9	50.7	00:15:23	00:16:53	14:15:57
3	C JUI	3.4	52.4	00:14:54	00:13:41	11:56:11
4	M MND	5.5	52.8	00:14:47	00:16:03	14:00:26
5	CTR & C PRES	4.6	37.5	00:20:49	00:17:23	10:42:18
6	C DESS	4	54.0	00:14:27	00:15:18	13:46:12

The remaining four layouts are designed with the principle of transporting the trolleys to the meals: the meals are placed at a fixed location and the trolleys are transported to the specified locations. Here, a product layout in combination with either a batch or a mass process has been used.

5.4.5 Layout 5: assembly line

As mentioned, according to the theory, a product layout is also applicable to the VLAS-process. Therefore, with the Lean principle of striving to a single-piece flow throughout the production and the use of a mass process, we designed an assembly line. As can be seen in Figure 5-12, there are six different workstations, for each individual type of product. The line is split-up between the C- and M-class, to avoid the employees crossing each other's paths when retrieving trolleys. As the speed through the assembly line will be high, the meals and juices should be supplied to the assembly line in bulk.

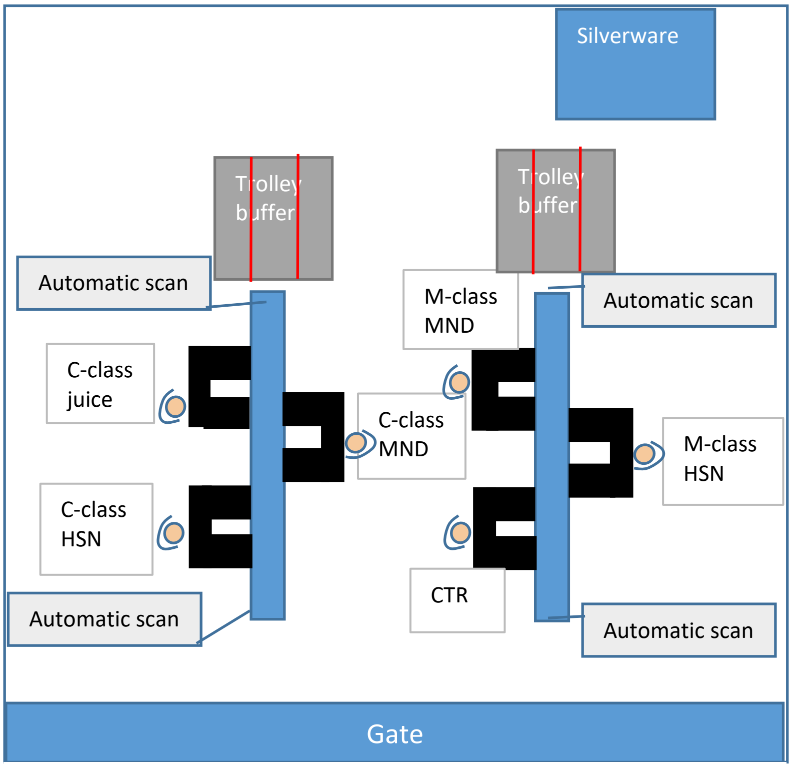

Figure 5-12 - Layout 5

In front of the assembly line, there is a designated area to buffer trolleys and other equipment that will go through the individual work cells. The buffer is split up in three rows, with each row containing the trolleys for one specific work station. The buffer supplies, through a transportation belt, the trolleys to the main conveyor belt.

At the main conveyor belt, the production cards are scanned automatically, so that the information system that controls the assembly line knows the location the trolley must be transported to. Using a roller conveyor belt and a push system, the trolleys are pushed off the main belt to the specified work station. These work stations are not located on the main belt, to avoid congestion of trolleys. This can happen when, for example, the C-class juice employee has finished a trolley, but C-class HSN has not. Then, the juice trolley must wait for the HSN-trolley to be completed, in order to receive a new trolley from the trolley buffer.

On the roller conveyor belt, at each work station, there is a buffer of 3 trolleys, so that the employee at a work station can be producing continuously. When the employee finishes a trolley, a signal is given to the system that it can be transported to the end of the main belt. The two remaining and waiting trolleys on the belt then proceed to the work space of the employee and are then filled by that employee. From the trolley buffer, a new trolley is then transported to the roller conveyor.

At the end of the main transportation belt, there is another automatic scanner, that makes sure the trolley gets the 'finished' notification, and the trolley is then manually pushed to the gate to distribution. Unfortunately, the transportation from the belt to the gate cannot be done automatically, due to that employees must be able to walk through that area.

Compared to the previously described layouts, the visualization of the content of a trolley on a monitor can be implemented more easily, due to the fact that an automatized scan moment is included in the process. Using this scan, the system would know exactly which trolley is located on what place, so that the visualization can be shown for the right trolley. Next to this, because of the automatic scan, a uniform moment for scanning in the entire process has been created, so that the scan data are more reliable for analysis and insight in the progress of the day.

Using this assembly line layout, the transportation of trolleys can be done partially automatically. This results in a lower throughput time and a lower waste percentage, as the employee does not have to transport the trolley anymore. The throughput time for one trolley is between 2 and 3 minutes, as shown in Table 5-6. This is equal to the estimated stowing time for a trolley. For the same reason, the ergonomics will improve as well.

The implementation of such a layout is more difficult however, due to the complexity of designing the control system and the fact that the entire VLAS-area would have to be rebuilt. Furthermore, the (development) costs will be higher.

Looking at the throughput times per work cell, a huge time reduction can be established. Because all main transportation is done automatically, as much as 14,5 hours can be saved, compared to the current situation. However, this is under the assumption that all trolleys and meals are transported to and from the assembly line automatically as well. In practice, this is not feasible, because of the walking paths of employees at other work cells within KCS.

Therefore, a dedicated runner must be added to the process. He will make sure that all trolleys are pushed to the trolley buffer and that all meals are transported to the work cells. The amount of FTE that the runner should be accounted for is very hard to estimate. This should be tested and simulated, in order to make a good estimation. In Table 5-6, the throughput time and total time spent is shown (detailed calculations in Appendix VIII).

Table 5-6 - Output Layout 5

Lifting table	Product	WIP (T12)	Takt time	Throughput time	Time spent
1	C JUI	3	0:04:23	0:02:42	08:00:36
2	C MND	3	0:04:39	0:02:42	07:33:36
3	C DESS	3	0:03:37	0:02:42	09:43:12
4	M MND	3	0:02:43	0:02:06	10:03:45
5	M HSN	3	0:02:37	0:02:06	10:27:54
6	CTR & C PRES & C HSN	3	0:03:15	0:02:48	11:10:36
				Total	56:59:39

5.4.6 Layout 6: assembly line with extra cooling

When further improving the assembly line, again a cooling area is added to the process, likewise to Layout 3. (Figure 5-13). This is done in order to reduce the transportation times of meals even more, as well as to realize an improvement in the temperatures of the meals.

The pros and cons of adding a cooling to the process are described in section 5.4.3.

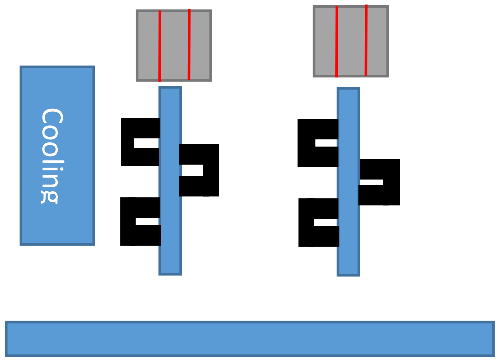

Figure 5-13 - Layout 6

5.4.7 Layout 7: Automated Guided Vehicles

After designing the assembly line, we aimed to automate the transportation process of trolleys even more. Because if doing so, employees can focus more on the stowing of meals into the trolleys, which will have positive impact on the mistake probability and on the throughput time. Therefore, to fully automatize transportation of trolleys and equipment, we use Automated Guided Vehicles (AGVs), with the layout shown in Figure 5-14.

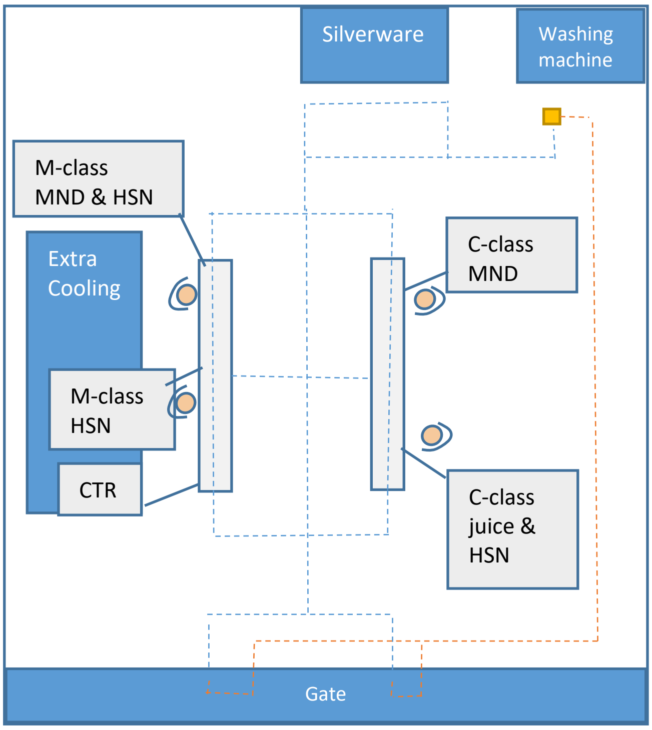

Figure 5-14 - Layout 7 (number of employees must be calculated)

In the process, the AGV picks up the trolley at the washing machine. Through implementing RFID chips in the trolley, the AGV will know the type of trolley and the assigned destination. By following the predestined paths to the several locations, the trolley arrives at one of the work cells, at which the meals or items will be stowed. After receiving the indication by an employee that the trolley has been fully stowed, the AGV transports the trolley to the assigned location in the gate. Then, the AGV is empty, so it travels back to the washing machine and picks up a new trolley, and the process restarts.

Here, single-piece flow can be realized, as each AGV transports one trolley per time. This would mean a significant throughput time reduction for a trolley. However, it could be more efficient to increase the amount of trolleys per AGV: using small batch sizes. For example, if all M-class HSN trolleys for a certain flight are transported to a work cell using one AGV, the employee can fetch the types of hot snacks assigned to that flight from the cooling area and stow them. Through this, the throughput time for an entire flight could be reduced, compared to the situation now.

Obviously, the benefit of this solution is that the transportation of equipment is fully automated, so that employees should only focus on stowing the trolleys. Through this, the throughput time will be reduced significantly. Furthermore, the workload for employees (at the washing machine, VLAS and at the gate) will be more levelled out, through removing the use of large batches.

However, the implementation of such a system would be difficult. Firstly, due to the somewhat more sophisticated technology that is linked to a good control of the AGVs. Secondly, because of the higher costs that go with this system. Furthermore, too many walking paths of employees will be crossed, as other work places within KCS will not be automated in such a degree. Thirdly, there is not enough floor space to implement this system in a good way.

The use of such a system might be very interesting for KCS in the future, when it is necessary to move out of the current location, due to the growth of Schiphol Airport. Then, there is an opportunity to redesign the entire logistical process. However, this solution is not feasible for application in the current situation, for the reasons mentioned before. Therefore, no calculations regarding throughput times and WIP have been made. But, by logic, the throughput times and productivity improvement will be a bit better than the output of the assembly line. This is because of the degree of automatic transport is is higher (by AGVs), the only time employees 'touch' the trolleys, is when stowing the products.

5.4.8 Layout 8: supermarket

For the final option, we were researching ways to create a production layout, based on one of the Lean principles: pull. The concept of a supermarket is used for this, which is one of the pull strategies within Lean manufacturing.

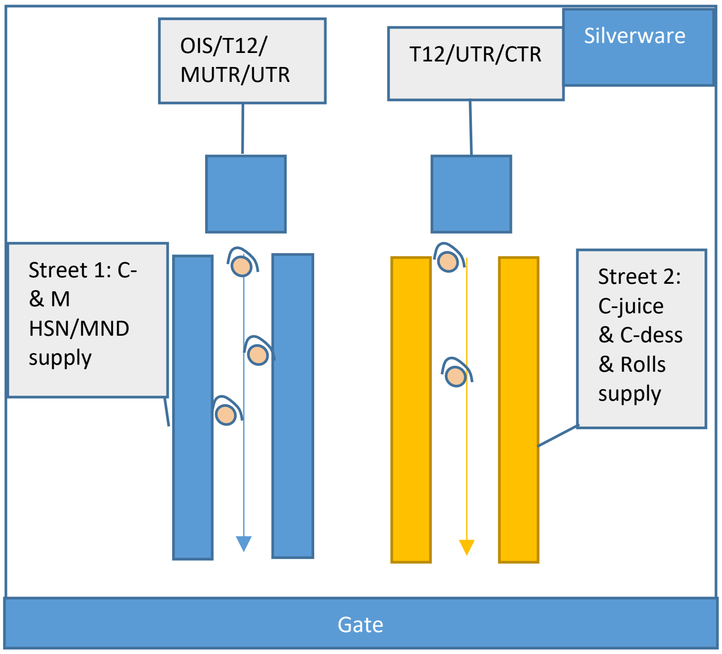

Figure 5-15 - Layout 8

In Figure 5-15, two production 'streets' (supermarkets) are shown. In Street 1, two cooling areas are placed, containing supply for C- and M-class MND and HSN (the blue rectangles). In Street 2, the C-class juice and dessert, and supply of rolls has been placed in a cooling. The equipment (oven inserts, T12, UTR, MUTR and CTR) is placed in a buffer in front of the supermarket. The concept of the supermarket is then to pull the trolley through the supply. So, the employee picks a trolley with a specified production card from the buffer, and travels to the places in the cooling where the meals for that trolley are located. After stowing the trolley, he pushes it to the right place in the gate and walks back to the trolley buffer, and the process starts again.

In order to have sufficient meals in the cooling area of the two streets, there should be continuous replenishment. A Kanban-system will be used for this. Every type of meal will have its own location, based on the frequency of use for the type of meal. For example, the fast runners should be placed close to the trolley buffer. If the stock of a type is running below a certain threshold, a signal (Kanban) will be sent to the runner, who will have to replenish that meal in the cooling.

To determine the optimal batch size, the average time used per trolley in a certain batch size is calculated, here exemplified for Street 1. Using an estimation of the time necessary for retrieving ovens, stowing an oven, transporting the oven to the gate and walking back to the buffer, the optimal batch size could be determined. Included hereby is a batch factor: this is the extra time needed when increasing the batch size: for example, a higher batch size leads to a higher chance of rework, as well as a higher interpretation time and more transportation time. The batch factor was, after consideration with KCS, set at 1.03, which is multiplied with the stowing time. In Table 5-7, this is shown.

Table 5-7 - Determining the optimal batch size (seconds)

Batch size (ovens)	1	2	3	4	5	6	7	8	9	10	11
Retrieve ovens	20	20	20	20	20	20	20	20	20	20	20
Stowing products	70	140	210	280	350	420	490	560	630	700	770
Batch factor (sec)	1.4	5.7	12.9	23.1	36.4	53.0	72.9	96.1	122.9	153.3	187.4
Transport oven to gate	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0
Returning to buffer	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0
Total time	**131.4**	**205.7**	**282.9**	**363.1**	**446.4**	**533.0**	**622.9**	**716.1**	**812.9**	**913.3**	**1017.4**

So, having determined the total time needed for a certain batch size, the average time used for filling an oven insert in a certain batch size was calculated. This is shown in Figure 5-16. Here can be concluded that the optimal batch size for Street 1 is 6 oven inserts, as the average time there is the lowest.

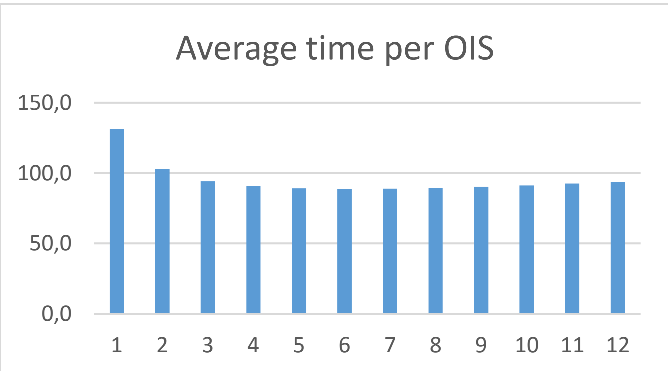

Figure 5-16 - Average time per OIS

For Street 2, the same calculation was made. There, the optimal batch size was determined to be 5 T12 trolleys.

Using the batch sizes of the two different streets, the total time spent was calculated. Here, we calculated that in Street 1, three employees are necessary, whereas Street 2 uses 2 employees. Compared to the current situation, this is a productivity gain of 1 FTE. For the employees in Street 1, this resulted in 13,5 hours per employee, whereas 13 hours are available. However, for Street 2, every employee needs 11 hours and 50 minutes, so there is excess capacity, as can be seen in Figure 5-17. Using work force planning for distributing the work load of the employees more evenly, the division as shown in Figure 5-18 is reached.

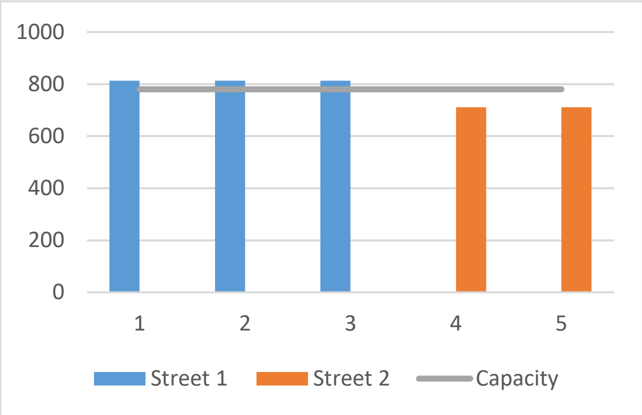

Figure 5-17 - Before workforce planning

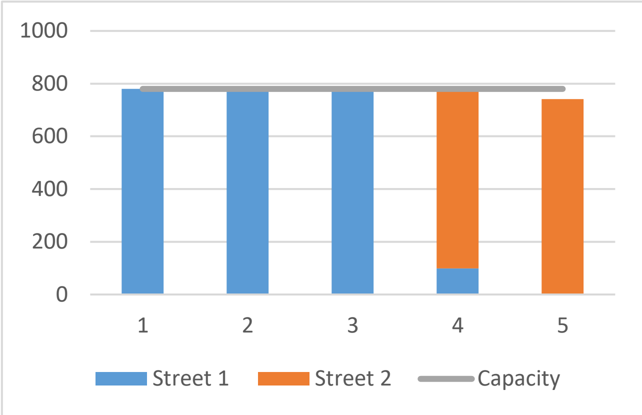

Figure 5-18 - After workforce planning

In the current situation, 6 FTE is used for stowing all the trolleys. Using the supermarket concept, somewhat less than 5 FTE is needed. However, in the 5 FTE situation, the transportation of trolleys to the buffer and meals to the cooling are not accounted for. Therefore, a dedicated runner must be added to the process. Likewise to Layout 5, it is not feasible to estimate the amount of time needed for this.

Using the workforce planning as mentioned, results in extra flexibility, as employees are able to work in Street 1 and Street 2. Whenever extra capacity is needed in a street and there is excess capacity in the other, employees can easily switch streets. Next to the flexibility and possible productivity gain, batch sizes are reduced significantly, so that the ergonomics will improve, as well as a smaller probability of mistakes. The throughput time for a batch in both streets will be shorter as well. For Street 1, this will be 16:08 minutes and for Street 2, 15:03.

A summary of the output is shown in Table 5-8 (detailed calculations in Appendix VIII). Comparing this total time to the current total time, 7 hours and 15 minutes is gained. However, the meals and trolleys still must be supplied to the streets, which is not accounted for in the calculations.

Table 5-8 - Output option 8

	Throughput time	Batches	Total time
Street 1	00:16:08	274,5	40:38:25
Street 2	00:15:03	113	23:43:06
Total			64:21:32

The difficulty here however, will be determining the different locations of the meals in the supermarket. As there are multiple employees walking through the two streets, there is a chance that their paths cross very often. It must be designed in such a way, that their crossing of paths is minimized, as well as waiting time when, e.g. two employees need access to the same meal at the same time. Furthermore, creating the streets, with four cooling areas, will be difficult due to the space restrictions at VLAS and the costs of the cooling area.

5.5 Conclusion

In this chapter, we completed the ideation phase and described several quick wins regarding the poor ergonomics at the Silverware work cell and M-class MND & HSN, the different work paces of the two employees at the C-class juice & HSN work cell, visuals with the contents of the trolleys that can be placed above a lifting table, and finally a new way of supplying the champagne bottles to improve the ergonomics at C-class juice & HSN.

After the small wins, we designed several alternatives for the entire layout of VLAS. These alternatives are designed using two different basic layout types: a cell and a product layout. In the cell layout, the meals are transported to the trolleys, whereas in the product layout this is the other way round.

Furthermore, several layout types are used from the literature research: in Layouts 1 until 4, the work cell layout is still used, using batch-wise production. Next to this, two layouts (5 and 6) include an assembly line, Layout 7 uses AGVs and Layout 8 has a Lean supermarket in which supply is located.

6. Evaluation of alternatives

After having designed several small wins and solutions for improving the entire layout at VLAS, we set-up a meeting with all stakeholders. Several aspects regarding technical, quality, control and flow issues were discussed. Through this meeting, a final improvement to the solutions and designs could be applied. In the end, all alternatives were plotted in an impact/ease of implementation matrix (6.1) and selected through the AHP (6.2). After that, we describe the practical implications of the solutions in 6.3.

6.1 Impact/Ease matrix

The Impact/Ease matrix was used to categorize all alternatives into whether they are interesting to implement immediately (as a quick win), or that they require even more intensive research, or even that they are not interesting for implementation at all. The choice for this type of matrix was made, to be able to filter the ideas that are not interesting in a relatively short period of time. The remaining ideas could then be used for further research or even a quick implementation.

In Figure 6-1, the Impact/Ease matrix is shown. On the X-axis, the ease of implementation is stated. This is a quick scan of whether it is easy or hard to implement a certain solution. In this category, aspects such as feasibility, technology and costs were regarded, as well as whether employees would be able to work with the solution. On the Y-axis, the impact of alternatives on the operation is given: this impact varies from low to high. For this, aspects such as throughput time, WIP, probability of mistakes and ergonomics are regarded.

Using these two axes, four quadrants are formed, as can be seen in the figure. In the upper right quadrant, where the impact on the operation is high and the implementation would be easy, the quick wins are placed. These are the alternatives that can be implemented right away. In the upper left quadrant, alternatives with a high impact, but lower ease of implementation are placed. These alternatives are worth doing, but require research in further detail. In the lower right quadrant, the alternatives with a high ease of implementation, but with a low impact are placed. These could be worth doing, but are less interesting compared to alternatives in the two previously mentioned quadrants. Finally, in the down left quadrant, the alternatives with low impact and high difficulty of implementation are placed. These are the alternatives that are not interesting and should be dropped, as they cost too much time for too little impact.

In Figure 6-1, the quick solutions as described in section 5.3 and the layout alternatives of section 5.4 are plotted in the Impact/Ease matrix.

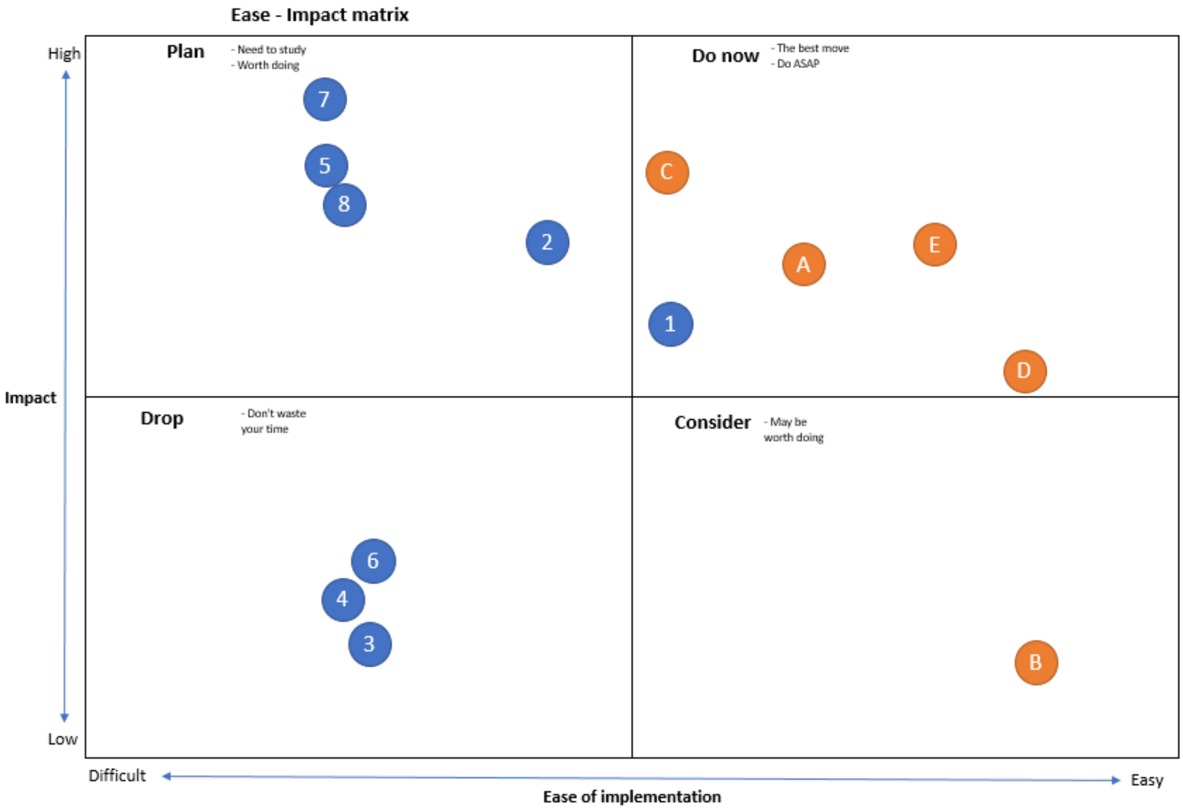

Figure 6-1 - Impact/Ease matrix

Quick wins (orange dots)	**Layouts (blue dots)**
A – Silverware concept B – Visualization production progress C – Visualization trolley contents D – Mobile lifting aid for C-MND, M-MND and M-HSN E – Different supply of champagne bottles	1 - No physical adaptation, flight specific production 2 – Splitting up the lifting tables 3 – Splitting up the lifting tables with an extra cooling 4 – Splitting up the lifting tables per individual product 5 – Assembly line 6 – Assembly line with extra cooling 7 – Automated Guided Vehicles 8 - Supermarket

As can be seen in Figure 6-1, there are three layout options that are in the “Drop” quadrant: the two options (3 and 6) with an extra cooling and the option of splitting up the lifting tables per product. These do not meet the future requirements as posed in 5.1. The cooling options were dropped because of the high costs and high amount of space that goes with the option. Furthermore, an extra cooling would require an (extra) employee to deliver the supply continuously, which would be time consuming. Layout 4 is in the drop quadrant, because the throughput times cannot meet the requirements as specified. The takt time as specified cannot be reached, so the impact is low, as well as the ease of implementation.

All small wins, except the production progress visualization, are placed in the "Do now" quadrant. The progress visualization is thought to be implemented very easily, but the impact on the process would be low, as the employee has to do an extra action for the visualization to function. This option could still be viable to use, but preference is given to the other four wins. The other four wins are all relatively easy to implement and above average in terms of impact on the operation. These four wins could be tested and implemented as soon as possible.

Layout 1 has also been placed in the 'Do now' quadrant. As there are no physical modifications necessary for this, the ease of implementation is quite high, with high impact. Therefore, tests could be started up immediately, to simulate the effect of building and stowing the trolleys per flight. Layout 2 is comparable to Layout 1, with the difference that the lifting tables are split-up. Therefore, the implementation is harder, but with a higher impact on the operation.

Layouts 5, 7 and 8 are thought to have similar difficulties of implementation. Either implementing an assembly line, AGVs or a supermarket are regarded to be quite hard to implement, due to the more complex technology and control of the systems. The impacts however, differ slightly. The layout with the AGVs is thought to have the highest impact on the operation, as the transportation is fully automated, but the AGVs can level the workload automatically as well. Layout 5 has a higher impact than Layout 8 due to that 5 has a slightly bigger productivity gain, as can be concluded from the total time spent.

Through this impact/ease matrix, the layouts and wins have been categorized in four quadrants. The three layout options, that do not meet the future requirements, are placed in the "Drop" quadrant. These will not be included in the AHP, as there is no support for implementing them. The remaining five layouts will be assessed in the AHP, to determine which alternative fits KCS best.

6.2 Analytical Hierarchy Process

The five alternatives that remain after the filter of the impact/ease matrix must be judged on different criteria. Through this measurement, a comparison of the performance of each layout alternative can be made and ideally, the best alternative can be selected. To do so, together with all stakeholders, we performed the Analytical Hierarchy Process. Firstly, the proposed criteria are compared against each other, to assign weighing factors to the criteria. After that, we compare the alternatives on each individual criterion. After multiplying the score of each alternative with the weighing factor of a criterion, a ranking of overall performance of the alternatives is created and the best can be selected.

Before starting the AHP immediately, the goal of the research was set to determining the best solution if possible. After that, the criteria that alternatives are measured on were agreed. These criteria originate from the research goal, as posed in section 1.3, and are as follows:

- **Ergonomic** impact of the alternative
- **Quality** impact, e.g. through reducing the time that meals are outside of the cooling
- **Productivity improvement**, an indication of the number of FTE that is used
- **Feasibility**, whether the alternative can be implemented (easily)
- **Costs**, an estimation of the costs that are linked to each solution
- **Throughput time reduction**

During the discussion, the weighing factors for the criteria were determined. These are shown in Table 6-1. A more detailed explanation is given in Appendix IX.

Table 6-1 - Weighing factors criteria

Criteria	Weighing factor
1. Ergonomics	0.201
2. Quality	0.179
3. Productivity improvement	0.181
4. Feasibility	0.312
5. Costs	0.058
6. Throughput time	0.068

Due to the inability to estimate the required number of hours for a runner, needed for the supply of trolleys and meals at Layout 5, 7 and 8, it is impossible to determine the actual productivity improvement. Therefore, the performance of the alternatives on criterion cannot be quantified. We will use the AHP scales as described in section 4.6 to determine the productivity performance. In discussions, with the data that is available and the other 'soft' criteria, the five different concepts were pair wisely compared.

Table 6-2 - Ranking of alternatives

Rank	Layout alternative	Score
1	7. Automated Guided Vehicles	0.28
2	5. Assembly line, flight specific	0.22
3	2. Split-up lifting tables	0.19
4	1. No physical change: flight specific	0.17
5	8. Supermarket	0.14
		1.00

The results of the performed AHP are shown in Table 6-2. It becomes clear that the concept with the AGVs is preferred above the other four alternatives, even though that it received the worst score on the feasibility criterion, compared to the other four alternatives. It performed the best on all the other criteria, barring costs, as well.

The second ranked alternative is the assembly line with the short throughput times, closely followed by the split-up lifting tables. This concept has a slightly better performance than Layout 1, due to its better performance on all criteria except costs. The supermarket is ranked 5th and last.

However, even though the layout alternative with the AGVs turns out to be the best in the AHP, it cannot be implemented at KCS. After the AHP session, there was a discussion about the eventual implementation of the AGVs, which turned out to be impossible in the current location. There are too many obstacles that need to be overcome, such as the location and space requirements at VLAS, safety issues, as the AGVs would cross footpaths of employees and the complexity of the control system. However, in the future, KCS might have to move to a new location, due to the ever-on-going developments of Schiphol Airport itself. Then, an entire new layout of the whole process can be designed and the AGVs would be very interesting to look at again.

The AGVs turned out to be the best ranked alternative in Table 6-2. However, as this layout is not feasible, we performed another AHP. In this AHP we omitted the alternative with the AGVs, to compare the feasible four layout alternatives. The results are shown in Table 6-3.

Table 6-3 - Ranking feasible alternatives

Alternative	Score
5. Assembly line, flight specific	**0.39**
2. Split-up lifting tables	0.23
1. No physical change: flight specific	0.21
8. Supermarket	0.17
	1.00

Again, the layout alternative with the assembly line turns out the best. Therefore, we can say that this alternative is the most interesting for KCS. However, this layout requires some more research, for example, a simulation study should be conducted. The second ranked alternative is the layout with the split-up lifting tables, which can be implemented quite easily. The same goes for Layout 1. The supermarket layout alternative remains the last ranked alternative, so is not interesting for KCS to look at anymore.

As it turned out to be the best alternative, we select Layout 5 for further research. However, to be able to improve the current VLAS-process, we also select Layout 1 and 2 for testing and, eventually implementation.

6.3 Conclusion

After the design of the different layouts and small wins in Chapter 5, alternatives had to be evaluated and selected. To start, after considering with all stakeholders, we plotted the different alternatives in an Impact/Ease matrix. Through this, we determined which options could be interesting for implementation, and which are not. Most small wins, except for the visualization of production progress, were plotted in the Do Now quadrant. For the layouts, three options were plotted in the Drop quadrant, so these layouts were taken out of consideration.

The five remaining layouts were then judged and ranked using an AHP. They were judged on ergonomics, quality, productivity, feasibility, costs and throughput time criteria. In the end, the AGV option turned out to be the highest ranked, but after discussing this output, it was determined that this layout is not feasible for implementation.

Therefore, we performed another AHP in which the AGV layout option was omitted. After comparing the four feasible alternatives, the assembly line was ranked first, with the (split-up) lifting tables second and third. These three alternatives are selected for further research, testing and implementation.

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7 Implementation

After we evaluated the proposed quick wins and layout alternatives, the selected concepts can be implemented. Therefore, for these options, we propose a small implementation plan.

7.1 Quick wins

The quick wins that are in the "Do now" quadrant, can be done immediately, as the ease of implementation and the impact on the process are high.

7.1.1 Silverware flow rack

Currently, we already started a project for improvement of the silverware work cell, using the concept as described in 5.3.1. The possibility to put the container boxes through the washing machine has been researched, in cooperation with the technical service (whether the machine is suitable) and the quality department (hygiene restrictions). The results stated that it is technically possible. Also, the hygiene quality of washing improved significantly. Next to this, research is being done about the design of the flow rack. For this, it is necessary to see which drawers are frequently used and should be placed in the flow rack. The lifting aid, to put the containers on a CTR, is available at KCS and can be tested immediately.

If all these boxes are ticked and research is finished, a test setup will be created in a non-production environment, to see whether everything is working properly and whether employees would like the setup. This way, production is not interrupted and the eventual flaws of the design can be resolved. If all this is conceived positively, the actual set-up of silverware can be implemented in the production area.

To see whether the process at this work cell has actually improved, measurements regarding throughput time, ergonomics, quality and the waste percentage should be done, as well as looking at employee satisfaction with the design.

7.1.2 C-class juice & hot snack

The new division of the lifting table can be tested immediately. To test this, a physical border can be drawn on the table, using floor marking tape. This will create a sense of awareness of the employees at that work cell. Furthermore, when using Variant A, the products should be delivered by GOC in a different way. These should be stacked up and counted per flight, per block, so that the juice and hot snack supply can be stationed on both sides of the table. After implementing this small change, it should be observed that there is a better synchronization of working tempo of the two employees, and that their waiting times are reduced.

7.1.3 Lifting aid

The mobile lifting aid that is suggested in 5.3.3 has already been tested at KCS. Firstly, the lifting aid was assigned to the M-class MND & HSN working table, where one employee used the lifting aid. This lifting aid is perceived positively by the employees: they find it useful and easy to work with. The same goes for the testing of the lifting aid at the other work cells. Therefore, several lifting aids have been purchased, so that every employee at VLAS can use one.

7.1.4 Visualization of trolley content

The visualization of the trolley content is regarded as a quick win, but would be still a lot of work for the IT-department to create. An application for the visualization has already been created, but would have to be modified for it to be shown on a large monitor. Another difficulty here is to make it easy for employees: when putting e.g. 6 trolleys on a lifting table, every trolley has to be scanned before it can be visualized on the big screen, so an extra action has to be performed. Therefore, a smart scanning moment should be implemented. When implementing the assembly line layout, there is an automatic scanning moment, so that the visualization can be shown automatically.

7.1.5 Champagne bottles

For the champagne bottles to be delivered in a different way, cooperation must be sought with the NF&B department. Currently, at NF&B, drawers are built containing the three champagne bottles. For implementing the solution, NF&B should not build the drawers anymore, but only deliver the champagne bottles to the C-class juice & hot snack work cell. Another small change there, is that in the loading diagram of a trolley, an empty drawer has to be placed, so that the champagne bottles can be stowed in the drawer.

7.2 Layout designs

Unlike the quick wins, only one layout can be implemented. In the AHP, the assembly line turned out to be the best alternative, followed by the split-up lifting tables and the layout without physical modifications.

However, for the implementation of an assembly line, further research, such as a simulation study, should be done. Therefore, to gain momentum for change, KCS should start with testing Layout 1. This layout can be tested right away, as there are no modifications required. If this test is regarded positively, it can be implemented. If after a while, employees get used to the new working method, the choice can be to either improve that method by splitting up the lifting tables, or completely rebuilding the VLAS-area by implementing an assembly line. Following, for each different layout, a very brief and general implementation plan is described.

7.2.1 Layout 1 (production per flight)

Next to the four quick wins, Layout 1 is placed in the "Do now" quadrant, as well. The ease of implementation is due to that there are no physical modifications necessary, to realize this layout. For implementation, only a change at GOC is necessary: that department must deliver every meal or juice specifically for each flight. So, when a flight needs 100 curry dishes, a stack of totes containing 100 curry dishes for that certain flight should be delivered. However, this is not a process that can be changed overnight, so when testing and simulating this process, a temporary workaround and assumptions will be made.

Furthermore, a change in work method for the employees must be realized, as they are going to produce trolleys flight by flight. Therefore, in order for them to not (accidentally) use the full capacity of the lifting table, floor marking tape will be used to visualize the space that they can use. This is not a physical border, but will remind employees to not fall back into their old pattern.

7.2.2 Layout 2 (split-up lifting tables)

As mentioned in 5.2, in theory, Layout 2 is preferred to Layout 1, but would require significant and costly physical changes to the VLAS-area. Therefore, only when Layout 1 has been successfully implemented, Layout 2 can be a regarded. There is only a physical change-over to this layout: the entire control and delivery from GOC will be the same, the only difference will be that the lifting tables are physically split-up. This should result in shorter throughput times and more productivity gains. If the employees are enthusiastic about their working with Layout 1, creating acceptance for implementing Layout 2 will be easy, as this layout will improve their new work methods even more.

But, before making the decision, a comparison of the further gains through this layout and the costs that go with it should be made. If the payback period of splitting-up the lifting tables is shorter than one year, this layout can be implemented.

7.2.3 Layout 5 (assembly line)

Before the choice is made to implement this layout, further research must be done. The costs of creating and implementing an assembly line have to be researched. Furthermore, a simulation study is necessary to simulate the potential outcomes. Using these outcomes and the costs, a decision can be made whether this layout is financially attractive. When this is the case, the current design concept should be made into more detail, to create a clear visualization of the assembly line.

This layout will profit from the implementation of Layout 1. Layout 1 ensures that all meals and other products are delivered to VLAS, flight specifically. For the concept of the assembly line, this is the case as well. So, if the choice is made to implement the assembly line, the work method at GOC is already implemented. The acceptance among employees will be somewhat tougher to gain however, as their entire working method and tools are changed.

7.3 Conclusion

In this chapter, for the quick wins individually, a small implementation plan is described. The quick wins (except for the visualization) as mentioned can be implemented immediately. Several activities have already been put into motion for this.

The assembly line turned out to be the best alternative, through the AHP. However, for implementation of the line, further research is needed. Therefore, KCS should start with testing Layout 1. For this, work methods at GOC will have to change, to supply the VLAS per flight of meals. After that, tests for flight-specific production can start.

If the performance of Layout 1 improves the current situation, Layout 2 and 5 can be regarded, to further improve the working methods of Layout 1.

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8 Conclusions & recommendations

The goal of this research was to improve the VLAS-process, while reflecting the requirements of all stakeholders. For this goal, we posed the following central research question:

> How can the VLAS-process of KLM Catering Services be redesigned, so that an improvement of on-time deliveries, productivity, ergonomics and quality can be realized?

8.1 Answers to the research questions

In order to answer the central research question, five sub-questions were set-up. In this chapter, we will answer the central research question by answering the sub research questions.

8.1.1 What is the current situation at the VLAS-process?

At ICA Food, firstly, the trolleys and equipment that return from the inbound aircraft are received and washed in the ROA-area. The next step is then to stow the trolleys with a certain number of products, depending on the requirements of a flight in the assembly area (this step is done at VLAS). When the trolleys are completed, they are pushed to the gate for distribution to the plane.

Within the assembly area, the VLAS-process is located. Here, depending on the flight, main dishes and hot snacks for the C- and M-class, as well as the rolls and juices, are stowed into the trolleys. Next to VLAS, the silverware work cell is located, at which the containers with cutlery, tea jugs, et cetera, are produced.

Generally, the process at silverware and the other four work cells to produce trolleys and containers is similar and consists of five steps:

1. Retrieval of trolleys or containers
2. Retrieval of meals and items
3. Stowing of meals and items in the trolleys
4. Scanning barcodes
5. Pushing trolleys to the gate

There is a difference in the method of supply however: for the M-class MND & HSN work cell, the main dishes are delivered specifically per flight, whereas the meals for the other work cells are delivered in bulk for two production blocks.

After having described the VLAS-process, we assessed the current performance. For this, the current KPIs of KCS do not sufficiently cover the process performance. Therefore, we introduced three new KPIs (meal productivity, waste time and throughput time). Using the performance indicators, we identified the bottlenecks and problems at VLAS:

Employees make use of high batch sizes, e.g. they put 20 trolleys on a lifting table and then stow these with products. This use of batching leads to:

- **(high) throughput time** of approximately one hour. Employees put their batch at a lifting table and start stowing products. After one hour, all trolleys are ready and put through to the gate.

- **mistakes**: employees pick one type of meal and visit all trolleys that should contain that meal. However, if they forget to stow one trolley, it is possible they will not find out and push it through to the gate. Next to this, if they pick the wrong type of meal themselves, all trolleys contain the wrong meal.
- **deliveries done too late:** through batching, the trolleys are either all too late, or on-time.

Following up, the high throughput time as described leads to:
- **high WIP:** this results in less overview in production progress and chance of damaging equipment.
- **quality issues**: as meals are outside the cooling for about an hour (throughput time), the probability of the temperatures rising above 7 degrees Celsius is increasing

The **ergonomic** working conditions at the work cells can be considered as tough:
- At silverware, a high risk was measured, through that all containers are built on the floor.
- At M-class MND & HSN and C-class MND, employees are lifting heavy totes too often
- At C-class juice & HSN, the drawers with champagne bottles require a lot of heavy lifting of the employees

Finally, the probability of an employee making a mistake increases, through the **similarity of the meal codes**. Employees can misread of misinterpret a meal code.

8.1.2 Which methods are suggested in literature for designing a new VLAS-process?
To answer the research questions as posed, we used literature to provide a methodology. Firstly, we found a framework in the problem-solving model of Hicks. This first regards the mess and finds a solution after performing several steps. For the analysis of the VLAS-process, we found literature regarding the several types of waste, as well as ways for identifying the amount of waste in the process (Process Activity Mapping). After analysis, the next step was to design concepts for improvement of the VLAS-process. For this, we searched literature regarding different layout types, in order to apply the theoretical concepts to practice. Then, for the evaluation and selection of the proposed solutions, we chose to use the Analytical Hierarchy Process.

8.1.3 What are feasible alternatives for the work cell design of the VLAS-process?
To solve the bottlenecks and problems we found in the analysis, we performed a brainwriting session to generate ideas to further improve the VLAS-area. These are either quick wins that can be implemented quite easily, or ideas for a general layout design.

We designed quick wins for the silverware work cell, to improve its poor ergonomics. This layout contains a roller conveyor and a flow rack, in order to have the employees working on a normal height. Furthermore, for the M-class MND & HSN lifting table, a mobile lifting aid was introduced, to reduce the manual lifting of heavy totes with meals. At C-class juice & HSN we described a different division of trolleys on the lifting table, as well as a new method of supplying the champagne bottles. One quick win is applicable for all work cells: the visualization of the trolley content on a monitor.

For the design of the general VLAS-process, we used the described layout types in the literature review as a basis for solving the found bottlenecks and problems. We described Layouts 1 until 4, in which a work cell layout is used, with batch-wise (flight specific) production and (split-up) lifting tables. Layouts 5 and 6 contain an assembly line, to minimize the time spent on transporting the trolleys. Layout 7 uses AGVs for the transportation of trolleys and in Layout 8 a Lean supermarket is incorporated. For each individual layout alternative, we made an estimation of the throughput time and the effects of such an alternative on the posed KPIs.

We used the Impact/Ease matrix in a session with all stakeholders to determine the feasibility of implementation for each alternative. In this session, the layouts with an additional cooling and the layout with individual work cells for each type of product were deemed infeasible and therefore dropped. The layout that uses AGVs for transportation is also in the infeasible category, but because of its very promising output, we decided to incorporate this alternative the Analytical Hierarchy Process.

8.1.4 What are the advantages and disadvantages of each alternative and which alternative should be selected?

For the feasible layouts that were previously determined, the advantages and disadvantages are described. These are as follows.

Layout 1 (no modification, flight specific production)
Advantages: To implement this layout, no physical modification is necessary, only the method of production changes to producing per flight. This layout results in a productivity gain, a shorter throughput time and an improvement on quality, as meals are outside the cooling area for a shorter period of time.
Disadvantages: When keeping the current lifting tables, employees will still tend to return to the use of high batch sizes when production is behind schedule. Next to this, when two employees are working at a lifting table, one often finishes before the other does, which results in longer waiting times.

Layout 2 (split-up lifting tables)
Advantages: To make sure employees have no other option than producing per flight, the lifting tables are split-up. This split-up also results in that the two employees are no longer dependent of each other, which results in a productivity gain.
Disadvantages: Splitting-up the lifting tables could be quite costly, compared to the productivity gain.

Layout 5 (assembly line)
Advantages: The transportation of trolleys to and from the lifting tables is fully automated, which results in a productivity gain. Through that, and because of the strive to single-piece flow, throughput times are reduced significantly. Furthermore, meals are outside of the cooling area for a shorter time, which results in a quality improvement.
Disadvantages: Developing an assembly line and its control system takes up a lot of time. An assembly line would have higher costs as well.

Layout 7 (AGVs)
Advantages: The transportation of trolleys to and from lifting tables is fully automated. There would be quality and productivity improvements, as well as shorter throughput times.
Disadvantages: Impossible to implement in the current situation, due to AGVs crossing the walking paths of employees.

Layout 8 (supermarket)
Advantages: Big improvement in quality, as meals are placed in a cooling full time. Productivity is gained, as well as shorter throughput times.
Disadvantages: Costly and difficult for implementation, because of the cooling areas. Also, through the manual transportation of trolleys, ergonomically tough for employees.

After having identified the pros and cons of each layout, we proceeded to the next stage: ranking and selecting the best alternative through performing an AHP. In the ranking, Layout 7 turned out to be the best alternative, followed by the assembly line and the (split-up) lifting tables. Layout 8 was ranked last.

However, as mentioned, the AGV layout is infeasible. Therefore, to make sure that the best feasible layout alternative is indeed the assembly line, we performed another AHP. This time we omitted the AGV option. The assembly line was ranked first, again followed by the split-up lifting tables, with the supermarket being ranked last.

8.2 Recommendations

In this section, we will give recommendations to KCS to improve its VLAS-process.

On the short term, KCS should start implementing the quick wins. By implementing the silverware design, a quick improvement in the very poor ergonomic circumstances of the work cell can be realized. Next to this, more lifting aids should be purchased, so that all VLAS-employees can use one.

Furthermore, as there are no physical modifications to the lifting tables at VLAS, we recommend KCS to start producing flight-specifically (Layout 1). This must be done in cooperation with GOC. After GOC has ensured that it can deliver all meals specifically for each flight, flight specific production tests can start. We recommend implementing this layout on the short term, to quickly realize an improvement on the quality and throughput time KPIs. On the long term, after the implementation of Layout 1 has been done successfully, we recommend further improving flight specific production by splitting up the lifting tables.

The assembly line is the best ranked alternative in the AHP, but before it can be implemented, further research is needed. We therefore recommend building a simulation model of an assembly line at VLAS. Through this model, several scenarios can be tested, in order to see whether implementing the assembly line would be successful.

Finally, in the current situation, the layout with the AGVs is infeasible. However, it was ranked as the best alternative. Therefore, whenever KCS is moving to a different location, we recommend looking further into adopting AGVs.

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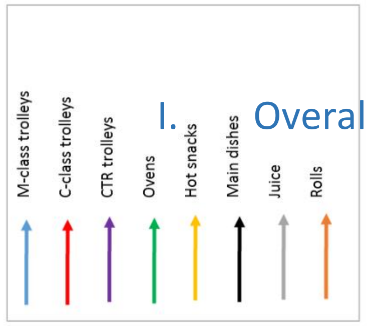
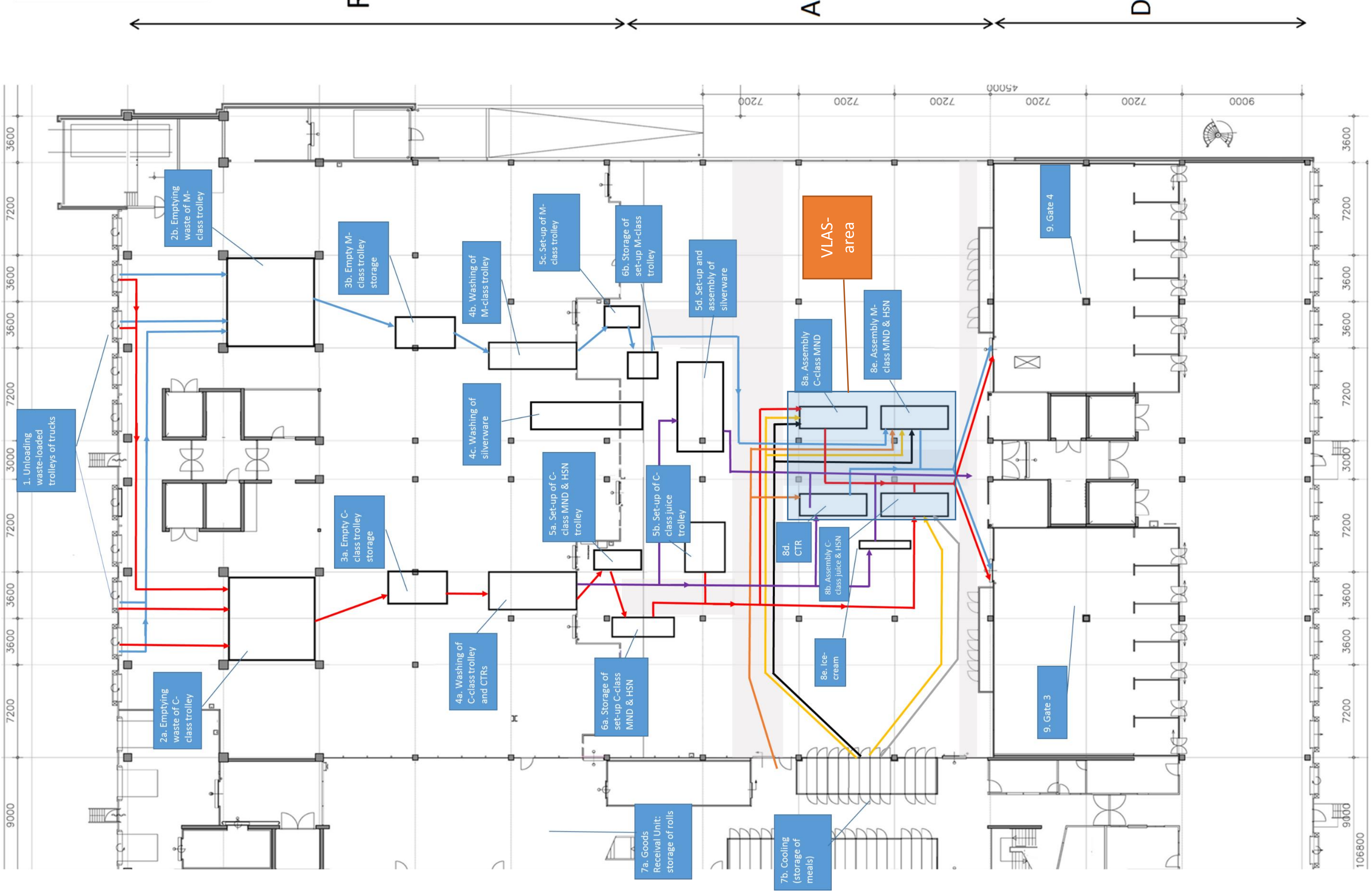
Appendix

I. Overall layout





II. Individual performance work cells

i. Performance C-class main dish

Customer complaints & extra delivery runs (CC & ED)

In Figure II-1 the extra delivery runs and the customer complaints are categorized for the C-class main dish work cell. Due to time restrictions, data was gathered for nine weeks that are representative for longer time periods, according to KCS. Also, due to the structure in the data about customer complaints and extra delivery runs, it is impossible to completely trace back the complaints or runs to a certain mistake. However, it is still possible to make general remarks about the cause of the error. Furthermore, the data indicate the frequency of the mistake.

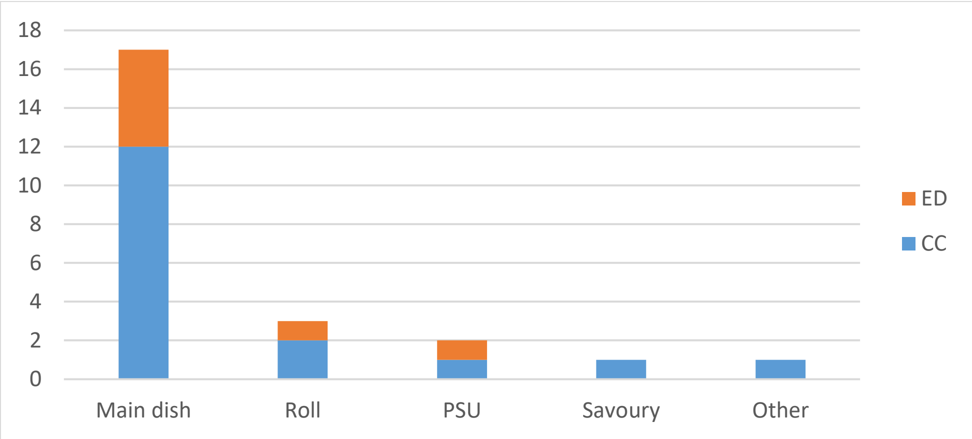


Figure II-1 - CC and ED C-class main dish

As you would expect, most EDs and CCs are relatable to the C-class main dishes. Shortages of meals and catering the wrong meal were causes for CCs and EDs. Overall, the performance on this criterion is relatively well.

On-time deliveries

With 95,8% deliveries made on time from the C-class main dish to the distribution gate, the performance here is good. Out of 2092 trolleys that were taken into account, only 87 were delivered too late to the distribution. In the morning, the pressure to deliver on-time to distribution is higher, as the trolleys have to be delivered to the plane that afternoon. This is partially reflected in the on-time deliveries per block: approximately 60% of the too late deliveries are done in the morning. But in the end, the overall performance on this KPI is excellent.

Lean rate

In Table II-1, the Process Activity Map for this work cell is shown. By adding up the percentages of the time in which value was added, so the time spent on filling trolleys with equipment and stowing the main dishes in the trolleys, the Lean rate can be calculated. For the C-class MND this is 64%. Meaning, of the total available time an employee has, barring lunch breaks et cetera, 64% he is adding value and the remaining 36% is waste.

It should be kept in mind that the 48% of stowing main dishes in the trolleys is a percentage that is a very positive measurement. The Start measurement-activity for this was when the first item was stowed in the trolley, whereas the Stop measurement-activity was when the last trolley was finished. Even in this measured time, employees retrieved additional trolleys or additional meals from the cooling. Therefore, the 48% is in reality much lower. This is also the case for the other work cells.

Table II-1 - Process Activity Map C-class main dish

	Activity	Flow	NVA/VA	Waste type	Average time	% of time
1	Retrieve set-up C-trolleys from storage area and put them on the lifting table. Gather oven racks for special meals.	T	NNVA	Transport. Waiting. Inventory.	00:05:08	6%
2	Fill the trolleys with equipment according to the specified loading diagram	O	VA	-	00:12:51	16%
3	Retrieve totes with C-class main dishes from cooling	T	NNVA	Transport	00:04:12	5%
4	Stow main dishes in trolleys	O	VA	-	00:38:39	48%
5	Scan production card bar codes to notify the trolleys are complete	C	NNVA	Motion	00:02:04	3%
6	Push completed trolleys to the distribution gates	T	NNVA	Transport. Inventory. Waiting.	00:03:15	4%
7	Other waste: cleaning work space, searching for equipment, etc.	O	NNVA	Transport. Motion. Waiting.	00:13:38	17%
				Total time	01:20:34	100%

As can be seen from the table, the employee is spending almost half of the time stowing main dishes in the trolleys, whereas an additional 16% is spent on filling the trolley with the right equipment. These are the activities that are value adding and the time spent on this has to be maximized (relatively to the other activities).

Next to that, 15% of the time, employees are either retrieving trolleys from the storage area or totes from the cooling or pushing the trolleys to the distribution gates. There is no value added in these transporting processes, so this time has to be minimized. This activity also includes the waste of waiting time: for example, when a trolley is completed, it has to wait until the other trolleys of the batch are completed, for it to be transported to the gate. This process of batching also means a pike in the work load of distribution, as all of a sudden, a big batch of trolleys come into the gate.

Finally, the scanning process is NVA to the customer, as it is an internal communication measure to notify that the trolleys are ready for distribution. Next to the transport of full or empty trolleys, the employee picks up equipment from totes that are placed at the work cell. This results in a lot of walking distance between the trolley and that small inventory position.

Finally, 17% of the time is spent on other waste: for example, on pushing the emptied totes back to the cleaning area or searching for the right equipment. These are either transport, motion or waiting types of waste.

Ergonomics
The health risk for this work cell through repetitive motions is average, bordering on a high risk. This is through the work (body) position that employees work in. Employees pick up the products with a certain grip, which, if done very frequently, can be potentially damaging. However the working tempo at this work cell is quite low through the China plates that are used, there still is a lot of repetitive heavy work.

The performance on the pushing/pulling-criterion is good. Employees transport the trolleys and meals to and from the work cell to different destinations. After analyzing these movements, the total distance for pushing the trolleys is quite low, so the same goes for the health risk on this criterion.

Lastly, on the lifting criterion, the performance was poor. The products that are stowed into the trolleys are picked up out of a tote. As to not having to pick up meals from a tote that is put on the ground, employees stack totes up manually, to be able to pick the products from a more ergonomic height. However, this has a downside: these totes weigh above 10 kilograms, and lifting these occurs very frequently, which is why the score on this criterion is low.

ii. Performance C-class juice & hot snack

Customer complaints & extra delivery runs

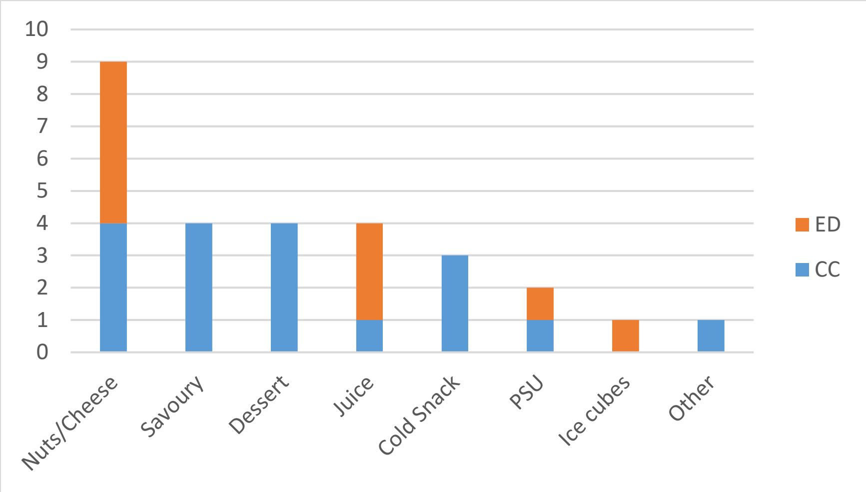


Figure II-2 - CC and ED C-class juice & hot snack

The two categories that stand out regarding ED and CC are the Nuts/Cheeses, as can be seen in Figure II-2. A cause for the shortages of nuts and cheeses could be that the totes containing these items are stacked on a lowerator together with meals for an entirely different work place. There, the totes have to be sorted and the cheese tote is picked out. Positively however, the number of complaints about shortages of juices is very low, especially regarding the high amount of juice boxes that are stowed in the trolleys.

Overall, the performance on CC and ED is relatively good.

On-time deliveries

92,1% of the deliveries from C-class juice to the gate are on-time, which is just above the target of 92%. This is mainly caused by the Cold Snack and Dessert trolleys, of which respectively 28% and 8% are delivered too late to the distribution gate.

A further look into the delivery times of these trolleys learned that the first and third production blocks cause the too-late deliveries for the morning shift, due to the start-up time and the breakfast brake employees take between the second and third production block. The trolleys that are scheduled for the late shift, are either produced on purpose very late in the evening or the morning after, which is the reason they are, theoretically, delivered too late to the gate. This way of scheduling needs to be examined, but this is out of the scope of this project.

Furthermore, through the batch sizes that are used, performance goes down: either all trolleys in the batch are on time, or all trolleys are too late.

Lean rate
In Table II-2 the Process Activity Map for the C-class juice & hot snack is shown. When adding up the percentages of time of the value adding activities, a lean rate of 61% is reached. So 39% of the time spent per building a lifting table of trolleys is waste.

Table II-2 - Process Activity Map C-class juice & hot snack

	Activity	Flow	NVA/VA	Waste type	Average time	% of time
1	Retrieve set-up C-trolleys from storage area and put them on the lifting table. Gather oven racks for special meals.	T	NNVA	Transport. Waiting. Inventory	00:06:25	9%
2	Retrieve totes with C-class juices & hot snacks from cooling	T	NNVA	Transport	00:05:49	8%
3	Stow juices and crackers in the juice trolleys. Stow hot snacks and the required number of PSU plates in the hot snack trolleys.	O	VA	-	00:42:26	61%
4	Scan production card bar codes to notify the trolleys are complete	C	NNVA	Motion	00:03:34	5%
5	Push completed trolleys to the distribution gates	T	NNVA	Transport. Waiting.	00:06:22	9%
6	Other waste: cleaning work space, searching for equipment, etc.	O	NNVA	Transport. Motion. Waiting	00:04:58	7%
				Total	01:09:34	100%

Also in this C-class work cell, approximately 61% is spent on the stowing of products in the trolleys. These activities include the building of drawers with PSU items, trays with tray mats, et cetera.

Over 25% of the time is used for transporting trolleys and totes, when including the other waste of pushing the empty totes to the cleaning area. These are classified as necessary NVA-activities, as the trolleys and totes must be transported, or there wouldn't be trolleys to fill or products to fill with, but the transport does not add value. Next to that, 5% is used for scanning the production cards.

Compared to the C-class MND work cell, the waste percentage here is a bit higher, through the higher transportation time of trolleys and totes.

Besides that, the cycle times of building a C-class juice trolley and a C-class hot snack trolley differ significantly. This is problematic, as these two types of trolleys are placed on the same working table, where one employee builds the juice trolley and the other one the hot snack trolley. That leads to, for example, the juice trolleys being completed faster than the hot snack trolleys. What occurs then is that, when the juice trolleys are completed, even if the hot snack trolleys are not, the lifting table goes down, the employee lifts the juice trolleys from the ground and pushes these finished trolleys to the gate. The lifting table then goes up again, the other employee proceeds with the hot snack trolleys and the "juice employee" retrieves new trolleys. The lifting table then goes down again, the new juice trolleys are put on the lifting table again, which goes up. After a while, the hot snack trolleys are completed and the whole cycle is repeated again, this time for the hot snack trolleys.

Figure II-3 - Juice trolleys are completed and transported to the gate, whereas the hot snack trolleys are not completed yet.

Ergonomics

The performance on repetitive motions is very similar to the C-class MND work cell. The grip to pick up the products and the work position are the same. However, the performance is a bit worse, through the higher frequency of motions that occur here. The same can be said for the pushing/pulling-criterion for the transport of trolleys and meals.

Furthermore, a high health risk was observed for the lifting criterion. The products that are lifted here are above 3 kilograms, such as the drawers containing champagne bottles or orange juice packs, or trays that contain water bottles. These items are lifted very frequently, and are picked up from a very low position, which can be very hurting for the backs of employees. Next to that, the previously described inefficiency regarding the different throughput times of the juice and hot snack trolleys, leads to employees having to lift full, heavy juice or hot snack trolleys, which is ergonomically poor. This all results in a very poor performance on the lifting criterion.

To sum up, the ergonomic performance of this work cell is average on the repetitive motions and the pushing/pulling-criterion. However, a very poor score was measured on the lifting criterion.

iii. Performance M-class main dish & hot snack

Customer complaints & extra delivery runs

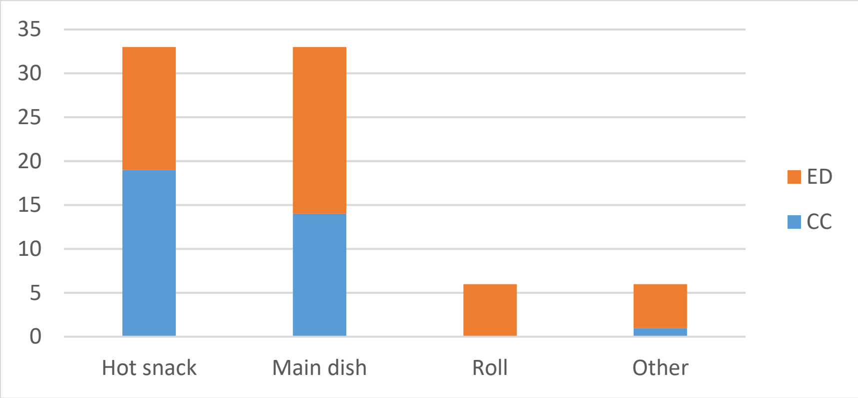


Figure II-4 - CC and ED M-class main dish & hot snack

In Figure II-4, the EDs and CCs of the M-class MND & HSN are shown. Compared to the other work cells, the amount of complaints and runs is significantly higher. This is expected, as the number of trolleys and meals stowed in this work cell is also significantly larger, compared to e.g. the C-class MND work cell. However, 66 complaints or runs regarding the main dishes and hot snacks in nine weeks is still a large amount.

Surprisingly, the amount of complaints and ED runs are equal for both categories. This is unexpected, as the main dishes are supplied to VLAS specific for each flight, whereas for the hot snack everything is delivered in bulk. This could be caused by GOC delivering the wrong amounts of meals, whereas the employee assumes that the right amount of meals is delivered. Next to that, the employee has to count the stowing of the dishes by heart, so a miscount can be made easily when he loses his focus suddenly, e.g. after searching for equipment or meals and returning to the lifting table. This is interesting, but as there are no data available about the completeness of deliveries and this process is outside the scope of this research, this will not be looked into in further detail. However, this should be kept in mind when recommending to supply all meals flight specifically.

Within the 66 mistakes, there is a surprisingly high amount of complaints and EDs in which more than twenty meals are short or missing in a trolley: 29 times. In these cases, either an oven rack or a container had been forgotten to be transported to the plane, or an employee had skipped a certain oven rack per accident. This can be caused because batching is used for filling the trolleys. Through this, a trolley or oven rack can be easily overlooked.

On-time deliveries

With 91,9% of the deliveries made on time, the M-class MND & HSN performs just below the target of 8%. It must however be kept in mind that the amount of trolleys that is be produced here, is much higher than the amount at e.g. the C-class MND work cell.

Looking at the performance in the different production blocks, most overdue deliveries originate from the morning shift: 84%. This could be caused by the start-up time of approximately 30 minutes that is needed every shift, as well as the employees having a lunch-break after the first two blocks. Therefore, they are a bit behind schedule already at the start of day, which causes the too-late deliveries for the first blocks, as well as extra pressure for the employees to be able to finish the remaining scheduled trolleys in time. Because, as mentioned before, the trolleys that are scheduled for the morning must be transported to the aircraft in the afternoon.

Lean rate
In Table II-3, the Process Activity Map for the M-class MND & HSN is shown. In this work cell, on average 55% of the time is used for value adding activities, whereas the remaining 45% can be classified as waste.

Table II-3 - Process Activity Map M-class main dish & hot snack

	Activity	Flow	NVA/VA	Waste type	Average time	% of time
1	Retrieve set-up M-trolleys from storage area and put them on the lifting table. Gather oven racks for special meals.	T	NNVA	Transport. Waiting. Inventory.	00:09:30	18%
2	Retrieve totes with M-class main dishes & hot snacks from cooling	T	NNVA	Transport. Motion.	00:03:14	6%
3	Stow main dishes and hot snacks in trolleys	O	VA	-	00:30:38	55%
4	Scan production card bar codes to notify the trolleys are complete	C	NNVA	Motion	00:03:43	7%
5	Push completed trolleys to the distribution gates	T	NNVA	Transport. Waiting.	00:04:20	8%
6	Other waste: cleaning work space, searching for equipment, etc.	O	NNVA	Transport. Motion. Waiting.	00:03:54	7%
				Total	00:55:19	100%

Likewise to the other work cells, over 50% of the time is used for stowing the main dishes and hot snacks in the trolleys. This is the only value-adding activity of this work cell, the others are all non-value adding.

The percentage of time used for transportation of trolleys in this work cell is higher than the previous two work cells, this is because there are more trolleys and totes with meals that have to be transported. However, 32% of the time (trolley and tote transport combined) is still a very high percentage.

Ergonomics
Compared to the C-class juice & hot snack work cell, the frequency of movements is higher, because of the high amount of meals that are stowed in the trolleys. These meals are stowed in a very high tempo over a long time in a day, which results in a poor score on the repetitive motions criterion. Next to this, the lifting score is below average. This is due to the stacking of

totes, to be lifting meals from a better height (similar to the C-class MND work cell), but here, the weight of totes is higher, so the score is a bit worse. Lastly, a very poor score on the pushing/pulling-criterion was measured. The weight of the trolleys is similar to the other work cells, but the frequency of transporting the trolleys is higher, which results in a higher transporting distance and therefore a worse score.

Overall, ergonomically speaking, this work cell can be qualified as very tough. The working tempo is high, and on every criterion as posed a below average score was measured.

iv. Performance CTR

Customer complaints & extra delivery runs

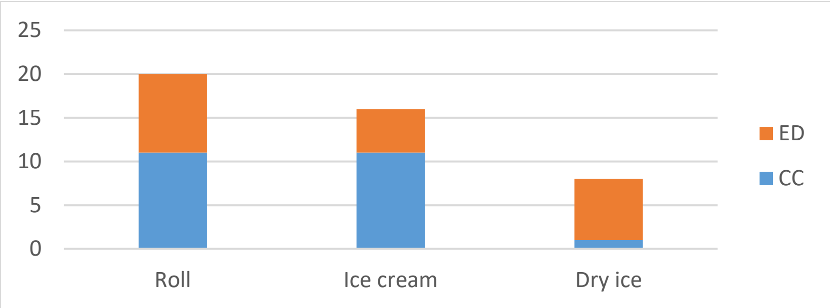


Figure II-5 - CC and ED CTR

Figure II-5 visualizes the CCs and EDs for the CTR work cell. Compared to the amount of meals and containers that are produced over here, there are a lot of mistakes made here. Most complaints and runs are caused by shortages of rolls, this is a problem that has occurred at KCS for a longer while now, resulting in several problem-solving projects to reduce the number of mistakes here. One of the main causes of shortages of rolls is that sometimes not all bags of rolls fit in the container, so the employee considers the container to be completed. Next to this, some ice-cream boxes tend to be forgotten to be stowed in the containers by employees, as well as the bags of dry ice.

On-time deliveries

The performance on on-time deliveries of the CTR work cell is quite poor. 85,8% of all deliveries are done on time. Of all the deliveries that are done too late, 25% occur in the first production block. This is again caused by the start-up time that is needed in the beginning of the shift.

Next to that, a lot of time is taken up for the building of ice-cream boxes. This is reflected in the terrible delivery performance of the ice-cream containers: as many as 34,4% of these containers are delivered too late. In the process, employees have to retrieve the ice-cream boxes from the cooling, put these in Steropor boxes (that have to be picked up as well) and close the boxes with tape, and stow these in the trolley.

Finally, the batch size of producing the CTR trolleys is high. During the observations, it occurred that more than 30 CTR trolleys, containing two or more containers, were ‘in production’. These are trolleys that are scheduled for production in one, sometimes two blocks. Through this, either all trolleys are on time, or all trolleys are too late, which causes a poorer performance.

Lean rate
In Table II-4, the Process Activity Map for the CTR work cell is shown. The lean rate here is 56%, meaning that 44% of the time used consists of waste activities.

Table II-4 - Process Activity Map CTR

	Activity	Flow	NVA/VA	Waste type	Average time	% of time
1	Retrieve set-up CTR-trolleys from storage area	T	NNVA	Transport. Waiting. Inventory.	00:06:06	9%
2	Retrieve ice-cream cups from cooling and totes with rolls from GOC.	T	NNVA	Transport. Motion	00:08:28	13%
3	Stow rolls and boxes in the containers and building ice-cream boxes.	O	VA	-	00:36:28	56%
4	Scan production card bar codes to notify the trolleys are complete	C	NNVA	Motion	00:02:38	4%
5	Push completed trolleys to the distribution gates	T	NNVA	Transport. Waiting.	00:03:24	5%
6	Other waste: cleaning work space, searching for equipment, etc.	O	NNVA	Transport. Motion. Waiting.	00:07:33	12%
				Total	01:04:37	100%

Also for the CTR work cell, the employee spends more than half of the time stowing the rolls and boxes in the containers. This includes the building of ice cream boxes, resulting in a time expenditure of 56%.

Likewise to the other work cells, just over a quarter of the time is spent for the transportation of empty and full trolleys, as well as the totes with rolls and meals.

Ergonomics
The performance on repetitive motions in the CTR work cell is reasonably good. This is due to the low frequency of stowing products into the trolleys. However, the trolleys here are not put on a lifting table, but are placed on the floor. Therefore, employees have to bend forward to stow the products in the CTRs, which could potentially be damaging to employees' health. The analysis shows a substantial health risk to their backs and legs.

On the pushing/pulling-criterion the same average performance was measured. Next to this, the score on lifting is perfect. The weight of the products that are stowed into the trolleys is less than 3 kilograms, so no potential health risk is measured.

So overall, the ergonomic performance is average here. Employees regard this work cell as a relatively easy (although the EDs and CCs don't reflect this) and calm work place, as the work load is not as high as in the other work cells. Also, they perceive the variation of work in this work place to be good.

v. Performance Silverware

Customer complaints & extra delivery runs

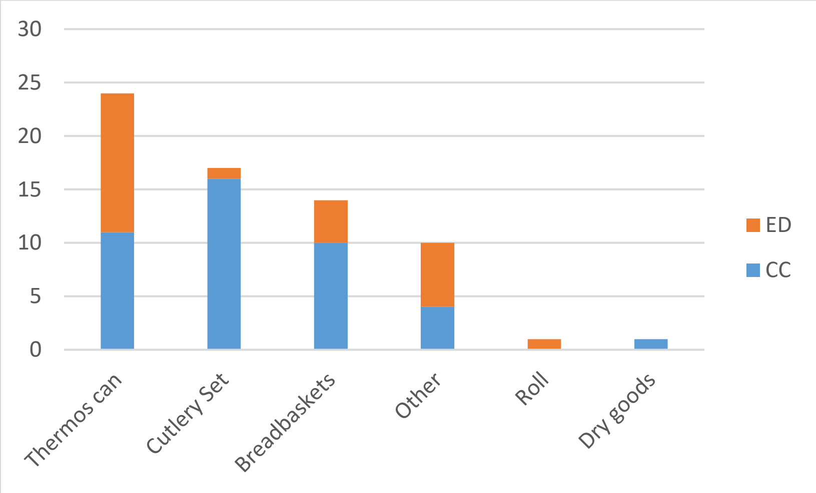


Figure II-6 - CC and ED Silverware

In Figure II-6, the amount of EDs and CCs are shown for the silverware work cell. The performance here is, especially regarding the number of items and containers stowed, poor. This is mostly due to the high complexity and variability in the content of drawers that go into the drawers.

Most mistakes occur in the thermos cans that should be provided, 24 times coffee or tea jug position hasn't been filled. Possibly, this could occur because these positions are built on the floor. The employee has to bend over to do a visual check of completeness, which therefore does not happen often. Next to this, 17 mistakes have been made regarding the cutlery sets. The cause of this can be that sometimes employees interchange the cheese and bread thongs, which is only found out about on board. Another poor performer are the breadbaskets, of which shortages occur quite often.

The use of batching for building the silverware containers, could be the cause of a lot of mistakes. Employees sometimes gather a batch of over 60 containers in one block. Then they pick an item and visit every container that requires the item. Then however, if one action is done wrong, either the mistake is made for all containers, or the container on which the mistake is made, is easily overlooked.

On time deliveries

The Silverware work cell is also a bad performer on the on-time deliveries KPI. Just 85,5% of all its deliveries to the gate are on time, which is way below the target of 92%. There is a big difference between the morning and late shifts here: as many as 82% of all too-late deliveries occur in the morning shift. This is again due to the start-up time, but also because of the fact that Silverware is very dependent on the input of equipment of the incoming flights. It takes some time to get the flow of items from the plane to KCS going. Furthermore, the items that come back, need to be washed first, which costs even more time. It takes approximately three production blocks to catch up with the schedule.

Again, the large batch size that employees use to build the Silverware trolleys does not help performance. Through this, the sorting process of the different containers relatively takes up more time, as the number of containers to be filled is higher. Also, through the large batch size, a huge number of trolleys are either all on time or they are all too late.

Regarding the two KPIs ED/CC and on-time deliveries, it can be said that silverware is performing very poorly.

Lean rate
The lean rate of the Silverware work cell is 52% (48% being waste) and is thereby the worst performing work cell of the five in terms of lean rate.

Table II-5 - Process Activity Map Silverware

	Activity	Flow	NVA/VA	Waste type	Average time	% of time
1	Retrieve set-up CTR-trolleys from storage area	T	NNVA	Transport. Waiting. Inventory.	00:16:15	24%
2	Build bread basket and serving tray supply	O	VA	Inventory.	00:06:43	10%
3	Set-up containers with the built-up supply according to production card. Stow other items from totes in container.	O	VA	-	00:28:20	42%
4	Scan production card bar codes to notify the trolleys are complete	C	NNVA	Motion	00:02:46	4%
5	Push completed trolleys to the distribution gates	T	NNVA	Transport. Waiting.	00:03:11	5%
6	Other waste: cleaning work space, searching for equipment, etc.	O	NNVA	Transport. Motion. Waiting.	00:09:34	14%
					01:06:49	100%

Like the other work cells, 52% of the time, the employee is occupied with either filling the containers with items, or building the bread baskets and serving tray supply. These are value adding activities. The other activities are all non-value adding.

The work cell is placed near a washing machine, so the travel distance to pick up trays, coffee jugs, etc. is minimized. Therefore, it is remarkable that still a huge part of the time is spent for the transportation of trolleys: 29% in total. Especially the retrieval of the set-up trolleys takes, compared to the other work cells, much longer. Averagely, employees here spend 6 minutes more than the other work cells on this. This is due to that employees first gather all the CTRs that are to be built in a block and then sort the containers per type on a CTR. Employees put the SQC and STCs that belong in a certain galley on one CTR, which takes a lot of unnecessary waiting and sorting time, as two employees 'touch' the containers for the same action.

Ergonomics
The ergonomic performance on pushing/pulling is similar to the other work cells. The items that must be lifted are not very heavy, but as the silverware trolleys are also built on the floor, the pose the employees use to lift items could be very damaging to their backs. Next to this, when observing repetitive motions, for the shoulder and arms, performance is normal. However, employees must bend over forward to stow the items in the containers, and do this on a high frequency. Especially when the employee is quite tall the movements ask a lot of his body. To sum up, the health risk through repetitive motions of the upper body is very high.

Summing up, the ergonomic performance in this work cell is terrible, because of the fact that the containers are built on the ground and not on a normal working height. When interviewing employees about their perception of this work cell, the ergonomic performance was confirmed. They found this work cell to be very tough and hurting for their backs.

III. Equipment

The most frequently (approximately 14.000 per day) stowed meals at VLAS are the main dishes and the hot snacks for the M-class. These are stowed on one of the seven or eight skids in an oven insert (Figure III-2). Depending on the type of meal (HSN or MND), these oven inserts are put in either a UTR (Figure III-1), T12 (Figure III-3), MUTR (Figure III-4) trolley. In a MUTR or the normal UTR, up to four oven inserts are placed. The transport UTR of is only used for transportation of the oven inserts. The trolley is transported to the plane, where the oven inserts are placed in an oven in the galley, and then goes back to KCS, empty. The other trolleys are also transported to the plane, but remain there for the flight.

Figure III-1 - UTR transport trolley

Figure III-2 - Oven insert (OIS)

Figure III-3 - T12 trolley

Figure III-4 - MUTR trolley

Other carriers that are used, are STC (standard containers) and SQC (squared containers), as shown in Figure III-6 and Figure III-7. These containers are placed on a CTR (Figure III-5). Likewise to the transport UTR-trolley for the main dishes, the CTR is only used for the transportation of the containers through KCS and to the plane, and returns to KCS empty. The SQC and STC containers are filled with rolls at the CTR work cell, and with silverware equipment at the respective work cell.

Figure III-5 - CTR

Figure III-6 - Standard Container (STC)

Figure III-7 - Squared Container (SQC)

Before the meals are picked up for being put into one of the trolleys, they are placed in the cooling. Here, per different category (M-MND, M-HSN, C-MND) the products are separated by a small fence and have their own dedicated area. In each cooling per category, meals are packed in totes and stacked on a wheeled chassis (Figure III-9). In these stacks, for the M-class main dishes, meals are delivered in numbers specifically for a certain flight. On a stack, totes for different flights are put on each other and are separated by a black tote. For the hot snacks and C-class main dishes, this is not the case, as these are delivered in bulk for an entire block, so these are not counted out per flight.

Figure III-8 - Cooling area

Figure III-9 - Cooling cell

The trolley types have been described, as well as where the meals come from. However, for the employee at the washing machine, it is necessary to know what type of trolley is needed, and which equipment needs to be put into the trolley. Therefore, production cards are assigned to each trolley or container. An example is given in Figure III-. This is the production card for a M-class hot snack trolley for the flight KL445 to Kuwait. The amount of meals that need to be stowed in the trolley is specified: 31 cinnamon rolls (99382A53) and 11 cheese quiches (99382A63). These codes are usually learned by heart by employees, so it can be easily seen that this is mistake prone in real life.

Furthermore, the location where it should be produced is written. Below the flight number, there is information about the aircraft type, flight date and time and the number of C- and M-class passengers. Finally, the position number is shown. This is the place that the trolley should be put in, in one of the galleys in the plane. The trolley in this example, should be put in the M-galley, in number 673.

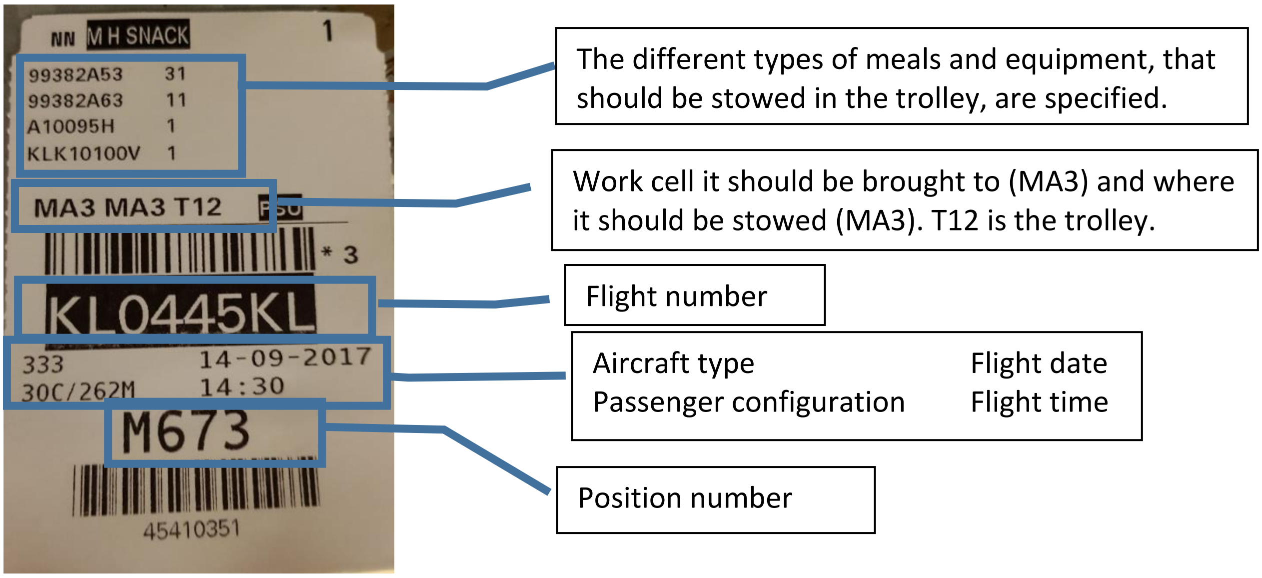


Figure III-10 - Production card

IV. Determination of sample size

For the determination of the number of measurements that had to be done in order to create data that are statistically correct, the formula of Pollux has been used.

$$n = \frac{4p\,(100 - p)}{(2s)\hat{}2}$$

Hereby is *n* the sample size, *p* the estimated time-percentage spent and *s* the accuracy of the measurement.

For every activity per work cell, firstly an estimation was made about the percentage of the time that is spent. In alignment with KCS, an accuracy of 15% was used for each measurement, as it is a global indication of the time spent on each activity. Filling in the estimated time-percentage and the accuracy led to a certain number of measurements. As can be seen from the tables below, the maximum amount of measurements that was indicated is 11. Therefore, for each activity 11 measurements will be done, in order to analyze the data statistically correct.

Table IV-1 - Measurements C-class MND

	Activity	Estimated time (%)	Accuracy	#Measurements necessary	Start/stop
1	Retrieve set-up C-trolleys from storage area and put them on the lifting table. Also gather oven racks for special meals.	15%	0,15	5,67	Start: when leaving lifting table. Stop: back at lifting table
2	Fill the trolleys with equipment according to the specified loading diagram	20%	0,15	7,11	Start: when first tray is stowed. Stop: when last tray has been stowed.
3	Retrieve totes with C-class main dishes from cooling	5%	0,15	2,11	Start: when leaving lifting table. Stop: back at lifting table
4	Stow main dishes in trolleys	45%	0,15	11,00	Start: when first meal is stowed. Stop: when last meal is stowed.
5	Scan production card bar codes to notify the trolleys are complete	5%	0,15	2,11	Start: when scanner is picked up. Stop: when last card has been scanned.
6	Push completed trolleys to the distribution gates	10%	0,15	4,00	Start: when lifting table goes down. End: when coming back to lifting table.

Table IV-2 - Measurement C-class juice & HSN

	Activity	Estimated time (%)	Accuracy	# Measurements necessary	Start/stop
1	Retrieve set-up C-trolleys from storage area and put them on the lifting table. Gather oven racks for special meals.	15%	0,15	5,67	Start: when leaving lifting table. Stop: back at lifting table
2	Retrieve totes with C-class juices & hot snacks from cooling	10%	0,15	4,00	Start: when leaving lifting table. Stop: back at lifting table
3	Stow juices and crackers in the juice trolleys. Stow hot snacks and the required number of PSU plates in the hot snack trolleys.	45%	0,15	11,00	Start: when first meal is stowed. End: when last meal is stowed.
4	Scan production card bar codes to notify the trolleys are complete	10%	0,15	4,00	Start: when scanner is picked up. End: when last card has been scanned.
5	Push completed trolleys to the distribution gates	15%	0,15	5,67	Start: when lifting table goes down. End: when coming back to lifting table.

Table IV-3 - Measurements M-class MND & HSN

	Activity	Estimated time (%)	Accuracy	# Measurements necessary	Start/stop
1	Retrieve set-up M-trolleys from storage area and put them on the lifting table. Gather oven racks for special meals.	15%	0,15	5,67	Start: when leaving lifting table. Stop: back at lifting table
2	Retrieve totes with M-class main dishes & hot snacks from cooling	10%	0,15	4,00	Start: when leaving lifting table. Stop: back at lifting table
3	Stow main dishes and hot snacks in trolleys	45%	0,15	11,00	Start: when first meal is stowed. End: when last meal is stowed.
4	Scan production card bar codes to notify the trolleys are complete	10%	0,15	4,00	Start: when scanner is picked up. End: when last card has been scanned.
5	Push completed trolleys to the distribution gates	15%	0,15	5,67	Start: when lifting table goes down. End: when coming back to lifting table.

Table IV-4 - Measurements CTR

	Activity	Estimated time (%)	Accuracy	# Measurements necessary	Start/stop
1	Retrieve set-up CTR-trolleys from storage area	20%	0,15	7,11	Start: when leaving lifting table. Stop: back at lifting table
2	Retrieve ice-cream cups from cooling and totes with rolls from GOC.	15%	0,15	5,67	Start: when leaving lifting table. Stop: back at lifting table
3	Stow rolls and boxes in the containers	40%	0,15	10,67	Start: when first meal is stowed. End: when last meal is stowed.
4	Scan production card bar codes to notify the trolleys are complete	10%	0,15	4,00	Start: when scanner is picked up. End: when last card has been scanned.
5	Push completed trolleys to the distribution gates	15%	0,15	5,67	Start: when lifting table goes down. End: when coming back to lifting table.

Table IV-5 - Measurements Silverware

	Activity	Estimated time (%)	Accuracy	# Measurements necessary	Start/stop
1	Retrieve set-up CTR-trolleys from storage area	15%	0,15	5,67	Start: when leaving lifting table. Stop: back at lifting table
2	Build bread basket and serving tray supply	15%	0,15	5,67	Start: when building first basket. End: when last one is built.
3	Set-up containers with the built-up supply according to production card. Stow other items from totes in container.	30%	0,15	9,33	Start: when first meal is stowed. End: when last meal is stowed.
4	Scan production card bar codes to notify the trolleys are complete	10%	0,15	4,00	Start: when scanner is picked up. End: when last card has been scanned.
5	Push completed trolleys to the distribution gates	15%	0,15	5,67	Start: when lifting table goes down. End: when coming back to lifting table.

V. Ergonomics

For the measurement of the ergonomic performance of the work cells, we performed some ergonomic measurement tests, in cooperation with the physiotherapist at KCS. The ergonomic circumstances are split-up in repetitive movements for shoulder, leg and torso, and pushing/pulling and lifting of items.

To measure the health risk of the repetitive movements, we used the Occupational Repetitive Action (OCRA) checklist, as explained in Peereboom & Vermeulen's book. To measure the repetitive movement performance, the checklist seperates 6 different criteria:

- Frequency of the action: number of movements per minute
- Force factor
- Work position for the shoulder. E.g. is the arm placed above the shoulder height.
- Other factors, like cold, pressure, vibrations, etc. These factors make the work more physically tough.
- Recovery: can the employee recover from the movements.
- Work time: how much time is effectively spent on the repetitive work

For these six criteria, in the checklist, scores are assigned to certain performances.

The OCRA checklist score is then calculated by:

$$Score = (Frequency + Force + Work\ position + Other\ factors) * Recovery * Work\ time$$

For the checklist score, a scale has been set, which is explained in Table V-1.

Table V-1 - Checklist score scale

Checklist score	Risk
<7,5	Acceptable
7,6 – 11	Limited risk
11,1 – 14	Low risk
14-,1 – 22,5	Average risk
>22,5	High risk

In Table V-2, the performance on the repetitive shoulder movements is shown. It can be concluded from this that all work cells are tough, and risk is quite high.

Table V-2 - Repetitive movements shoulder

	Frequency	Force	Recovery	Position	Other factors	Work time	Checklist score	Risk
C-class MND	0	4	4	5,5	1	1	14,5	Average
M-class MND & HSN	2	4	4	5,5	1	1	16,5	Average
Silverware	0	4	4	3,5	1	1	12,5	Low
C-class juice & HSN	1	4	4	5,5	1	1	15,5	Average
CTR	0	4	4	4	1	1	13	Low

However, Table V-2 only shows the repetitive movements for the shoulder, and not for the torso and legs. Therefore, a different version of the OCRA checklist was performed, as we saw that at the silverware and CTR work cells, people are bending over to stow trolleys.. In this checklist, three zones are distinguished (Figure V-1). Zone I is not physically tough, but Zone II and III are. For this, the more movements that are done in zone II or III, the more physically tough it is.

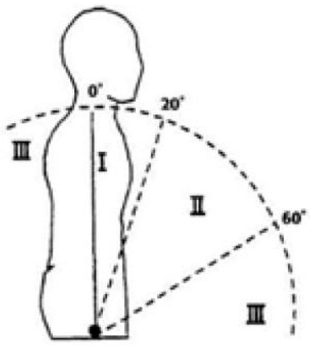


Figure V-1 - Zones

For this method, traffic lights are used to show the ergonomic performance. In Table V-3, these traffic lights are shown.

Table V-3 - Traffic lights per zone

Zone	Frequency
I	All
II	<1 per minute
III	1 – 2 per minute
	2 – 4 per minute
	>4 per minute
	<0,5 per minute
	0,5 – 1 per minute
	1 – 2 per minute
	>2 per minute

In Table V-4, the frequency of repetitive movements for each work cell is shown, for the torso and legs in their respective zones. It can be concluded that the repetitive movements at the silverware work cell, regarding the torso, are physically very demanding. This should be improved as soon as possible, as it could ruin the backs of employees there. For the CTR work cell, the repetitive movements aren't as bad, through the low frequency.

Table V-4 - Repetitive movements leg and torso. Frequency per minute

	Torso		Legs	
Repetitive movements	**Zone II**	**Zone III**	**Zone II**	**Zone III**
C- MND				
M-MND&HSN				
Silverware	>4	>2	-	-
C-juice				
CTR	<1	0,75	<0,5	0,75

Then, we determined the ergonomic performance on the pushing/pulling criterion. Employees are pushing the trolleys to and from the different lifting tables at VLAS. To measure the performance, we used the Key Indicator Method (KIM). Here, five different criteria were measured.

- Distance that the trolleys are pushed by employees each day
- Weight of the trolleys
- Accuracy, whether the employees have to put away the trolleys very accurately, or that the placement margin is high
- Work position, whether the employee can work standing upright, or has to bend over to use force to push trolleys
- Work environment, regarding the floor the trolleys are pushed on (is the floor even, no bumps etc.)

The checklist score is then calculated by

$$Score = Distance * (Weight + Accuracy + Work\ position + \ Work\ environment)$$

For this as well, there is a scale to determine the health risk through pushing/pulling, as shown in Table V-5.

Table V-5 - Risk scale

Checklist score	Risk
<10	Low
10 – 25	Medium
25 – 50	High
>50	Very high

The performance on each criterion and the final checklist score is shown in Table V-6. It can be seen that neither work cell is performing well, but the M-class MND & HSN is performing the worst, through the high frequency that trolleys are pushed.

Table V-6 - Pushing/pulling

	Distance	Weight	Accuracy	Work position	Work environment	Checklist score	Risk
C-class MND	2	2	2	2	2	16	High
M-class MND & HSN	4	2	2	2	2	32	Very high
Silverware	2	2	2	2	2	16	High
C-class juice & HSN	2	1	2	2	2	14	High
CTR	2	2	2	2	2	16	High

Finally, for the lifting criterion, a different KIM checklist was used. Again, five different criteria were measured:

- Lifting: frequency of the lifting per day
- Effective load: weight of the item that is picked up
- Work position: whether the person is performing the action upright or (slightly) bent over
- Work environment: regarding light, no obstacles nearby, clean and steady floor, etc.

The checklist score is then calculated:

$$Score = Lifting * (Effective\ load + Work\ position + Work\ environment)$$

For the determination of the risk per work cell, the scale from Table V-5 is used. The performance of the work cells is shown in Table V-7.

Table V-7 - Lifting

	Lifting	Effective workload	Work position	Work environment	Risk score	Risk
C- MND	4	1	3	1	20	High
M-MND&HSN	4	2	3	1	24	High
Silverware	2	1	4	1	12	High
C-juice	6	1	3	1	30	Very high
CTR	0	0	0	0	0	Low

Here, the C-class juice & HSN performs the worst, due to the drawers with champagne bottles that are lifted very frequently. The CTR work cell has a perfect score, because of the low frequency there.

VI. Work in Progress

To calculate the Work in Progress inventory per work cell, Little's formula will be used. For this, we firstly determined the average number of arrivals on a day per work cell. Hereby, we distinguished the type of carriers.

Table VI-1 - Arrivals of a carrier per day

	T12	UTR	OIS	SQC	STC
C-MND	70	0	217	0	0
C-JUI & HSN	250	100	0	2	0
CTR	91	0	0	266	1
M-MND & HSN	199	47	527	0	37
Silverware	0	0	0	185	235

To calculate the arrivals of a carrier per hour, we divided the arrivals of a carrier from Table VI-1 by the available time per day. The total available time is 15 hours, but through the lunch breaks and other activities, the actual available time is around 85% of those 15 hours, namely 13 hours. By dividing the arrivals per day by 13, we calculated the arrivals of a carrier per hour, as shown in Table VI-2.

Table VI-2 - Arrivals of a carrier per hour

	T12	UTR	OIS	SQC	STC
C-MND	5	0	17	0	0
C-JUI & HSN	19	8	0	0	0
CTR	7	0	0	20	0
M-MND & HSN	15	4	41	0	3
Silverware	0	0	0	14	18

To be able to calculate the WIP, we have to multiply the arrivals per hour (lambda) with the cycle time per trolley. We calculated this CT per work cell, as shown in Table VI-3.

Table VI-3 - Cycle time per trolley

	CT
C-MND	1:06:08
C-JUI & HSN	1:04:36
CTR	0:57:05
M-MND & HSN	0:41:26
Silverware	0:57:15

Then, having the lambda and the cycle time, Little's formula can be applied. Through this, the Work in Progress of each carrier, per cycle can be calculated for each work cell, as shown in Table VI-4.

Table VI-4 - Work in Progress per cycle

	T12	UTR	OIS	SQC	STC
C-MND	5.9	-	18.4	-	-
C-JUI & HSN	20.5	8.2	-	-	-
CTR	6.7	-	-	19.4	-
M-MND & HSN	10.2	2.4	29.0	-	-
Silverware	-	-	-	13.5	17.2

As each work cell uses different carriers for their items, it is not possible to compare the WIPs of the work cells. Therefore, we opted to convert the carriers to a T12-unit. Meaning, one UTR consists of 2 T12s and 1 OIS/SQC/STC is 0,5 T12. We chose for this, because of the size of the different carriers compared to the T12. The T12 Work in Progress is shown in Table VI-5. It is clear that at C-class juice & HSN the WIP is the highest, followed by M-class MND & HSN. The remaining three work cells are very similar in terms of WIP.

Table VI-5 - Work in Process per cycle converted to T12-trolleys

Work cell	T12
C-MND	15,1
C-JUI & HSN	36,9
CTR	16,3
M-MND & HSN	29,5
Silverware	15,3

VII. Brainwriting session

In the brainwriting session, we set-out several problems and bottlenecks that we wanted to generate solutions for. Then, per problem individually, we took 10 minutes per person to conceptualize several ideas, whether they are completely out of the box or very simple. In this Appendix, we show the different ideas that we generated for these themes. After generating ideas, we very quickly judged the ideas on the impact of a certain solution and whether the idea would be easy to implement.

Table VII-1 - Reducing the batch size

	Impact	Ease
Physical planboard	Medium	Easy
Single-piece flow	High	Hard
Instead of working in 12 blocks, create more blocks to reduce the batch size	Medium	Medium
Visualization of production proress	Low	Medium
Reducing the stock in the cooling. Firstly finish that stock, before continuing with other trolleys	Medium	Medium
Reducing the size of the lifting tables	High	Easy
Using takt times for trolleys, use a traffic light to show whether you are on schedule	High	Medium

Table VII-2 - Reducing transportation time

	Impact	Ease
Automatic transportation belts (conveyor belts)	High	Hard
RFID chips for automatic transportation using markers on the floor	High	Hard
Use a runner to deliver supply	Medium	Hard
Extra cooling area near the lifting tables	High	Medium
Move the lifting tables to the cooling area	High	Hard
Use a monorail to transport the trolleys	High	Hard
Put the carriers on a more central location, instead of using to washing machines	Medium	Medium
Create a shopping list	Medium	Hard

Table VII-3 - Improving reliability of scan data

	Impact	Ease
RFID chips or using automatic scanners at the end of the belt or process	Medium	Medium
Use automatic scanners at the gate to distribution	Medium	Medium
Use RFID chips to continuously know the location of the trolley	High	Hard
Use a scanning system on the finger of an employee (like an order pick system)	Medium	Hard

Table VII-4 - Reducing time spent on scanning

	Impact	Ease
Application on the scanner, check whether the employee has batched scanning different trolleys	Medium	Hard
Work instruction to not batch with scanning	Medium	Easy
Hang the scanner above the lifting table	Medium	Easy
Buy an extra scanner	Medium	Easy
Implement an employee dedicated to scanning the bar codes	Medium	Easy
Work instruction to scan a production card immediately after finishing a trolley	Medium	Easy

Table VII-5 - Minimizing mistakes

	Impact	Ease
Visualization of trolley content on a monitor	High	Medium
Use more recognizable seals on the meals	Medium	Hard
Use a pick-to-light system for meals	High	Hard
Whether there are enough meals in a trolley: possibility to weigh the trolley	High	Hard
Use a Kanban system for an oven filled with a certain amount of meals	Medium	Hard
Create a mobile application to help counting	High	Hard
Do not batch the trolleys in production	High	Medium

Table VII-6 - Synchronizing the throughput times at C-JUI and HSN

	Impact	Ease
Change the ratio of Juice : HSN trolleys on a lifting table	Medium	Easy
Put juice & HSN trolleys on a conveyor belt with a lower throughput time	Medium	Hard
Put C-HSN trolleys at the C-MND lifting table	Medium	Easy
Produce two flights on one lifting table: each employee produces one flight	High	Easy
Split-up the lifting table: one for juice, one for HSN	High	Medium

Table VII-7 - Improving ergonomics at C-JUI and HSN

	Impact	Ease
Create a flow rack for the champagne drawers	Medium	Hard
Put the heavy drawers in the bottom of the trolley instead in the top	Medium	Hard
First use a empty drawer, then place the champagne bottle in the drawer	Medium	Hard
Use a drawer cart instead of a rolling container	Medium	Hard
Use a lowerator type of system instead of a rolling container	Medium	Medium
Lower the place the employee is standing, like in a car garage (employee there is below the car)	Medium	Hard
Use a lifting aid to lift the drawers	Medium	Hard
Mobile lifting table, with which you visit the trolleys	Medium	Hard

Table VII-8 - Improving ergonomics at M-class MND and HSN and C-class MND

	Impact	Ease
Use a lowerator	Medium	Easy
Use a chassis that can be adapted in height	Medium	Easy
Use a cart for the different totes	High	Hard
Create a different way of supplying the meals, instead of in a stack, deliver one meal per stack	Low	Hard
A flow rack to sort out the HSN and MND meals	Low	Hard
Create a tool for unpacking the bags with C-class MND dishes	High	Medium
Create a garbage station, to put the plastic bags in	Medium	Easy

Table VII-9 - Improving ergonomics at silverware

	Impact	Ease
Use a conveyor belt, which is at a normal working height to build the containers on.	High	Medium
Lifting tables or a monorail	High	Medium
Use a flow rack to build the drawers and stow the drawers in the container	Medium	Medium
Supermarket, visit the different places of equipment	High	Easy
Use a smaller lifting table	Medium	Easy

Table VII-10 - Reduce time spent on sorting silverware containers

	Impact	Ease
Sort the different production cards before printing	Medium	Easy
Use a plan board at the washing machine, so the employee there can already sort out the different containers	High	Easy
Immediately regenerate the drawers and items that are received from the washing machine	High	Medium
Better communication between ROA and Silverware about the necessity of containers	Medium	Hard
Put the containers in the washing machine and regenerate	High	Medium
Do not batch, only build the items that you can	Medium	Medium
Visualize the build-up of the CTRs with containers	Medium	Easy

VIII. Throughput time of layouts

For determining the performance regarding the throughput time and the productivity gain (i.e. the difference between the current total time needed and the total time needed for the new layouts), estimations were made regarding the new throughput times. For this, each process is simplified and consists of five steps:

1. Retrieve trolleys
2. Retrieve meals from the cooling area
3. Stowing the meals in the trolleys
4. Scanning the production cards of the trolleys
5. Pushing the trolleys to the gate

For each type of product, the stowing time per trolley has been measured. Using this, and the batch size of trolleys per lifting table/assembly line/supermarket employee, the total time per batch could be calculated. Using this time per batch, the total time necessary per day is calculated, for the different layout options.

Layout 1: flight specific production & layout 2 and 3: split-up lifting tables
Here, per different lifting table, a time per different activity is put down. Using these different times per activity, the throughput time per lifting table for a batch is calculated. For the Layouts 1, 2 and 3, this is shown in Table VIII-1.

Table VIII-1 - Throughput times layout 1, 2 & 3

Lifting table		Batch size	Retrieve trolleys	Retrieve meals	Stow meals	Scan	Trolleys to gate	Total mins
1	C MND & HSN	5,2	1,25	1	13	0,5	1	16,8
2	CTR & C PRES	4,6	1	1	12,9	1	2	17,9
3	C JUI & C DESS	7,4	1,25	1	19,2	1	2	24,5
4	C JUI & C DESS	7,4	1,25	1	19,2	1	2	24,5
5	M MND & M HSN	11,4	1,25	1	24,0	1	1,5	28,7
6	M MND & M HSN	11,4	1,25	1	24,0	1	1,5	28,7

Using the time needed per process or batch, the total time necessary to produce all trolleys in a day could be calculated. Firstly, the number of batches was determined, and through that the takt-time. The throughput time must be lower than the takt time, in order to be able to reach the production goals. For this layout, this is achieved. By then multiplying the throughput time with the number of batches, the total time necessary per day is estimated, as shown in Table VIII-2.

Compared to the current situation, an improvement of 1,5 hours is reached.

Table VIII-2 - Performance Layout 1, 2 & 3

Lifting table		#batches	Takt time	Throughput time	Total time
1	C MND & HSN	45,6	0:16:57	0:16:45	12:43:25
2	CTR & C PRES	37,1	0:20:49	0:17:53	11:02:44
3	C JUI & C DESS	26,6	0:29:18	0:24:29	10:51:58
4	C JUI & C DESS	26,6	0:29:18	0:24:29	10:51:58
5	M MND & M HSN	25,7	0:30:11	0:28:41	12:18:01
6	M MND & M HSN	25,7	0:30:11	0:28:41	12:18:01
					70:06:05

Layout 4: individual work cells
Similar to the Layouts 1, 2 and 3, the total time needed per batch for Layout 4 is calculated.

Table VIII-3 - Throughput time layout 4 (mins)

Lifting table	Product	Batch size	Retrieve trolleys	Retrieve meals	Stow meals	Scan	Trolleys to gate	Total time
1	C MND & C HSN	5,2	1	1	13	0,5	1	16,5
2	M HSN	5,9	1	1	12,4	1	1,5	16,9
3	C JUI	3,4	1	1	9,2	1	1,5	13,7
4	M MND	5,5	1	1	11,6	1	1,5	16,1
5	CTR & C PRES	4,6	1	1	12,9	1	1,5	17,4
6	C DESS	4	1	1	10,8	1	1,5	15,3

Using the throughput times as estimated in Table VIII-3, the total time needed for Layout 4 can be calculated. However, as can be seen in Table VIII-4, at lifting tables 1, 2, 4 and 6, the throughput time does not meet the specified takt time. Therefore, this layout is not feasible.

Table VIII-4 - Performance layout 4

Lifting table		#batches	Takt time	Throughput time	Total time
1	C MND & C HSN	47,5	0:16:25	0:16:30	13:03:45
2	M HSN	50,7	0:15:23	0:16:53	14:15:57
3	C JUI	52,4	0:14:54	0:13:41	11:56:11
4	M MND	52,4	0:14:54	0:16:03	14:00:26
5	CTR & C PRES	37,0	0:21:06	0:17:23	10:42:18
6	C DESS	54,0	0:14:27	0:15:18	13:46:12
					77:44:50

Layout 5 and 6: assembly line

Again, the same calculations are made for layout 5 and 6, with the assembly line. The big difference here is however that all transportation in the process is fully automated, as 0 seconds are spent by the employee on transporting the trolleys or meals. Next to that, here the assumption is made that the delivery of trolleys and meals to and from the assembly line is taken care of.

Table VIII-5 - Throughput time layout 5 (mins)

Cell	Product	Batch size	Retrieve trolleys	Retrieve meals	Stow meals	Scan	Trolleys to gate	Total time
1	C JUI	1	0	0	2,7	0	0	2,7
2	C MND	1	0	0	2,7	0	0	2,7
3	C HSN & C DESS	1	0	0	2,7	0	0	2,7
4	M MND	1	0	0	2,1	0	0	2,1
5	M HSN	1	0	0	2,1	0	0	2,1
6	CTR & C PRES	1	0	0	2,8	0	0	2,8

Using the throughput time per trolley from Table VIII-5, the total time for this layout can be calculated and is shown in Table VIII-6.

Table VIII-6 - Performance layout 5 & 6

Cell	Product	# batches	Takt time	Throughput time	Total time
1	C JUI	178	0:04:23	0:02:42	8:00:36
2	C MND	168	0:04:39	0:02:42	7:33:36
3	C HSN & C DESS	285	0:02:44	0:02:42	12:49:30
4	M MND	287	0:02:43	0:02:06	10:02:42
5	M HSN	299	0:02:37	0:02:06	10:27:54
6	CTR & C PRES	170,5	0:04:34	0:02:48	7:57:24
					56:51:42

Here, there is a difference of 14,5 hours with the current situation. However, as mentioned, this is when assuming the meals and trolleys are delivered to the assembly line automatically. The hours an eventual runner should use to continuously supply the assembly line is unaccounted for and impossible to estimate.

Layout 8: supermarket

After determining the batch size for Street 1 (6 OIS with 3 employees) and Street 2 (5 T12-trolleys with 2 employees), throughput times could be calculated.

The determination of the batch size is described in 5.4.8.

Table VIII-7 - Performance Street 1

Street 1	OIS	Total per day	# batches	Takt time per batch	Throughput time per batch	Total time
C HSN	138	1647	274,5	00:08:31	00:08:63	40:38:25
C MND	336					
M MND	575					
M HSN	598					

Table VIII-8 - Performance Street 2

Street 2	T12	Total per day	# batches	Takt time per batch	Throughput time per batch	Total time
CTR	147	564.5	112.9	0:13:49	0:12:36	23:43:06
C PRES	23.5					
C DESS	216					
C JUI	178					

When adding up the total times of each street, 64:21:31 is used in total. This is a reduction of 7:15:47. However, also for this layout goes: the meals and trolleys still have to be supplied by a runner. It is impossible to estimate the amount of time that he has to spend on this.

IX. Analytical Hierarchy Process

In the AHP, firstly we performed a pairwise comparison of the criteria, in order to assign weights to the criteria. The scale of the scores given can be found in section 4.6. In Table IX-1, the pairwise comparison of the criteria is shown.

Table IX-1 - Pairwise criteria comparison

Criteria	1. Ergonomics	2. Quality	3. Productivity improvement	4. Feasibility	5. Costs	6. Throughput time
1. Ergonomics	1.00	3.00	1.00	0.33	3.00	3.00
2. Quality	0.33	1.00	3.00	0.33	3.00	2.00
3.Productivity improvement	1.00	0.33	1.00	1.00	3.00	3.00
4. Feasibility	3.00	3.00	1.00	1.00	5.00	3.00
5. Costs	0.33	0.33	0.33	0.20	1.00	1.00
6. Throughput time	0.33	0.50	0.33	0.33	1.00	1.00
Column total	**6.00**	**8.17**	**6.67**	**3.20**	**16.00**	**13.00**

At every comparison, a consistency check is performed. Here, the consistency rate must be lower than or equal to 0,10. As can be seen in Table IX-2, the criteria were compared consistently.

Table IX-2 - Criteria consistency check

Consistency check	
l_{max}	6.63
CI = (l_{max} - n)/(n-1)	0.12666
Consistency Rate	0.10

After having established that the scores are assigned to the criteria in a consistent way, the definitive weighing factors for each criterion are determined. As shown Table IX-3, the feasibility criterion is determined to be most important, as the concept must be implemented eventually. The weighing factor quality, ergonomics and productivity criteria are approximately on the same level, whereas throughput time and costs (also through the strong link with productivity) are of less importance.

Table IX-3 - Weighing factors criteria

Criteria	Weighing factor
1. Ergonomics	0.201
2. Quality	0.179
3. Productivity improvement	0.181
4. Feasibility	0.312
5. Costs	0.058
6. Throughput time	0.068

After this, we compared the alternatives against each other, for each individual criterion. We only scored the 5 layouts that we categorized in the "Do now" or "Plan" quadrant. We excluded the three layouts that were in the "Drop" quadrant. The scores for each criterion are shown in the tables below, For all criteria, the consistency index is below 0,10.

Tabel IX-4 - Criterion productivity

Alternative	**1. No phys. change**	**2. Split-up LT**	**5. Assembly line**	**7. AGV**	**8. Supermarket**
1. No physical change: flight specific	1.00	0.25	0.20	0.20	0.33
2. Split-up liftingtables	4.00	1.00	0.33	0.25	0.50
5. Assembly line, flight specific	5.00	3.00	1.00	0.33	3.00
7. Automated Guided Vehicles	5.00	4.00	3.00	1.00	5.00
8. Supermarket	3.00	2.00	0.33	0.20	1.00
Column total	18.00	10.25	4.87	1.98	9.83

Tabel IX-5 - Criterion feasibility

Alternative	1. No phys. change	2. Split-up LT	5. Assembly line	7. AGV	8. Supermarket
1. No physical change: flight specific	1.00	1.00	4.00	9.00	3.00
2. Split-up liftingtables	1.00	1.00	4.00	9.00	3.00
5. Assembly line. flight specific	0.25	0.25	1.00	9.00	1.00
7. Automated Guided Vehicles	0.11	0.11	0.11	1.00	0.20
8. Supermarket	0.33	0.33	1.00	9.00	1.00
Column total	**2.69**	**2.69**	**10.11**	**37.00**	**8.20**

Table IX-6 - Criterion ergonomics

Alternative	1. No phys change	2. Split-up LT	5. Assembly line	7. AGV	8. Supermarket
1. No physical change: flight specific	1.00	0.25	0.20	0.20	3.00
2. Split-up liftingtables	4.00	1.00	0.20	0.20	3.00
5. Assembly line, flight specific	5.00	5.00	1.00	1.00	5.00
7. Automated Guided Vehicles	5.00	5.00	1.00	1.00	7.00
8. Supermarket	0.33	0.33	0.20	0.14	1.00
Column total	**15.33**	**11.58**	**2.60**	**2.54**	**19.00**

Table IX-7 - Criterion quality

Alternative	1. No phys. change	2. Split-up LT	5. Assembly line	7. AGV	8. Supermarket
1. No physical change: flight specific	1.00	0.33	0.25	0.20	0.14
2. Split-up liftingtables	3.00	1.00	0.25	0.20	0.14
5. Assembly line, flight specific	4.00	4.00	1.00	0.33	1.00
7. Automated Guided Vehicles	5.00	5.00	3.00	1.00	3.00
8. Supermarket	7.00	7.00	1.00	0.33	1.00
Column total	**20.00**	**17.33**	**5.50**	**2.07**	**5.29**

Table IX-8 - Criterion costs

Alternative	**1. No phys change**	**2. Split-up LT**	**5. Ass. Line**	**7. AGV**	**8. Supermarket**
1. No physical change: flight specific	1.00	2.00	5.00	7.00	4.00
2. Split-up liftingtables	0.50	1.00	3.00	5.00	4.00
5. Assembly line, flight specific	0.20	0.33	1.00	2.00	0.20
7. Automated Guided Vehicles	0.14	0.20	0.50	1.00	0.20
8. Supermarket	0.25	0.25	5.00	5.00	1.00
Column total	**2.09**	**3.78**	**14.50**	**20.00**	**9.40**

Table IX-9 - Criterion throughput time

Alternative	1. No phys change	2. Split-up LT	5. Assembly line	7. AGV	8. Supermarket
1. No physical change: flight specific	1.00	0.25	0.20	0.14	2.00
2. Split-up liftingtables	4.00	1.00	0.33	0.20	2.00
5. Assembly line, flight specific	5.00	3.00	1.00	0.33	7.00
7. Automated Guided Vehicles	7.00	5.00	3.00	1.00	7.00
8. Supermarket	0.50	0.50	0.14	0.14	1.00
Column total	**17.50**	**9.75**	**4.68**	**1.82**	**19.00**

Through comparing the alternatives with each other on every individual criterion, the final scores per alternative per criterion are calculated. These are shown in Table IX-.

Table IX-10 - Scores per criterion

Alternative	**1. Ergonomics**	**2. Quality**	**3. Productivity improvement**	**4. Feasibility**	**5. Costs**	**6. Throughput time**
1. No physical change: flight specific	0.08	0.05	0.05	0.35	0.43	0.06
2. Split-up liftingtables	0.13	0.08	0.11	0.35	0.28	0.12
5. Assembly line, flight specific	0.36	0.19	0.25	0.13	0.07	0.27
7. Automated Guided Vehicles	0.38	0.43	0.46	0.03	0.05	0.49
8. Supermarket	0.05	0.26	0.13	0.14	0.18	0.05
Column total	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**

Finally, the weighing factors per criterion (Table IX-3) are multiplied by the scores of Table IX-. By this, the final performance scores are obtained. These are shown in Table IX-11. From this, the ranking could be determined. Alternative 7 with the AGVs is measured to be the best, followed by the assembly line. The split-up lifting tables and the layout without physical change are shortly behind that. Fifth and last is the supermarket concept.

Table IX-11 - Final scores per alternative

Rank	**Alternative**	**Score**
4	1. No physical change: flight specific	0.17
3	2. Split-up liftingtables	0.19
2	5. Assembly line, flight specific	0.22
1	**7. Automated Guided Vehicles**	**0.28**
5	8. Supermarket	0.14