IMPROVING THE PERFORMANCE OF THE TROLLEY SUPPLY CHAIN
WITH A FOCUS ON VISIBILITY

Using The Best-Worst Multi-Criteria Decision Making Method

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Preface

This thesis report is the final deliverable of the study programme Systems Engineering, Policy Analysis and Management at the faculty of Technology, Policy and Management of Delft University of Technology. The research is conducted during a graduation internship at KLM Inflight Services. The research aims to improve the performance of the trolley supply chain at KLM. The focus of the research is to enable the decision-making process regarding the trolley fleet management. Therefore, the focus of the research is to increase the visibility of the trolley supply chain and so enable the decision-making process.

I would like to thank the following people who supported me during my research and my time in delft:

Bastiaan Kroes & Anja Doze, I would like to thank you for giving me the opportunity to conduct my graduation project at the KLM Inflight Services. I would like to thank you for the useful insights and the valuable experience of the internship. It was truly an amazing experience to work along at KCS Centrum and the KCS Warehouse. Especially experiencing the complexity between the different people involved in the trolley supply chain.

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Last but not least I would like to thank my family and friends. I would like to thank my father, mother, and brother for their unconditional support in the choices I have made and will make. And for giving me the opportunity to study in Delft and conduct an exchange year at the ETH Zürich.

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Sam Bakker

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Executive Summary
The lack of visibility, significant investment, and a presumption of fleet shrinkage are common problems of KLMs trolley supply chain. The lack of visibility of the trolley supply chain faltered the entire trolley decision-making process. The lack of visibility was caused by the following reasons:

- No registration of all trolley movements in the ERP system
- Therefore, no accurate trolley inventory levels in the ERP system.
- No overview of trolley procurement contracts (both lease and bought)
  - Therefore, no insight in lease contract conditions.
- Changes in the organisation. Key persons have left NSM, which led to a knowledge gap.
- Lack of information and coordination throughout the trolley supply chain.

In addition, the trolley fleet is most expensive asset of the NSM. Therefore, the decision regarding the ownership is important. In addition, to the financial aspect, the operational aspect of the ownership structure is very important. For example in case of leasing the trolley fleet, you require adequate processes to return the leased trolleys at the end of the contract term.

The purpose of this research is to improve the visibility of the trolley supply chain to stop the faltering of the trolley decision making process. Subsequently, improving the performance of the entire trolley supply chain. This to ensure the continuity of the trolley supply chain operation.

We have analysed the trolley supply chain by interviewing key personnel, work along in the operation, and reviewing the literature. As a result, we have established four improvement measures and implemented them to enable the trolley decision-making process.

1. Registration of the repair inventory level in the ERP system. We have given Van Riemsdijk a Portal access, which enables them to register all incoming and outgoing trolleys.
2. Overview of all the lease trolleys and procured trolleys since 2007. Via analysing internal documents, invoices, and interviewing former NSM personnel we have made a comprehensive overview of all the trolleys we have acquired since 2007.
3. Create urgency on the Planning department to monitor and ensure an accurate the trolley inventory level in the ERP system.
4. Total trolley counting at KCS Centrum. During three weeks we have counted all the trolleys at KCS Centrum. We registered all the trolleys in a database with the characteristics age, brand and type. The trolley counting was executed to verify the trolley overview and it served as input for the procurement decision of new Atlas trolleys.

This research increased the visibility of the trolley supply chain to such level that it stopped the faltering of the trolley decision-making process. Therefore, it is recommended to take the following points into account:
• Keep the overview of lease contracts updated. This is also part of the communication and coordination structure, but give someone in the NSM organisation the responsibilities over the contracts overview. Communicate this to all stakeholders, that in case there are adjustments the person responsible can update the overview.

• Train KCS Centrum and KCS Warehouse staff to recognize the different types of trolleys. This will prevent wrong entries in SAP. The KCS Centrum staff entails the planning department and the staff responsible for the assembly of the damaged trolleys. The KCS Warehouse staff entails the persons who are responsible for the receiving and storing of trolleys.

• In the current solution for registering the repair flows the external party Van Riemsdijk registers the inflow. This means that there is no control over his entries. There no signals that VRR is adjusting the entries, but KLM would like to be in control. Therefore, it is recommended to train KCS Centrum personnel, but more important to prepare the SAP that KCS Centrum can create an order for damaged trolleys to VRR. In contrast the registering process is now working so should we really change process and except the fact that we can’t control the outflow of damaged trolleys?

• A major part of the visibility of the trolley supply chain is determined by accurate trolley movements and so inventory levels in SAP. Therefore, it is highly recommended for the Planning department of NSM to closely monitor the movements of trolleys and check if outstanding orders are taken. If outstanding orders are not taken and the trolleys did enter the KCS Warehouse the inventory level is not correct any longer.

• The inventory levels of the outstations are an important determinant of the trolley supply chain. Therefore, it is recommended to let the outstations count their trolley stock every month. Note that KCS Centrum has to count the inventory of all catering products for China Southern every two weeks. This can prevent the hoarding of trolleys and other catering products.

• Currently, the cooperation on operational level between the NSM and KCS Centrum is minimal. In the researchers opinion it is recommended that the NSM and KCS cooperate more closely. NSM is owner of the trolley fleet and contains all the knowledge, while KCS Centum is the operator. Knowledge could be exchanged prior to flight schedules changes, which occur every half year. In the current situation NSM defines the trolley need, a cooperation with KCS Centrum might optimize the trolley need.

• It is recommended for the management team to create an environment where the staff does not hesitate to be in charge of the trolley fleet. The current staff does not like to be responsible for the trolley project, because it is complicated and it is almost impossible to do well.

• It is recommended to create the awareness that visibility depends mostly on the registration of actions by personnel. This means that you can have such a good process and registration system, the success depends on the entry of the personnel. Therefore, it is recommended for the management team to create this awareness otherwise every solution will be a failure. Therefore, it is recommended to register in SAP all the trolleys
that are returned to the lease company. The researcher has initiated the registration, but it is highly recommended to keep registering it.

- It is recommended to involve the KCS Centrum employees, who are working on the floor, in the design process for new trolleys. I noticed that many employees are working over 10 years on the work floor. These persons have a large knowledge about what good characteristics are for a trolley, because they handle every day hundreds of trolleys.

In addition, to the above improvement strategies and recommendations additional improvement strategies which improve the performance of the trolley supply chain in the long-run have been developed. This entails further improvements on the visibility of the trolley supply chain, but also recommendations on the ownership structure of the trolley fleet and monitoring the performance.

We have divided the additional improvement strategies into five decision areas, for each decision area the NSM has determined the best improvement strategy. For the determination of the best improvement strategy we have used a novel multi-criteria decision making method: Best-Worst Multi-Criteria Decision-Making Method. The decision areas and best improvement strategy have been presented in the table below.

<table>
<thead>
<tr>
<th>Decision areas</th>
<th>Best improvement strategy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ownership of trolley fleet</td>
<td>Buying</td>
</tr>
<tr>
<td>Enhancing traceability and identification</td>
<td>RFID</td>
</tr>
<tr>
<td>Registration structure for movements and contracts</td>
<td>Batch Management</td>
</tr>
<tr>
<td>Communication and coordination structure</td>
<td>Embedded in the organisation</td>
</tr>
<tr>
<td>Monitoring the performance of trolley supply chain</td>
<td>15 KPIs</td>
</tr>
</tbody>
</table>

*Table 1 Best improvement strategy per decision area for improvement*

**Ownership of trolley fleet**

The next steps in implementing the chosen improvement strategy differ per decision area of course. The implementation of financing improvement strategy – buying – is not going to be easy, because the financial board of KLM needs to agree on this decision. Therefore, it is recommended to have a solid and comprehensive business case which also includes the operational benefits of buying the trolley fleet. Thereby, must be realised that the financial board might reject the buying alternative and opts for leasing. Therefore, it is recommended to prepare the trolley supply chain to continue leasing.

**Enhancing traceability and identification**

RFID is selected to best enhance the traceability and identification of the trolley fleet. The amount of potential benefits of RFID are much larger than the amount of risks or obstacles. Nevertheless, there should be great care during the implementation RFID technologies. First the strategy of the NSM needs to be aligned with RFID technologies. This means that the management team must actively support RFID technologies. Second, the organisational structure needs to be adopted for the use of RFID. Third, the question about data management arises. This means that KLM needs to specify what they exactly want to know, because you
can store all possible data on RFID tags. Fourth, who becomes the owner of the data in case you lease the trolleys? This are very important questions that need to be answered before implementing a RFID tracking technology.

Furthermore, it is recommended to use RFID software and hardware that is already on the market, and not develop it yourself. In addition, take a look at your SkyTeam partners and other AirFrance/KLM division such as the Cargo, who already using RFID for track and trace of their equipment. The change of failure is much higher when you develop the software and hardware yourself. Often there is the tendency to design software and hardware that can do everything, which in results in nothing because the design becomes too comprehensive and too complex. Cooperation with KCS Centrum is very important, because they have already conducted a pilot with RFID a few years ago. In addition, the operational manager is open for the use of RFID on trolleys.

On the other hand you ask yourself the question if the RFID benefits are worth the hurdles that have to be overcome. This is a question the management team must answer, because the support of the management team is crucial for the success of the RFID implementation.

**Registration structure for movements and contracts**
The advantage of Batch Management (BM) is that this way all the data regarding a trolley batch can be registered in SAP. Furthermore, it possible to make more efficient use of the trolley fleet. Use newer trolleys instead of older trolleys. The blocking of a specific batch due to end-of-lease agreement or a technical error is executed very easy. Finally, this is a method that is incorporated in SAP and not a workaround method. BM reduces the mess of article numbers in SAP and creates clarity.

It is recommended for the batch management registration to combine it with the introduction of the new Atlas trolley in the end of 2015. At that moment new article numbers in SAP must be created anyways. It is very costly to enable BM on an already active article number.

For a successful implementation the support of KCS Warehouse is crucial, because BM affects their processes most. The storage plan of KCS Warehouse has to be adjusted, and they have to store trolley according to a batch. Now the trolleys are stored according the more general article number, which is easier than BM.

**Communication and coordination structure**
For embedding the communication and coordination plan it is recommended to embed the tasks and responsibility in the organisation as soon as possible. In addition, it is recommended that the ‘Manager Operation’ and ‘Manager Regie’ both attend this meeting to ensure that the every hurdle is overcome.

It is recommended to embed the tasks and responsibilities in the following four functions:

- Central Planner, who is responsible for the trolleys.
- Contract Manager, who is responsible for the contracts with the lease company, repair company, manufacturer and KCS.
• Supply Chain Specialist, who is responsible for calculating the demand for trolleys and is responsible for the reverse logistic activities.
• Project Buyer, who actually procures the trolleys.

Important aspects that need to be divided:

• Owner the trolley contract overview and responsibly for adjustments.
• Monitoring the inventory levels and movements in SAP. Assuring accurate inventories and the administration of the plant REPA in SAP.
• Responsible for the shoot-out of trolleys that return to the lease company.
• Storage of repair certificates. These certificates need to be stored for three years.
• Place orders for new trolleys.
• Create/change or block trolley article numbers in SAP
• Communication with …
  o Area Planning for which trolleys they can send to the outstations
  o KCS Centrum which trolleys they have to order.
  o KCS Warehouse which article numbers need to be blocked
  o Checking that the above actors also do what they are instructed.
• Responsible for defining the trolley need.
• Initiating decisions regarding end of lease agreement.

Monitoring the performance of trolley supply chain
At the moment the performance of the trolley supply chain is not measured. None key performance indicators have been established. In order to monitor the trolley supply chain the choice is made to define a set of 15 key performance indicators, which ensure the continuity of the operation. Then it becomes possible to take precautionary measures in a timely manner. Furthermore, the information from the RFID technology, BM, and communication & coordination structure should be reflected in the monthly KPI reports.

The next steps for the design of the 15 KPIs is to set up a workshop to determine the exact KPIs. It is recommended to align the KPIs with the CIM strategy, because if there is a misalignment then the management steers on the wrong KPIs. Then, the way of measuring and reporting needs to be determined. Finally, the actual measuring of the KPIs needs to be put in place. It is recommended for the design of KPIs to support the workshop with relevant literature to find the optimal KPIs.
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<th>Description</th>
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<tr>
<td>AHP</td>
<td>Analytical Hierarchy Process</td>
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<td>AP</td>
<td>Area Planning</td>
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<tr>
<td>Atlas</td>
<td>Trolley equipment standard</td>
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<tr>
<td>BBO</td>
<td>Bijzondere Beladings Opdracht (Cabin load)</td>
</tr>
<tr>
<td>BWM</td>
<td>Best-Worst Method</td>
</tr>
<tr>
<td>C&amp;D</td>
<td>Customs Affairs &amp; Distribution (Douane &amp; Distributie)</td>
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<tr>
<td>CA</td>
<td>Cabin Attendant</td>
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<tr>
<td>C-Class</td>
<td>Business Class</td>
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<td>CIM</td>
<td>Cabin Inflight Management</td>
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<td>CM</td>
<td>Contract Management</td>
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<td>CP</td>
<td>Central Planning</td>
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<td>DESSERT</td>
<td>See FS</td>
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<tr>
<td>DM</td>
<td>Decision Maker</td>
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<td>DOW</td>
<td>Dry Operating Weight</td>
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<td>EBC</td>
<td>European Business Class</td>
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<td>EPC</td>
<td>Event-driven Process Chain</td>
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<td>Eq.</td>
<td>Equation</td>
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<td>EUR</td>
<td>Europe flights</td>
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<tr>
<td>FS</td>
<td>Full size trolley</td>
</tr>
<tr>
<td>Homebound flight</td>
<td>A flight to the base airport of an airline</td>
</tr>
<tr>
<td>HS</td>
<td>Half size trolley</td>
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<tr>
<td>IATA</td>
<td>International Air Transport Association</td>
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<td>ICA</td>
<td>Intercontinental Airway</td>
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<td>K&amp;N</td>
<td>Kuehne &amp; Nagel</td>
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<td>KCS</td>
<td>KLM Caterings Services B.V.</td>
</tr>
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<td>KLM</td>
<td>Koninklijke Luchtvaart Maatschappij (Royal Dutch Airlines)</td>
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<tr>
<td>KPI</td>
<td>Key Performance Indicator</td>
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<td>KSSU</td>
<td>Trolley standard of KLM</td>
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<tr>
<td>L&amp;O</td>
<td>Loading &amp; Ordering</td>
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<tr>
<td>MCDM</td>
<td>Multi-Criteria Decision Method</td>
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<tr>
<td>M-Class</td>
<td>Economy class</td>
</tr>
<tr>
<td>MT</td>
<td>Management Team</td>
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<tr>
<td>NFC</td>
<td>Near Field Communication</td>
</tr>
<tr>
<td>NSM</td>
<td>Network Supply Management</td>
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<tr>
<td>OS</td>
<td>Outstation – caterer abroad, prepares catering trolleys for inbound flight</td>
</tr>
<tr>
<td>Outbound flight</td>
<td>A flight from the base airport of an airline</td>
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<tr>
<td>PAX</td>
<td>Passenger</td>
</tr>
<tr>
<td>PSU</td>
<td>Pre-setup</td>
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<tr>
<td>RFID</td>
<td>Radio Frequency Identification</td>
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<td>SAP</td>
<td>Supplier of the ERP system at KLM</td>
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<td>Supply Chain Management</td>
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<td>T12</td>
<td>See HS</td>
</tr>
<tr>
<td>UTR</td>
<td>See FS</td>
</tr>
<tr>
<td>VRR</td>
<td>Van Riemsdijk (Repair Company)</td>
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<tr>
<td>WBC</td>
<td>World Business Class</td>
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<td>WH</td>
<td>Warehouse</td>
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1. **Introduction**

KLM Royal Dutch Airlines (KLM) was founded in 1919 and it is The Netherlands oldest operating airline. Since the start KLM has been evolved into an important worldwide player in the aviation industry. Since 2004 KLM is part of the AIR France – KLM group, which entails one group, two airlines and three businesses (KLM, 2013). KLM has also 100% ownership over the brands KLM Cityhopper (KLC), Transavia.com and Martinair (KLM Group, 2007).

The research is executed within the department Network Supply Management (NSM), who is responsible for the management of catering articles and equipment around the world. NSM is part of the division Inflight Services. A more detailed organizational structure of the division Inflight Services is presented in APPENDIX B – Organogram KLM Inflight Services on page 144.

In the airline catering industry every airline uses trolleys to serve the inflight catering product to its passengers. According to the ISO 17364, Layer 3 [17364] trolleys can be described as reusable transport item (RTI) (Bowman, Ng, Harrison, & Illic, 2009). The trolley supply chain of KLM can be described as a closed-loop supply chain with RTIs. Limited visibility, fleet shrinkage and significant investments are three common problems in closed-loop supply chains (Carrasco-Gallego & Ponce-Cueto, 2010).

The question that KLM asked the researcher in the beginning of the research project was: *How can we get now and in the future control and grip over our trolley fleet?*

The incentive for this question arose in the beginning of 2013 when calculations for the procurement decision of new trolleys differed a lot. In addition, decisions regarding for example the end of the lease agreements could not be made (Kroes & Dubelaar, 2013). Furthermore, in the end of 2015 the entire trolley fleet has to be renewed due to a new trolley standard imposed by the introduction of the Boeing 787 (“Dreamliner”). Furthermore, the catering trolley is the most expensive asset of the NSM department. Therefore, NSM strives to have an optimal amount of trolleys in their fleet. Any excess of trolleys has a negative influence on the financial performance of KLM. In summary, the decision making process regarding the trolley fleet the most expensive asset of NSM falters.

Therefore, the aim of this research is to provide KLM improvement strategies for the trolley supply chain that enables the current decision-making process and ensures the decision-making process in the long-run.

The remaining of this chapter consists out of the following parts the research objective, the problem description, research questions, defining of concepts and the delineations, the research framework, the data, the relevance, and the outline of the report.

1.1 **Research objective**

The research objective is to improve the overall performance of the trolley supply chain. And thereby enable the current and future decision-making process concerning the catering trolley fleet. This is achieved by first a detailed analysis of the trolley supply chain. Subsequently,
improvement strategies for the current decision-making process are presented and discussed. Then, additional improvement strategies that improve the performance of the trolley supply chain and ensure the decision-making process in the long-run are designed and evaluated. Finally, recommend KLM on how to implement the selected additional improvement strategies.

1.2 Problem description
At this moment the department Network Supply Management (NSM) has no inside and control over their trolley supply chain. That means that NSM is not able to make any decisions regarding the management of their trolley fleet. This entails decisions concerning procurement, lease agreements, inventory management, quality issues and usage of a specific trolley batch. Furthermore, the characteristics of the trolley fleet, the inventory levels and movements of trolleys are not accurately registered in SAP. The overview of all the lease contracts is not up to date. Trolleys that were supposed to return to the lease company are sent to outstations.

Another aspect that complicates the process are the outstations. Outstations are external caterers worldwide that clean and setup the trolleys. Every outstations has a set of trolleys at their disposal. Therefore, KLM has 69 small inventories worldwide and one large warehouse here at Schiphol.

<Not attached due to confidentiality reasons.>

The combination of limited visibility, significant investment decisions, and the fact that in no case a trolley shortage can occur led to the faltering of the decision-making process.

Therefore, the focus the research is first to stop the faltering of the decision-making process by improving the visibility of the trolley supply chain. Subsequently, improving the overall performance of the trolley supply chain and thereby ensuring the continuity of the trolley supply chain.

<Not attached due to confidentiality reasons.>

1.3 Research questions
The main research question of this research is the following:

What are the best improvements strategies that enable the current trolley decision-making process and improve the performance of the closed-loop trolley supply chain at Cabin Inflight Management, taking into account that the proposed improvement strategies must meet KLM’s criteria cost, reliability, quality, and flexibility?

In addition, to the four criteria cost, reliability, quality and flexibility, which are provided by KLM, the researcher has added a fifth criterion ‘ease’ to the research. This will be explained in the chapter 4.

The main research question is divided into the following sub-questions:
What does the closed-loop trolley supply chain of KLM entail in terms of flows and nodes?

How did the literature contribute in solving the problem?

What are appropriate improvement strategies to improve the current decision-making process?

What are appropriate improvement strategies to improve the performance of the trolley supply chain in the future?

What is the scientific, managerial and societal contribution of this research?

1.4 Defining concepts and delineation

In this part the core concepts of the research and KLM will be described.

1.4.1 Defining trolleys.
A first important concept that needs to be explained and described is the definition of trolleys. There are 5 sorts of trolleys in the operation a full size (UTR) trolley, full size Marcel Wanders (MW11) trolley, a half size trolley (T12), a half size Marcel Wanders (MW12) trolley, and a Waste trolley. The fleet of trolleys is produced by two manufacturers Zodiac Aerospace Driessen and Diethelm Keller Aviation. Trolleys are used inflight as carrier for all kind of catering products. A trolley is an example of a returnable transport item (RTI) (Carrasco-Gallego et al., 2012).

1.4.2 Difference ICA-M, EBC and WBC
KLM has divided their flight schedule in two groups Europe and Intercontinental (ICA). Both groups are divided into an Economy Class (M-class) and Business Class (C-class). The ICA business class is called World Business Class (WBC) and the Europe business class is called Europe Business Class (EBC). The ICA and Europe economy class are called the M-class.

1.4.3 Outstations
Outstations are caterers at other destinations that unload, clean – reconditioning (Carrasco-Gallego, Ponce-Cueto, & Dekker, 2012) – and prepare the catering equipment again and finally upload it. You can compare an outstation with KCS. Only difference is that KCS handles over 200 KLM flights per day and that an outstation handles an average of one KLM flight per day.

KLM has around 69 outstations on the ICA destinations. Not all the ICA destinations have an outstation, because some destinations are part of a tailpiece flight. For example Denpasar, Indonesia is an ICA destination of KLM, but there is no outstation in Denpasar. This is due to the fact that there aircraft makes a stopover in Singapore. All catering equipment for the flight to and from Denpasar is catered at Singapore. Within Europe there are only 10 outstations, because the aircraft is waiting overnight at that destination. On all the other Europe destinations the aircraft is set up with both outbound and inbound catering products. Outbound is a flight leg departing from Schiphol Amsterdam and a homebound is a flight leg arriving at Schiphol Amsterdam.

KCS Centrum is the caterer at Schiphol, besides KLM KCS also handles China Southern, Kenya Airways and Etihad. KCS has divided the KLM flights in a Europe and ICA flow.
Subsequently, the flows are divided in a Non Food & Beverage (NFB) and a food flow. Every flow has its own type of equipment and different processing times.

The research first focusses on the trolley supply chain. There has been chosen for the trolley supply chain, because this the most expensive piece of catering equipment and the amount of trolleys inflight is bounded by the technical specifications of an aircraft. All the outstations are taken into account and all the Europe destinations without an outstation. In the research should be made a distinction between both, because of the presence of an outstation. The presence of an outstation increases the need for trolley and the probability of hoarding.

Hoarding is the concept that outstations maintaining higher work floor inventories than agreed upon. This brings us to another concept of work floor inventory and warehouse inventory and its registration in SAP. The warehouse inventories of the outstations and Schiphol-Noord are listed in SAP. The work floor inventories of KCS and outstations are not listed in SAP.

1.4.4 Flows and nodes of the trolley supply chain

In the figure below a schematic overview is shown of the flows within CIM. Suppliers deliver their products to the Warehouse at Schiphol-Noord. Food suppliers deliver directly to KCS-Centrum. The outstations can be supplied by air or sea. The air supply is assembled at Warehouse and then brought to KCS Centrum and put on board. The sea containers are assembled at the Warehouse and then send to the outstations by the external handler Kuehne & Nagel.

![Figure 1 flows of all goods & services of KLM supply chain (adopted from: van Kleef, 2012)](image)

The figure shows the overall supply chain of catering products. A more in depth trolley supply chain is shown in the figure below. Suppliers of non-food products deliver all their products to the warehouse at Schiphol-Noord. Fresh food suppliers deliver their products directly at KCS Schiphol-Centrum. KCS Centrum issues daily products from the Warehouse and they are delivered within a few hours. The sea containers for the supply of outstations are also prepared at the Warehouse.
The figure above shows the nodes and flows involved in the trolley supply chain. AEL is the lease company, but they are not the supplier of the trolleys. AEL provides KLM a financial lease. This means that AEL is the owner of the trolleys and at the end of the lease-period gets the trolleys back and has to find a new owner for them. The manufacturer and designer of the trolleys is currently Driessen. Driessen designs in cooperation with CIM and manufactures the trolleys. When a delivery is ready Driessen will transport the trolleys to either VRR or directly to the WH. When the trolleys are transported to VRR, VRR will unpack the trolleys and register in the VRR database. If the trolleys are directly transported to the WH, the WH will do the unpacking and automatically insert the trolleys into the system.

As described before a broken trolley is shot out at KCS and then transported to VRR. VRR makes the decision based on KLM standards if a trolley can be scrapped or repaired. Every week VRR sends an email to the NSM planning department with the amount of trolleys that can be scrapped and the amount that is repaired. It is not known what the inventory or working stock of VRR is. Scrapped trolleys are sent to the WH and the reverse logistic department of the NSM is responsible for the disposal. There is not any registration in SAP of the scrapped trolleys.

KCS decides every day if it needs to issue trolleys based on counting lists in Excel. If KCS needs more trolleys an order is send to WH and they will prepare a shipment. Within in a few hours the shipment is delivered at KCS.

In Figure 3 the locations of KCS Centrum, KCS Warehouse and KLM Inflight Services are depicted. The distance by road between KCS Centrum and KCS Warehouse is 6.0 kilometre. The distance between KLM Inflight Services and the KCS Warehouse is 3.8 kilometre.
1.4.5 Concept of Need

Another important concept that needs to be described is the need for trolleys. The need of each node defines the total amount of trolleys needed for operation. The total amount of trolleys can be divided into three nodes KCS, in the air, and at an outstation.

The first and very important node is KCS, because this is KLM’s main hub. Therefore, it is of great importance to know the daily/weekly/monthly need of KCS. It is generally known that there is a peak during the weekend. Furthermore, it is of essence to know the method of working, e.g., cleaning, set up, etc. Because this will tell how many trolleys KCS needs on their work floor to operate efficiently. At the moment KLM CIM does not know the need of KCS and KLM CIM does not know how many trolleys there are present at the work floor. It is therefore important the exact time KCS needs to prepare a flight. This will influence the need for their trolleys.

Secondly, the needs of the outstations are important in the determination of the total need, because there are many outstations. At the opening of an outstation the amount of trolleys for the work floor is determined and provided. Later during operation it is not known what the work floor inventory is, only the warehouse inventory is known. Besides trolleys for the work floor an outstations also gets one or two spare trolleys for their warehouse inventory.

Thirdly, there is always an amount up in the air. This can be defined by the total amount of flights per day and the type of aircrafts. The CIM department Loading & Ordering (L&O) defines the amount of trolleys per type of aircraft.

1.4.6 The CIMplify project

The CIMplify project is currently developed. The aim of the CIMplify project is to reduce weight & waist, improve customer satisfaction and simplify the IT landscape.
Especially the first pillar, reducing weight and waste, is very interesting. In the future KLM wants to fly with the least weight as possible because every extra piece of weight costs fuel. In the context of CIMplify CIM is analysing the possibilities to let the amount of equipment and catering products be dependent on the amount of passengers. If there are 20 passengers on a flight it’s not desirable that the aircraft has catering products for 100 passengers.

The principle of carrying the full load of catering equipment on a flight leg is called the PSU (pre set-up) standard. This means that if on an ICA flight leg only 30 out of the 50 business class (WBC) seats are sold the catering equipment for the remaining 20 seats will be put on board as well (without the food). This is the so-called in-balance principle. It is to prevent an imbalance at the outstations, but by this carrying unnecessary weight during a flight leg.

The opposite of the in-balance principle is the imbalance principle. The imbalance principle encompasses carrying inflight only the catering equipment that is consumed during that flight. The imbalance principle entails gains and possible extra costs for higher stocks and higher inventory costs.

The in-balance principle makes planning of the inventories of outstations easier and more predictable. Therefore, abandonment would have a huge impact on the planning of the outstations inventories. This is why the insight and control over the trolley supply chain must be first improved prior to testing the abandonment of the in-balance principle.

1.5 Research framework

The research framework supports the researcher in structuring the research. The research is a schematic representation of the research objective and includes the appropriate steps that need to be taken in order to achieve it (Verschuren & Dooreward, 2010). The research objective is to improve the overall performance of the trolley supply chain. And thereby enable the current and future decision-making process concerning the catering trolley fleet.

The nature of this research is practice-oriented (a case study). Therefore, it is necessary to combine a literature review with a field observations, which means interviewing stakeholders and observing the processes of the trolley supply chain.
In the figure above a schematic representation of the research framework is presented. In the first phase a literature study is conducted, and open- and structured interviews are conducted. This establishes the theory on evaluation MCDM methods, theory on closed-loop supply chains, the organisational structure of the trolley supply chain, and the complexity of the trolley supply. The previous in combination with quantitative data is the input for the design of improvement strategies, and the mapping of the current situation of the trolley supply chain. The latter two will in combination with the theory on MCDM methods lead to the recommendations on suitable improvement strategies that enhance the current and future decision-making process.

1.6 Data
The research material needed is based on the main research questions and the research questions. The research material is collected by gathering data within KLM, face-to-face interviews both structured and non-structured and literature study.

In order to get a better picture of the current situation a literature review is conducted on the management of equipment – trolleys – in the airline industry and other industries. Furthermore, the literature review focusses on the management of closed-loop supply chains and suitable evaluation methods, methods for generation of improvement strategies, and methods for defining the objectives. Websites such as Google Scholar and Scopus are suitable. Next to that the literature and course material of the course ‘SPM4123 MAS Design from engineering perspective’ is reviewed, because it provides insights in existing methods (MCDM) to select the best improvement strategies. The literature study also focusses on the existing laws and regulation. Next to that a close look has been taken into previous research executed within KLM.

Interviews
Face-to-face interviews have been conducted with key personnel within KCS to gain more insight in the catering processes and the way they are working and to define the need of KCS.
A list of all the people that have been interviewed during the research is included in Appendix A on page 144.

Also an interview with the business unit Contract Management, Ingrid Schoenmakers, has been conducted to talk about the performance of outstations and the reliability of their work floor inventory – not listed in SAP – and the actual inventory – listed in SAP.

Next to that, an interview with procurement department is conducted to find out the details of the contracts with Zodiac, AEL, VRR, KCS and outstations. In addition, an interview is set up with the business unit controlling and account. They take care of all the incoming invoices and handle them. They can provide the researcher with insight over all the invoices KLM has paid. This will establish an image of the trolleys that have been bought and leased over the last decade.

Data gathering

KCS is contacted to receive data about their operation. In that it might be possible to define their equipment need. Sideways a mathematical need should be estimated based on the way KCS is working, the flight schedule and the loading of the different types of aircrafts.

KLM should provide the current flight schedule and the expected flight schedule. The business unit Loading and Ordering can provide the researcher the current equipment load per flight type. The business unit Planning could provide the researcher with information about the initial outlay of equipment at outstations, the frequency and type (air or sea) of supply of the outstations, the minimal stock levels at outstations and KCS, and the lead-times of the products.

The business unit Supply Chain Specialists and, in particular, P. van Dijk could provide information about the occupancy on a flight leg.

SAP the electronic backbone can provide the researcher with data about the current inventory levels at the Warehouse and outstations, the issue behaviour of KCS, the amount of scrapped trolleys, the amount of ordered trolleys, and the amount of received trolleys. Business analyst Michel Groenendijk is the KLM expert in SAP. Therefore, a meeting should be set up in order for him to explain the ways SAP is working.

The business unit Customs & Distributions should provide insight in the transportation costs by sea and air. Previous research gives an indication, but it should be verified if the transportation costs are still at the same level as two years ago.

Research through the invoices, the contracts and the KLM documents should provide the total amount of equipment owned by KLM. In addition, an interview with E. Zwager should be set up. She is a former Project Manager at CIM and the trolley project was her responsibility. Since one year Eline is working at KCS. CIM should provide the researcher access to all her documents. The interview with her should provide the researcher with more insight in the trolley process. Furthermore, she could elaborate on the trolley counting she executed two years ago.
There should also be set up a total trolley count at the KCS. This means that all the trolleys that currently in the loop will be labelled and scanned for type, brand and year.

An outstation should be visit to examine the reliability of the work floor and inventory.

1.7 Relevance
The relevance of the research can be divided into a scientific, managerial and societal relevance. In the following parts the three relevance dimensions will be described.

1.7.1 Managerial relevance
The managerial relevance relates to the contribution of this research for KLM. KLM contributes by the enabling of the current decision-making process regarding the trolley fleet. This research already contributed in the decision-making process regarding the renewal of the entire trolley fleet and the discussions with Lease Company. Furthermore, this research contributes in the form of recommendations how to improve the trolley supply chain in the long-run and prevent future faltering of the decision-making process.

1.7.2 Scientific relevance
The scientific relevance of this research is captured in applying a novel multi-criteria decision making method – The Best Worst Method by Rezaei (2014a) – on selecting the best improvement strategies. The literature review showed that there has not been writing about the trolley management in the airline catering industry. Therefore, this research uses a novel MCDM method, but also provides a scientific contribution on improvement strategies for the trolley supply chain in the airline catering industry.

1.7.3 Societal relevance
The societal relevance is captured in the fact that KLM at the moment has no insight in their current trolley fleet. This research contributes to increase the insight and control over the trolley fleet, which is a prerequisite for other measures such as abandonment of the in-balance principle, to reduce the inflight weight and waste. The societal relevance is captured in the reduction of the inflight weight and waste, because this will reduce the fuel consumption which is beneficial for the society.

Furthermore, increasing the insight and control might lead to reducing the trolley fleet costs, which in the end is beneficial for the passenger.

1.8 Outline of the report
The rest of this research is structured in the following way. First an analysis of the trolley supply chain is provided. In addition, to the analysis the already implemented improvements are described. These improvements enabled the current decision-making process. In the third chapter the design of additional improvement strategies for the trolleys supply chain is described. In the fourth chapter a detailed description of the improvement strategies is provided. In the fifth chapter the impact of improvement strategies on the trolley supply chain processes is provided. In the sixth chapter the improvement strategies are evaluated. In the seventh chapter the next steps in realizing the selected improvements strategies is provided. The final chapter encompasses the answer to the main research question. The recommendations
for KLM how to implement the chosen strategies and what to do next. In addition, recommendations for future research will be provided.
2 Analysis of the trolley supply chain

This chapter provides an analysis of the current status of trolley supply chain. Therefore, first the relevant literature is reviewed and examined which lessons can be learned from the literature. Subsequently, a detailed overview of the trolley supply chain is provided. Then, the lessons learned from the literature are applied and the results are depicted in the last section of this chapter. The application of the lessons learned enables the current decision-making process.

2.1 Literature review on closed-loop supply chain

There is not any article found in the literature that elaborates on any aspect of catering trolleys in the airline industry. Therefore, the literature review is expended to similar industries and the more abstract views on supply chains and to be more specific closed-loop supply chains.

2.1.1 Supply Chain Flows & Redesign

According to Coyle et al. (2013) the flows of a supply chain can be divided into the following four categories the product flow, information flow, cash flow, and demand flow (see Figure 5). The product flow entails the physical movement of goods and materials. The information flow entails the enabling of the physical flow of products, decision making, and supply chain coordination. The cash flow entails the management of working capital, which encompasses the financing aspects of the supply chain. The demand flow entails the detecting and understanding of demand signals and synchronizing of demand and supply.

<table>
<thead>
<tr>
<th>PRODUCT FLOW</th>
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<td>Physical movement of goods and materials</td>
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<tr>
<th>INFORMATION FLOW</th>
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<tr>
<td>Enabling physical flow of products</td>
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<td>Decision making</td>
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<td>Supply Chain collaborations</td>
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<th>CASH FLOW</th>
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<td>Management of working capital</td>
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<tr>
<th>DEMAND FLOW</th>
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<tr>
<td>Detect and understand demand signals</td>
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<td>Synchronize demand vs. supply</td>
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Figure 5 Supply Chain Flows, adopted from (Coyle, Langley Jr., Novack, & Gibson, 2013, p. 21)

In case of redesigning a supply chain the flows mentioned above are important. Hewitt (1994) argues that there are three dimension important for the redesign of supply chain processes (1) work structure dimension, (2) information flow dimension, and (3) decision authority dimension. These three dimension have to come together in order for a redesign to be successful. Earl and Khan (1994) state the in order for a successful supply chain redesign there needs to be attention to the following four variables: (1) structure, (2) task, (3) technology and (4) people. All the four variable are dependent on each other and all the four variables has to be optimized in order for the redesign to be optimal.

Chopra and Meindl (2007) state the drivers of supply chain performance consists out of the following drivers: facilities, inventory, transportation, information, sourcing and pricing. Furthermore, they state the goal of a supply chain strategy is to strike the balance between
**responsiveness** and **efficiency** that fits with the competitive strategy. Therefore, a firm needs to balance the six drivers in a right way to gain optimal supply chain performance. Each driver is dependent on other drivers, therefore a firm has to make choices for certain drivers which leads to either more responsiveness or more efficiency.

Coyle et al. (2013) define in their book the following logistic activities

**Logistics activities:**

- **Transportation**
  - Often largest variable logistic cost; the glue for the supply chain
- **Warehousing and storage**
  - Two activities: inventory management and warehousing.
  - Direct relationship exists between (mode of) transportation and the level of inventory and the number of warehouses required.
  - Decisions related to storage activities, including how many warehouse are needed, how much inventory should be held, where to locate the warehouses, what size the warehouses should be, and so on
  - Decision framework is needed to examine trade-offs with transportation
- **Industrial packaging**
  - Different mode of transportation requires a different packing material. This is an important sustainability issue.
- **Materials handling**
  - Handling is concerned with mechanical equipment used for short-distance movement and includes equipment such as conveyors, forklift trucks, overhead cranes, and automated storage and retrieval systems (ASRS). The materials design must be coordinated in order to ensure congruity between the types of equipment used and the storage devices they are moving.
- **Inventory control**
  - Two dimensions: (1) assuring adequate inventory levels and (2) certifying inventory accuracy.
  - (1) This means monitoring current inventory levels; and placing replenishments orders.
  - (2) To assure that the actual physical inventory levels match those shown in the information system, cycle counts are taken of selected items every period throughout the year. The use of barcodes and RFID tags has helped to make this process more efficient and effective. Accuracy has taken on increased significance as the concept of the ‘perfect order’ and lean supply chains have become important for logistics and supply chains.
- **Order fulfilment**
  - Filling and shipping customer orders. Important because of order lead time.
  - 4 activities: order transmittal, order processing, order preparation, and order delivery;
- **Inventory forecasting**
• Reliable forecasting is required for accurate inventory requirements.

• Production Planning and scheduling
  o The coordination of trolleys between KCS and WH

• Procurement
  o Procurement decisions need to be made from a systems perspective
  o Where you buy will influence inventory costs (lead times), transportations costs.

• Customer service
  o (1) the process of interacting directly with the customer to influence or take the order
    ▪ Logistics is concerned with being able to promise the customer, at the time the order is placed, when the order will be delivered. This requires coordination among inventory control, manufacturing, warehousing, and transportation to guarantee that any promises made when the order is taken as to delivery time and product availability will be kept.
  o (2) Levels of service an organization offers to its customers.
    ▪ Order fill rates
    ▪ On-time delivery rates
    ▪ Decisions about inventories, transportation, and warehousing relate to customer service level;
    ▪ Logistics play extremely important role in ensuring that the customer gets the right product at the right time, and in the right quantity. Logistics decisions impact product availability and lead time, which are critical to customer service.

• Facility location
  o Changes in location will affect transportation costs and service, customer services, and inventory requirements.

• Return goods handling
• Parts and service support
• Salvage and scrap disposal
  o Reverse logistics system that will allow, broken, or obsolete products to be returned to the supplier.

2.1.2 Reusable Transport Items –RTI’s – closed loop supply chains
Trolleys can be described as a reusable articles (RA). RA refers to products that are used multiple times by different users. In comparison with the life-time of an RA users use the RA quite short, and do not detoriate the RA. In addition, reconditioning of the RA is required because multiple users use the product Carrasco-Gallego et al., (2012).

Reconditioning can be defind as the process of required to bring an used RA back in a condition in which it can safely used again (Guide & Van Wassenhove, 2002) (Bowman, Ng, Harrison, & Illic, 2009).

RA is the generic name for the following three terms:

• Returnable transportation items (RTI),

[Diagram: RTI, RPM, RP, and Reusable Articles]
- Returnable packaging materials (RPM),
- Reusable products (RP).

Inflight catering trolleys can be categorized by the ISO 17364, Layer 3: RTIs (pallet, etc.) (Bowman, Ng, Harrison, & Illic, 2009). “RTI are not in direct contact with the product consumed by the end consumer” Carrasco-Gallego et al., (2012).

In general there can be made a distinction between two types of RTI models a closed-loop model and an open-loop model. Bowman et al. (2009) uses the terms exchange or closed-loop models and pooling or open-loop models. Carrasco-Gallego et al. (2012) uses the terms star network for the closed-loop models and multi-depot network for open-loop models.

The open-loop model or pooling model, which is shown in Figure 9, relies on the fact that a pool operator owns the RTIs and makes sure that the quality and quantity of these RTIs match the supply chain partners’ requirements. Or as Carrasco-Gallego et al. (2012) describes it as it is not compulsory for RA to return to the issuing depot.

In the closed-loop the RTIs flow between two hubs in a supply chain. One flow normal depicts a loaded flow and the other flow depicts often an empty flow. This is shown in Figure 8. Carrasco-Gallego et al., (2012) describe this as a star network. In star systems, RA return to the same plant or depot from where they were originally issued once they have been used.

Figure 7 ISO Hierarch, adopted from Bowman et al., (2009)
Reusable articles will in comparison with disposal articles reduce the purchase costs in the long run, reduce the article disposal costs, and RA reduces the firms’ ecological footprint via less waste. On the other hand RA provide extra costs for a firm, which includes the return transportation, reconditioning of a RA, and it entails additional costs for the management of the closed-loop supply chain. This includes extra costs for administrative effort and the cost of acquiring the necessary information for effective management (Carrasco-Gallego, Ponce-Cueto, & Dekker, 2012).

Typical characteristics of reuse closed-loop supply chains by Carrasco-Gallego et al. (2012):

a) New and reused products are treated as the same.
b) Simple reconditioning activities. Quick reintroduction in the forward supply chain.
c) The fraction of returned products is high. (Most demand is fulfilled with used products).
d) Many units in circulation of low-medium unitary value each.
e) Main operational challenge: balancing demand and returns.

However, next to the extra costs Carrasco-Gallego & Ponce-Cueto (2010) have identified three common problems in the closed-loop supply chains of reusable articles. First, there is fleet shrinkage via irreparably damaged, misplaced or stolen reusable articles. Second, the reusable articles entail often a significant investment. Third, there is a limited visibility of the reusable supply chain. This means that there is often no insight in how many articles get lost in the unobservable part of the supply chain, how long does it take for a reusable article to return to a depot, and how many articles are available in each location of the supply chain?

Carrasco-Gallego et al., (2012) made recommendations on the management aspects of reusable articles in Closed-Loop Supply Chains. The recommendations are presented below:

**Issue 1: Define the fleet size dimension.**

- Function that depends on demand and cycle time, which are both random variables subject to stochasticity.
Issue 2: control and prevent fleet shrinkage. Promote articles rotation.
- The RA fleet will shrink through time due to losses in the system.
  - Quality, incidental and structural losses.
- Recovery incentives to minimize losses by customers.

Issue 3: Define purchase policies for new articles.

Issue 4: Plan and control reconditioning activities.

Issue 5: Balance inventory between depots (only concerns multi-depot networks).

In an earlier paper Carrasco-Gallego & Ponce-Cueto (2010) have established three basic metrics for the management of a closed-loop supply chain of reusable articles:

1. **Return rate** is defined as the percentage of RA that eventually return to the depot after having been issued to the market.
2. **Cycle time** is defined as the time elapsed between the issue of an article and its return to the depot to be reused again.
3. **On-hand inventory at each location** is sometimes difficult to quantify, due to lack of visibility.

In the literature different mathematical optimizations for the management of closed-loop supply chains is found. For example in Yang et al. (2009), Elwany et al. (2007) and in the book of Dekker et al. (2004) which contains many papers that approach reverse logistics with a mathematical perspective. In this research a mathematical approach is left out of the scope.

### 2.2 Overview of closed-loop trolley supply chain at KLM

In the figure below the overall trolley supply chain is presented.

![Figure 10 Overview trolley supply chain](image)

The arrows represent the trolley flow from a node to another node. A rectangle represents a node of the trolley supply chain. This is both inventory, like the warehouse, but also production facilities – KCS Centrum – or repair. The control of the flows and nodes is not represented in
the figure. A detailed description of all the trolleys supply chain processes is presented in the EPC diagrams in the paragraphs below.

The inflow in the trolley supply chain comes from the manufacturer. In the last 10 years there have been only 2 manufacturer Zodiac Driessen and Diethelm Keller Aviation. The lease inflow is financed by AEL, at the end of the lease agreement they take back the trolleys – the outflow. The warehouse – operated by KLM Catering Services (KCS) – is responsible for the all the inventory activities here at Schiphol.

Van Riemsdijk is the current repair company for all the KLM trolleys. They receive twice a week trolleys that are collected at KCS Centrum and twice a week the repaired trolleys are transported to the Warehouse. When trolleys cannot be repaired, Van Riemsdijk will scrap them. Van Riemsdijk will store the scrapped trolleys, until they are transported to the scrap yard.

The two links between KCS Centrum and the outstations represent KLM flights – the outbound and homebound flight. The outstations have depending, on the flight frequency and type of AC, an amount of trolleys at their disposal to prepare a KLM flight.

KLM only has direct control over the Warehouse and KCS Centrum. Although this is not entirely through, because KCS Centrum and Warehouse is a private company within the KLM group. The ownership of KCS by KLM is 100%, so it is in KLMs control. Van Riemsdijk, AEL, scrap yard, manufacturer and the outstations are all external stakeholders involved in the trolley supply chain.

There are in general two ways to arrange the catering service of the homebound flight. The first way is to upload the homebound catering service already here at Schiphol. In general this is done on all the European flights. This saves a lot of money and turn-around time at the destination, but the catering product must preserve his quality during the outbound flight. For the trolleys this means that the trolleys will not be offloaded at the destination and therefore the destination does not have an outstation. This means that there is no inventory at that destination.

The second type of catering the homebound flight is by using an outstation. All direct intercontinental destinations have an outstation. At the destination the dirty trolleys are offloaded and fresh catering trolleys are uploaded. This means that there is an inventory, and therefore needs to be considered in the trolley supply chain.
The diagram above describes the global processes and inventories of the trolley supply chain, when the catering for the homebound is flight is prepared by an outstation. First the trolley is in the inventory of the supplier. Then, it is distributed to the KCS Warehouse, where it is placed in the stock of the KCS Warehouse. Subsequently, the trolleys are distributed by boat directly to an outstation or they are distributed to the stock of KCS Centrum for operation. From the KCS Centrums stock the trolleys will go through the ROA, this entails the cleaning of the trolleys. All the trolleys have to be cleaned before usage. Subsequently, the trolleys are moved into the set-up process of the trolley. According to the flight and aircraft specific loading plan, the trolleys are prepared with the catering product. When the trolleys are prepared they are stored in the cooling for several hours, before they are uploaded in the aircraft. During the flight the catering product is consumed and at the outstation the trolleys are offloaded and in case not broken placed in the stock of the OS. If a trolleys is broken at an outstation it is placed in the stock of the outstation and subsequently distributed to KCS Centrum, where it is placed in the stock with broken trolleys.

The not broken trolleys at the outstation that are offloaded will be washed in the ROA OS and subsequently set-up again. From the cooling stock at the OS the trolleys are uploaded to the aircraft and the catering products are consumed inflight. At Schiphol (SPL) the trolleys are offloaded by KCS and placed in the stock at KCS Centrum if they are not broken. The trolleys can also be broken or the lease term has ended, then the trolleys are not placed in the stock of KCS Centrum.

In case the lease term has ended the trolleys will be placed in a stock with other lease trolleys. From KCS Centrum the trolleys will be distributed to the lease company, where the trolleys are placed in the lease companies stock.
In case a trolley is broken, the trolley is placed in a special broken trolley stock from where they are distributed to Van Riemsdijk – the external repair company. The transport takes place on every Tuesday and Thursday of the week. When the trolleys are delivered at VRR the trolleys are placed in the stock at VRR and subsequently VRR repairs the trolleys. If a trolley can’t be fixed and therefore will be scrapped, it is placed back into the stock and finally distributed to the scrap yard.

When a trolley is fixed it is placed back in the normal stock and waits for transport back to the KCS Warehouse. The transport is scheduled every Tuesday and Thursday.

The process for trolleys without an outstation is more simplified. The process and inventories are presented in the scheme below.

![Diagram of trolley supply chain without Outstations](image)

**Figure 12 Inventories and processes of trolley supply chain without Outstations**

The process and inventories of the supply chain without outstations is less complex, because there is no process to distribute trolleys to the OS and store them. Second, the offloading, washing, set-up and uploading of the trolley is not present. Finally, broken trolleys do not have to be distributed from the outstation to KSC Centrum.

### 2.2.1 KCS Warehouse

*Not attached due to confidentiality reasons.*

### 2.2.2 KCS Centrum

Figure 13 describes the internal process at KCS Centrum. Trolleys are transported from the vendor to the In-/Out-/Storage Warehouse, which is KCS Warehouse. Subsequently, the trolleys are transported to KCS Centrum, where the trolleys are placed in the area GOC/ROA. This is the ‘dirty’ site of the catering process, this means that the trolleys first have to go through the washer, before a trolley is ready for operation. When the trolleys are washed, the
trolleys are set up with the specific catering product and then transported to the aircraft. Used trolleys from the aircraft are transported to the GOC/ROA area and subsequently the trolleys are washed and then ready for operation.

![Figure 13 Process of KCS Centrum operation]

In the tables below the need for equipment is calculated and presented.

<Not attached due to confidentiality reasons.>

In both trolley counts during two weeks every trolley is labelled and registered in a database. The results give an indication what the actual need for trolleys is. In the counting the not-moving trolleys, in inventories at outstations or KLM buildings, are not taken into account, because these trolleys are not immediately necessary for the operation. During the counting not all the trolleys that should have been in the process were registered. This means that they are standing in a storage at an outstation, KLM building or are stolen.

During the counting at KCS Centrum, the discovery was made that a partner airline was using KLM lease trolleys. They had placed their logo on the trolley. Inquiries with the relevant partner airline did KLM discover that the trolleys were provided with an airline that was bought by the partner airline from KLM.

The operation of intercontinental (ICA) and European (EUR) flights is separated at KCS Centrum. This is shown in the map of the KCS building in the figure below.

<Not attached due to confidentiality reasons.>

The trolleys are at the left hand side of the picture,

<Not attached due to confidentiality reasons.>

### 2.2.3 Van Riemsdijk

Figure X shows the monthly trolley flow from Van Riemsdijk to KCS Warehouse. As the inflow is not measured, it is not possible to say anything about the inventory level and inflow of trolleys. In addition, there is no information about what parts are repaired.

<Not attached due to confidentiality reasons.>
The DESSERT and T11 trolleys have been out of service since the introduction of the MW11 trolley in late 2013. Therefore, it is remarkable that in 2014 DESSERT and T11 trolleys have been repaired. They should not have been repaired and send immediately to the KCS Warehouse.

Another interesting point are the 34 MW11 and 37 MW12 trolleys that have been repaired by VRR in 2013, because they have been introduced in September 2013. Subsequently, there have been 120 trolleys repaired up to May 2014. In the first 10 months after introduction of the MW11 10% of the MW11 fleet has visited Van Riemsdijk. There is no data within KLM on the kind of parts that have been repaired.

<Not attached due to confidentiality reasons.>

Van Riemsdijk was allowed to scrap trolleys that are beyond the point that is economically beneficial to repair them. Van Riemsdijk has got strict instructions when to scrap and when to repair a trolley. Van Riemsdijk is licensed to repair aircraft engines, therefore the administration and registration of trolley repairs is excellent. Van Riemsdijk has provided the data for the table above. This to get a better insight in the scrapping amounts. The amount of scrapped trolleys is not high. Only the older trolleys as the 60521 and 60533 have larger scrapping amounts than the other trolleys. A part of the 60521 and 60533 trolleys are built in 2006 and 2007. Than it is not remarkable that those trolleys are scrapped.

2.2.4 Outstations

The data provided by SAP has been found not reliable by the experts. At the opening of an outstation a set of trolleys is provided. These numbers are known and will be provided in the table below. Subsequently, in April 2014 every outstation has counted there inventories. The comparison of the counted inventory and the set laid out is presented below. Although not everything is counted, the results indicates that outstations have more trolleys than they should have. It should be noted that not all the outstations provided their trolley inventory levels. Only 47 of the 69 outstations provided its data. Therefore, we have extrapolated the data to derive the numbers in the table below.

Outstations do not have waste trolleys at their disposal. There is made a difference between a full-size and a half-size trolley, because outstations are not capable of recognizing all the different kind of trolleys. The fact that outstations have more equipment, e.g. trolleys, is called hoarding. If everything goes according to plan than this would not be able to happen. If KLM sends a BBO with drinks to an outstation, it is assembled in a trolley. In that case the trolleys should stay on board, but the caterer might take the whole trolley off board and not only the drinks. Another example is that when there is change in the loading plan, and the outstation works with the old loading plan, it might happen that they use too less trolleys.

Another example is that not all the trolleys have to be offloaded at the outstation. Therefore, if the crew changes the position of certain trolleys it happen that trolleys are offloaded that should have stayed on board. Another example is that caterers might store trolleys in certain areas where they forget about it and then order new ones at KLM. This has happened in the past,
when a caterer in Asia closed, the KLM found over 100 trolleys stored in area that they forgot about.

<Not attached due to confidentiality reasons.>

### 2.3 Implementation of improvements enhancing the current decision-making process

The literature review and the analysis of the trolley supply chain confirmed the initial problem described by KLM. According to the literature the trolley supply chain can be described as a closed-loop supply chain with RTIs. For which the following three metrics have been identified: return rate, cycle time and on-hand inventory at each location. Due the size of the catering operation it was not possible to establish the return rate and cycle time. In addition, the literature review showed the following four common issues in the management of closed-loop supply chains.

**Issue 1:** Define the fleet size dimension.
**Issue 2:** control and prevent fleet shrinkage. Promote articles rotation.
**Issue 3:** Define purchase policies for new articles.
**Issue 4:** Plan and control reconditioning activities.

Especially the first three issues are applicable for KLM's trolley supply chain. The last issue is not an issue in the KLM trolley supply chain, because the recondition activities are the result of the flight schedule.

In addition, to the issues above the researcher has identified another issue which is the registration of flows in the ERP system. In the case of KLM not all the movements of trolleys are registered in the ERP system. Therefore, the trolley inventory of the repair company was not visible in the ERP system. In the following section the registration of movements is described. In the subsequent two sections the trolley fleet size is defined (see issue 1). First an overview of all the lease contracts is created by a desk research. Finally, at KCS Centrum all the trolleys are counted to verify the overview.

#### 2.3.1 Registration of all trolley movements

The researcher discovered that the flow of trolleys from KCS Centrum to the repair company Van Riemsdijk was not registered in SAP. Thus, the actual stock level of VRR was also unknown. Only the flow from VRR to KCS Warehouse is registered in SAP.

Therefore, the researcher initiated a meeting with two business analysts from KLM who both have many experience in SAP. The conclusion of this meeting was that Van Riemsdijk should get access to SAP by means of Portal account. In the portal Van Riemsdijk can indicate the amount of broken trolleys they received and request a transfer transaction for repaired and scrapped trolleys. As Van Riemsdijk is an external stakeholder it is desirable that they only have to accept the amount broken trolleys they receive, but in the current situation KCS is not able to provide accurate data of the amounts and types of broken trolleys. Secondly, the IT systems are not ready for such a transaction. Therefore, there has been decided to let Van Riemsdijk enter the amount of received trolleys in the Portal.
After this meeting the researcher had several individual interviews with the involved stakeholders. Finally, the researcher initiated a meeting with all the involved actors to discuss the implementation of the Portal access for Van Riemsdijk. In the first hour the researcher explained the issue and the proposed solution. During the meeting Van Riemsdijk stated that this solution has been tried several years ago. In the previous situation KCS had to provide the data of the amount of broken trolleys that will be transported to VRR. The correctness of the data was almost always a problem. Therefore, they had decided to abandon the Portal access. This input strengthened our solution that Van Riemsdijk must fill in the data.

After the first hour a test workshop was created with only the direct involved stakeholders Van Riemsdijk and a KLM Central Planner (CP). The CP maintains the plant REPA in SAP and the SP handles all the requests of Van Riemsdijk.

Before we could go live it was necessary to make the preparations in SAP. This included cleaning up the old data. We had started with this process before the final meeting, but this wasn’t finished in time. Three weeks after the final meeting the project went live and it is still working perfect. At this moment the inventory level at Van Riemsdijk and the flow from KCS to VRR is registered in SAP.

Assessing the impact of the Portal access

EPC – Repair process of a trolley

The impact of the portal access for Van Riemsdijk on the processes is assessed using an EPC diagram. First the current situation is described and subsequently the impact of the portal access is described.
When equipment is broken at KCS Centrum the broken trolleys are assembled at the first floor on pallets. Every Tuesday and Thursday morning a KLM driver picks up the palletized trolleys and brings the broken trolleys to Van Riemsdijk.

When the equipment is repaired or can’t be repaired, Van Riemsdijk sends every Monday and Wednesday an e-mail with the amounts and types of trolleys that are repaired and can be scrapped to the Central Planning. The e-mail from Van Riemsdijk is forwarded to the KCS Warehouse and a retour order is created in SAP. The KCS Warehouse prints the email and
hands it to the driver for pick-up of the next day. When the retour order and the pick-up list is handed to the driver the transport process can start. In practise the pick-up list is not always provided, because the driver states that checking the load repaired trolleys consumes too much time.

The Central Planning knows the amount of scrapped, but does not register this quantities in SAP. When there are enough scrapped trolleys compiled at Van Riemsdijk a transport assignment for the KLM driver is created to dispose the trolleys.

**Future situation**

![Diagram of Future situation](image)

In the future situation when the equipment is assembled for transport two activities has to be performed. First the types and quantities has to be registered via the Portal and then the order for repair is created. Second, the assembled equipment is set up for transport. Another addition, to current process is that Van Riemsdijk registers the incoming equipment via the Portal and then the incoming flow from KCS Centrum to Van Riemsdijk is registered in SAP.

The outgoing flow from Van Riemsdijk can happen by three different events. First equipment is repaired, second bought equipment can be scrapped, and third lease equipment can be scrapped. When equipment is repaired, Van Riemsdijk requests a retour order for Homebase via the Portal. When the retour order for Homebase is created, the Central Planning receives
the request and has to confirm the request in SAP. Subsequently, the retour order is created in SAP. This triggers the transport truck process and the goods receive process at the KCS Warehouse.

In case bought equipment has to be scrapped, Van Riemsdijk creates a request for scrapping via the Portal. When the request is created, the Central Planning has to approve the request. When this activity is completed, the scrapped amounts are registered in SAP. Finally, a transport assignment has to be made for the disposal of the scrapped KLM trolleys. When the transport assignment is created, the transport truck process starts.

The last outgoing flow of Van Riemsdijk is the scrapping of lease trolleys. The process is similar to the KLM property trolleys until the equipment is scrapped in SAP. Every month KLM employees visit Van Riemsdijk to inspect the scrapped lease trolleys, in order to make a decision about the destination of the scrapped lease trolleys. KLM can either decide to bring the scrapped lease trolleys to scrap yard or give them back to the lease company. In case the scrapped lease trolleys are disposed to the scrap yard a transport assignment has to be created. When this is completed, the transport truck process can start to dispose the scrapped lease trolleys. In case decided to give the trolleys back to lease company, the lease company has to be informed. When this is completed, a transport assignment has to be created. If this is completed, transport truck process can start.

2.3.2 Overview lease and KLM property trolleys

<Not attached due to confidentiality reasons.>

2.3.3 Trolley counting

This paragraph describes the structure of the trolley counting and the results of the trolley counting. In December 2011 a former NSM-employee conducted in close cooperation with KCS a similar project. Therefore, the researcher had interviews with those persons to learn from their experience.

The concept of the trolley counting is to give each trolley a unique yellow sticker with a barcode. When you stick the barcode on a trolley, you scan the barcode and then you fill in the type, manufacturer and year of construction. This information can be found on the unique identification plate of a trolley. The data was entered in a Microsoft Access database and later exported to Microsoft Excel for data analysis. If there was a yellow sticker on the trolley you would know that it was already counted.

Another easier solution would have been to use tie-raps with different colours. Each colour would indicate a type of trolley. As you know how many tie-raps you bought and how many will be still in your position you could determine the amount of trolleys in the loop. The disadvantage of this measure is that tie-raps can easily go missing and this provides no information about the year of construction and the manufacturer. Therefore, it was decided to use the method of the yellow stickers with a barcode.

<Not attached due to confidentiality reasons.>
There were zero MW11 and MW12 counted in 2011, because this type of trolley was at that
time not yet in operation. The MW11 is a full size trolley that replaced a part of the type FS
and the MW12 is half size trolley which replaced a part of the type HS. MW stands for Marcel
Wanders, because both trolleys have a unique outside design made by the Dutch designer
Marcel Wanders.

The trolley count in 2014 did not capture all the trolleys in KCS, because on the ICA
destinations trolleys are offloaded by the outstations. The outstations have a set of trolleys for
the largest aircraft type that could fly there. Therefore, there is at many outstations a part of the
trolleys that is not always used and it is unpredictable when they are going to use them. In
addition, outstations are hoarding trolleys. This means that they have more trolleys at their
work stock than laid out by KLM.

<Not attached due to confidentiality reasons.>

Figure X shows the results of the counting of all the inventories at the outstations in March
2014. The results indicate that outstations have 435 full size trolleys and 604 half size trolleys
too much in their possession. Therefore, the researcher has asked Contract Management to send
an email to all the outstations to use as many un-stickered trolleys as possible, but if all the
outstations did this remains the question.

2.4 Preliminary conclusion
The literature revealed that there has not been written any scientific publication on the
management of an airline catering trolley supply chain. A more broaden topic was found in the
literature namely on the management of closed-loop supply chains and reusable transportation
items. The main problems described in the literature also apply for the trolley supply chain.
Subsequently, the trolley supply chain is described. Finally, the already implemented
improvements are described which are the registration of the repair loop and inventory, and the
trolley overview and counting. Therefore, the current trolley decision-making process is
enabled. In the following chapter we will design improvement measures which improve the
performance of the trolley supply chain and ensure the trolley decision-making process in the
future.
3 Design of improvement strategies

In the previous chapter the closed-loop trolley supply chain is described and we have identified and implemented improvement strategies to enable the current decision-making process. This chapters describes the design of additional improvement strategies that ensure the trolley decision-making process in the future and optimize the performance of the trolley supply chain. This is achieved by first looking at the strategy, mission and vision of KLM. Subsequently, a problem tree, an objective tree and literature is used to define the decision areas for improvement and the objectives which result in the criteria. Finally, the analysis of interconnected decision areas method is used to design the alternatives per decision area. At the end of this chapter we have defined the decision areas and alternatives which can improve the performance of the trolley supply chain and ensure the trolley decision-making process in the future.

3.1 Strategy of KLM

The strategy of KLM is divided in the overall mission and vision of KLM. Moreover, the mission of Cabin Inflight Management is assessed. Finally, the Transform 2015 plan is assessed. This is done to get a better understanding of what KLM is striving to achieve. This will form the basis of the designing of the objectives and the criteria for assessing the improvement strategies.

3.1.1 Strategy & mission KLM

In order to gain a better understanding of the goals KLM is striving for the KLMs mission and vision is presented below.

KLM has formulated its mission as follows (KLM Group, 2007):

*With Air France, KLM is at the forefront of the European airline industry. Offering reliability and a healthy dose of Dutch pragmatism, 32,000 KLM employees work to provide innovative products for our customers and a safe, efficient, service-oriented operation with a proactive focus on sustainability. KLM strives to achieve profitable growth that contributes to both its own corporate aims and to economic and social development.*

*KLM works to create sustainable growth at Schiphol, to gain access to any market that will increase the quality its network and to maintain a level playing field for all industry players. It also works to ensure a balance between the company’s interests and those of the people living and working close to the airport.*

KLM has formulated its vision as follows (KLM Group, 2007):

*KLM wants to be at the front of the industry by being smarter than the rest. By merging with Air France KLM has come to occupy a leading position in the international airline industry. KLM wants to be the customers’ first choice, to be an attractive employer for its staff and, a company that grows profitably for its shareholders. With smart partnerships and pioneering new destinations, KLM offers global access through its extensive network. By responding to market opportunities and technological developments, KLM offers customers a contemporary product.*
In addition, to the mission and vision KLM takes a lot of care about their customers, safety and Corporate Social Responsibility (CSR). KLM sees their customers as individuals with each their own needs and demands. Therefore, KLM strives to fulfil every customer with a tailor-made product. *Never compromise on Safety!* is KLMs slogan by which it emphasizes the great importance of Safety over the entire organization. KLM has been at the top of the Dow Jones Sustainability Index in the sector airlines for the last nine years.

### 3.1.2 Strategy & Mission Cabin Inflight Management

The mission of the division Inflight Services is the following: “*Inflight Services has the ambition to position KLM as Europe’s most Customer Oriented airline in 2018, by professionalism of its Crew and tailor made Inflight Products.*”

In addition, to the tailor made Inflight Products, the CIM vision entails introduce easily new products and services and a flexible supply chain.

The contribution that Cabin Inflight Management makes to achieve the Inflight Services mission:

- Specify, secure and evaluate the delivery of the customer inflight experience, based on KLM Corporate and CRM strategy;
- Improve crew work methodologies on board;
- Optimize synergies with partners and other airlines Innovate the inflight experience;
- Improve cross functionality CIM organization (internal & external) Increase revenue through sponsors, retail & media;
- Maximize CSR opportunities;
- Re-shape and manage the total supply chain and crew operations;
- Comply with safety regulations;
- Achieve lower costs;

In this part the mission and strategy of the division Inflight Services and its business group Cabin Inflight Management (CIM) is presented. This is to enhance the understanding of what the objectives for the design process should meet.

The three core values of CIM are:

- Story telling
- Internationally Dutch
- Energy

Story telling means that every passenger must have a story to tell at home when he has travelled with KLM. An example of how CIM strives to achieve this is by offering passengers a postcard that they can send to family or friends during the flight. ‘Internationally Dutch’ encompasses the inflight spirit of the experience. This means that the inflight experience should reflect the Dutch origin. This is achieved by designing typical Dutch tray mats, e.g. ‘De Nachtwacht’ and the ‘Delfts Blauw’ porcelain. Energy encompasses the most difficult core value of the CIM, because KLM wants their customers to leave the aircraft (AC) with more energy than it
originally boarded the AC. This entails optimal inflight lighting, but also seating comfort and the ingredients of the inflight meals. Everything is focused that you get energy, instead of the opposite.

The NSM has defined the following goal for the trolley inventory control: optimal stock level at minimum cost level.

3.1.3 Transform 2015

“Transform 2015 / Securing Our Future is made up of a comprehensive package of measures to enable us to achieve our financial targets and secure a sustainable and lasting recovery in our competitiveness and financial strength” (KLM Royal Dutch Airlines, 2012)

The transform 2015 plan is divided into three objectives. They are presented below in order of importance.

- Turnaround profitability of the European and regional networks from loss-making to break-even.
- Reduce the debt position by more than EUR 700 million.
- Recover profitability through measures to cut cost and boost revenues by more than EUR 1 billion over the next three years.

The Transform 2015 plan is also translated into the goals for the division Inflight Services, which includes the CIM. The goals for the CIM Inflight Services are divided into four main goals customer centricity, cost efficiency design, Operations excellence, and sustainable profitability (KLM Inflight Services, 2013)

Customer centricity is achieved through the following goals:

1. Improve Customer Experience
   - Improve catering position by changing concepts
   - Enlarge benefits from partnerships
2. Expand Paid Options
   - Further develop & implement paid options (e.g. empty seats, First Bag-phase 2, paid option packages, …)
   - Promote ancillaries via personalized offers
   - Optimize upsell flow to enhance revenues

Cost efficiency design is achieved through the following goals:

1. Continue fleet renewal & adjust fleet configuration
   - Prepare introduction 787
   - Introduce Atlas-galleys
2. Reduce network cost
   - Increase fuel efficiency/MIS for entire fleet

Operations excellence is achieved through the following goals:
1. Keep the family together
   - Increase productivity
2. Realize CSR-ambitions
   - Maintain high level of sustainable catering (incl. reduction of waste)

*Sustainable Profitability* is achieved through the following goals:

   - Increase unit revenues by 2% per year
   - Decrease unit costs by at least 1% per year
2. Limit net investments
   - Invest only:
     i. Required by law and/or regulations
     ii. Related to SoF-project
     iii. Payback < 2 years
     iv. Required for ops integrity
   - Explore justifiable Sales and Lease Back possibilities for each investment

In the beginning of September KLM has announced a new strategic plan called ‘Perform 2020’ (KLM, 2014). At this moment it is not yet clear what the influence of ‘Perform 2020’ on the trolley supply chain will be.

### 3.2 Problem tree

This paragraph explains the objective hierarchy tree. The full version of the problem tree can be found in the APPENDIX C – Problem tree on page 148. Because the problem is too comprehensive the objective is divided into smaller pieces for ease of explanation.

![Problem Tree](image)

**Figure 16 Top of the problem tree**

Figure 16 shows the top of the objective tree. The main goal is to ensure the continuity of the operation. This is achieved by the following four means maximizing the reliability, quality and flexibility of the trolley supply chain, but also minimizing the overall costs of the trolley supply chain. In the following the four sub-objectives will be described.

How the reliability of the trolley supply chain is maximized is achieved by increasing the reliability of trolley delivery to the KCS Warehouse and outstations. This is achieved via ensuring realistic contracts and active monitoring of the delivery process. Another way to achieve reliability in the trolley supply chain is to ensure accurate trolley information in SAP.
Accurate trolley information is achieved by ensuring accurate OS inventory levels, ensuring accurate WH inventory levels, and ensuring accurate trolley information (contract and design details) in SAP.

Accurate OS inventory levels can be achieved by providing OS with more accurate data on trolley portfolio, to use technologies on a trolley for inventory management, to lower the amount of different trolleys in operation, and to let the outstation count their inventory every week.

![Diagram of Problem Tree Reliability of the Trolley Supply Chain](image)

Figure 17 Problem tree reliability of the trolley supply chain

Ensuring accurate KCS Warehouse inventory levels can be achieved by counting the trolley inventory every month and by ensuring registration of all trolley movements in SAP. The latter can be achieved by increasing the trolley fleet knowledge of KCS personnel and the use of technology for trolley inventory management. This can be the use of RFID or NFC.
Figure 18 Problem tree quality of the trolley supply chain

Figure 18 shows the second sub-objective of the main objective, to increase the quality of the trolley supply chain. This sub-objective can be achieved via five sub-objectives namely ensuring compatibility of the visibility improvements with the current system, a more accurate delivery lead time of orders, CSR factors (Safety), ensuring accurate forecasting of the trolley need, and ensuring optimal communication and coordination throughout the trolley supply chain.

Ensuring the compatibility of the visibility improvement strategies can be achieved by testing the proposed solutions in the current system, and by using expert opinions. CSR must be seen as safety in this case. Safety for it passengers and crew. Safety can be achieved via preventing malfunction of a trolley, using non-hazardous material in a trolley, and easily shoot out of a trolley in case of safety issues. Malfunctions of a trolley batch can be prevented by using the input of all crew that is using the trolley in the trolley design, and by extensively testing the trolley. The latter can be achieved by testing it by all personnel – both catering and crew – and hiring an external experts. Easily shooting out of trolleys can be achieved by enhancing the identification and traceability of a trolley.

Ensuring optimal communication and coordination throughout the trolley supply chain can be achieved by defining clear tasks and responsibilities and by shortening the communications lines.
The third sub-objective under the main objective is to minimize the total costs of the trolley supply chain, which is shown in Figure 19. This can be achieved by the following five objectives to optimize the financing of the trolley portfolio, to minimize the transportation costs of trolleys, to minimize the repair costs of trolleys, to prevent hoarding at outstations, and to optimize trolley stock levels in the KCS Warehouse.

Optimizing the financing of the trolley can be achieved by either buying, leasing and/or outsourcing the trolley fleet. The trolley transportation costs can be minimized by minimizing the amount of BBO’s and enhancing the monitoring on trolley stock levels at outstations. The trolley repair costs can be minimized by using the latest procured batch in the operation, and by sooner renewing the trolley fleet. Using the latest procured batch in the operation can be accomplished by using a Batch Management inventory system, or by checking by hand the trolley stock.

Optimizing the trolley stock levels in the KCS Warehouse can be accomplished by reducing obsolete and deteriorated stock, and by optimizing the safety stock. The latter can be accomplished by defining the shrinkage rate, and the yearly demand.
The fourth and last sub-objective under the main objective is to increase the flexibility of the trolley supply chain, which is shown in Figure 20. The flexibility of the trolley supply chain can be increased by enhancing the replacement of the trolley fleet, and by making it easier to change the content of a trolley. The latter to enhance customized meals for every passenger, while at the moment every customer gets the same meal. Enhancing the replacement speed of the trolley fleet can be accomplished by decreasing the depreciation period of a trolley, and by financial lease the trolley fleet.

Customizing the content of a trolley can be accomplished by hiring more catering personnel, because customizing is more labour intensive, and by using trolley recognition technology during the production. The latter can be QR-codes, NFC or RFID tags, which can be placed on a trolley.

Conflicts

Flexibility can be increases by leasing the trolleys, but this will be costly because you pay an interest. Enabling the track and trace of trolley by means of technology enhances the traceability of a trolley and it will lower the inventory costs, but it also requires a significant investment and the organisational structure needs to be adapted.

Discussing the objective tree with the DM it becomes clear that the visibility improvement strategies can be found in five decision areas. First decision area is the financing source of the trolley fleet, second is the technology that can be used to enhance the identification of a trolley, third is the registration of trolley movement and additional information in SAP, fourth is the communication and coordination structure for the trolley supply chain, and fifth is for managerial reasons defining KPIs to monitor the actual performance of the trolley supply chain. In the next chapter will be further elaborated on these five decision areas and the alternatives for each decision area will be described. In the end the DM has to make a choice for an alternative in each decision area.

3.3 Objective tree
The objective tree presented in Figure 21 defines the main objective for the trolley supply chain. The main objective is the continuity of the trolley supply chain. This is achieved by lower trolley fleet costs, more reliability, more flexibility, and more quality.

The objective lower trolley fleet costs can be achieved by a better tracking of the trolley (Price & Pilon, 2007), a smaller trolley fleet, lower transportation costs, lower purchase costs of the trolley, lower maintenance costs, and lower operating costs.

The objective more reliability can be achieved by a larger availability of trolleys, a better reputation of partners, more accurate inventories (registered in SAP), and correctness of delivery of orders. A larger availability of trolley can be achieved by more tracking of trolleys, a larger trolley fleet, and less different types of trolleys. More accurate inventories can be achieved by less inventory corrections, registration of all trolleys movements, and quicker identification of a trolley. The correctness of delivery objective can be achieved by less different types of trolleys and quicker identification of a trolley.

The objective more flexibility can be achieved by shorter lease contract terms and by easier identification of trolleys. By decreasing the lease terms in years, the age of the trolley fleet is younger. Easier identification is required in the operation to adjust the content of the trolley. Currently, the setup of the trolley is done manually with printed tickets. KLM strives in the future to have a passenger specific catering product.

The objective more quality can be achieved by higher safety standards and better quality of information concerning the trolley fleet. Higher safety standards can be achieved by quicker identification of the trolley, less malfunctions of a trolley batch, and less crew complaints (IFRs).

### 3.4 Closed-loop supply chain decisions

Considerations regarding decisions and criteria in closed-loop supply chains can arise between operational considerations, economical considerations, environmental considerations, and strategic considerations (Tuzkaya, Gülsün, Kahraman, & Özgen, 2010).

“I classify the literature in terms of strategic, tactical, and operational issues, but I focus on strategic issues (such as when should an original equipment manufacturer (OEM) remanufacture, response to take-back legislation, and network design, among others) and tactical issues (used product acquisition and disposition decisions)” (Souza, 2013).
According to Chopra & Meindl (2007) supply chain decisions can be divided into three categories.

1. **Supply Chain Strategy or Design.** A company decides how to structure the supply chain over the next several years. Strategic decisions relate to supply chain configuration.

2. **Supply Chain Planning.** For decisions made during this phase, the time frame considered is a quarter to a year. Therefore, the supply chain's configuration determined in the strategic phase is fixed.

3. **Supply Chain Operation.** Time horizon is here weekly or daily. At the operational level, supply chain configuration is considered fixed and planning policies are already defined. The goal of supply chain operations is to handle incoming customer orders in the best possible manner.

Souza (2013) uses the categories of Chopra & Meindl (2007) by naming them strategic, tactical and operational levels. For each level Souza (2013) has defined what the decisions and issues are for closed-loop supply chains.

<table>
<thead>
<tr>
<th>Level</th>
<th>Decisions and Issues</th>
</tr>
</thead>
</table>
| Strategic | • Network design: location and size of collection centres, remanufacturing facilities, etc.  
• Collection strategy: should customers return products to retailers or directly to OEMs?  
• Should the OEM remanufacture?  
• Leasing or selling?  
• Trade-in and buy backs programs  
• Supply chain coordination: contracts and incentives  
• Response to take-back legislation  
• Impact of recovery activities on new product design |
| Tactical | • Acquisition of product returns – how many, when and of which quality?  
• Returns disposition: remanufacturing, dismantling for spare parts, or recycling? |
| Operational | • Disassembly planning: sequence and depth of disassembly  
• Scheduling, priority rules, lot sizing, and routing in the remanufacturing shop |

Table 2 Examples of strategic, tactical and operational issues in CLSCs, adopted from Souza (2013)

The literature on closed-loop supply chain decisions supported the determination of the decision areas, which are presented in the following section.

### 3.5 Analysis of interconnected decision areas

The main objective formulated in the previous section is the continuity of the trolley supply chain operation. We use the technique ‘the analysis of interconnected decision areas (AIDA)’ by Harary et al. (1965) to describe the five decision areas and the improvement strategies per decision area. In the last column shows what objectives are influenced by the decision areas. AIDA supports the DM in determining the solution space.
The analysis of the current situation, interviews with experts and the problem and objective tree resulted in the selection of the five decision areas which can further improve the trolley supply chain. We have identified five decision areas for improvement strategies, which can be found in the first column of Table 3. For each decision area multiple alternatives have been generated. The second, third and fourth decision area relate directly to increasing the visibility of the trolley supply chain. The first decision area aims to reduce the costs of the trolley portfolio. The fifth and last decision area aims to monitor the performance of the supply chain.

<table>
<thead>
<tr>
<th>Decision areas</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>The relevant (influenced) objectives</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Ownership of trolley fleet</td>
<td>Buying</td>
<td>Leasing</td>
<td>Outsourcing</td>
<td>****</td>
<td>• Cost reduction</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Visibility</td>
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<td></td>
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<td></td>
<td></td>
<td>• Flexibility</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Reliability of inventories</td>
</tr>
<tr>
<td>2. Enhancing traceability and identification</td>
<td>RFID</td>
<td>NFC</td>
<td>Barcode</td>
<td>Metal plate</td>
<td>• Visibility</td>
</tr>
<tr>
<td></td>
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<td></td>
<td></td>
<td>• Safety</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Cost reduction</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Reliability of inventories</td>
</tr>
<tr>
<td>3. Registration structure for movements and contracts</td>
<td>Batch Management</td>
<td>LEASE/Space</td>
<td>****</td>
<td>****</td>
<td>• Visibility</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Accurate information</td>
</tr>
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<td></td>
<td>• Safety</td>
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<td></td>
<td>• Cost reduction</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Usage of trolley fleet</td>
</tr>
<tr>
<td>4. Communication and coordination structure</td>
<td>Trolley Manager</td>
<td>Embedded in organisation</td>
<td>****</td>
<td>****</td>
<td>• Visibility</td>
</tr>
<tr>
<td></td>
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<td></td>
<td>• Safety</td>
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<td>• Cost reduction</td>
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<td></td>
<td>• Reliability of inventories</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Accurate information</td>
</tr>
<tr>
<td>5. Monitoring the performance of trolley supply chain</td>
<td>KPIs</td>
<td>Balanced Scorecard</td>
<td>SCOR</td>
<td>****</td>
<td>• Monitoring performance</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Continuity</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Accurate information</td>
</tr>
</tbody>
</table>

Table 3 Analysis of interconnected decision areas

In the table above we have excluded the alternative to ‘do nothing’. The alternative or improvement strategy ‘do nothing’ is taken into account in the evaluation phase.

A way to evaluate the alternatives is by creating scenarios. Each scenarios contains one alternative out of each row. Using Eq. 1 the maximum amount of scenarios you can make is $3 \times 4 \times 2 \times 2 \times 3 = 144$, this is called the design space. It was decided that 144 scenarios are too many. Another way to evaluate the alternatives is by selecting the best alternative per row and then combining them into a package of best alternatives. This is only allowed if there no dependencies between the five decision areas (rows). The first and last row are independent from each other and the other three. Although the second till the fourth decision area enhance the visibility of the trolley supply chain, we assume that there is no dependency between the
decision areas. Therefore, we may select a best strategy per row and combine all the best per row into a package of best strategies.

\[
\text{The total # of scenarios} = \prod_{i=1}^{I} n_i
\]

\[I = \# \text{ of columns}\]

\[n_i = \# \text{ of options for column } i\]

In the decision area of the ownership of the trolley fleet there are in general three strategies buying, leasing and outsourcing of the ownership. The objective that is influenced most is the cost reduction.

The decision area enhancing the traceability and identification relates influences the objective of improved visibility. Furthermore, it also influences the safety objective, cost reduction, and reliability of inventories. In case of a malfunction of a trolley batch (safety issue) it is required to immediately shoot out the specific batch. Therefore, track and trace technology enhances the safety objective. Research by IATA has showed that RFID enables airline to increase the visibility of the trolley supply chain, but RFID solutions also reduce the operation, maintenance and inventory costs.

Registration structure for movements and contracts refers to the method how the physical movement of trolleys is registered and the how the contract information is secured. Optimizing this decision area influences the objectives visibility, safety, cost reduction, fleet usage and accurate information. If all the movements and contracts are registered it increases the visibility of the trolley supply chain and enhances accurate information. Batch management influences the safety, cost reduction (repair), and fleet usage objective. There are many software packages to register the movements and contracts, for example SAP, Oracle and Microsoft Dynamics. In this research we only focus on SAP, because SAP is currently KLMs ERP system and KLM has indicated that the solution must operate in SAP. The strategies Batch Management and LEASE/Space are both designed in cooperation with KLM experts.

Communication and coordination structure refers to the assignment of tasks and responsibility concerning the entire trolley fleet. Optimizing this decision area influences the visibility, safety, cost reduction, reliability of inventories, and accurate information objective. The strategies are limited in cooperation with KLM limited to embed in the organisation and the appointment of an internal trolley manager. It should be noted that there are strategies, but left out of the scope because it is the desire of the client.

Monitoring the performance of trolley supply chain influences the performance, continuity of control and insight, and accurate information objective. In the literature there is a wide variety of performance metrics such as Inventory Turns, Cycle Time, DPMO, Fill Rate and Benchmarking (Taras & Taras, 2014). Nukala and Gupta (2007) propose a linear physical programming (LPP) based quality function deployment optimization approach to evaluate the performance of a closed-loop supply chain. In cooperation with KLM we have limited the options to KPIs, Balanced Scorecard, and SCOR-model.
3.6 Preliminary conclusion
The strategy and vision of KLM served as input for the problem objective and problem tree. The latter two and the literature on decisions in closed-loop supply chains helped the researcher to define the decision areas for the improvement strategies. Finally, the analysis of interconnected decision areas supported the design of the alternatives. The decision areas for the improvement strategies are the following:

1. Ownership of trolley fleet.
2. Enhancing traceability and identification.
3. Registration structure for movements and contracts.
4. Communication and coordination structure.
5. Monitoring the performance of trolley supply chain.

In the following chapter the designed alternatives will be discussed in detail.
4 Detailed description of improvement strategies

In the previous chapter improvement strategies for the trolley supply chain have been designed. In this chapter we will discuss the designed improvements in detail. Five decision areas have been selected which can be improved to ensure the future trolley decision-making process and to improve the trolley supply chain performance. These areas are the following:

1. Ownership of trolley fleet.
2. Enhancing traceability and identification.
3. Registration structure for movements and contracts.
4. Communication and coordination structure.
5. Monitoring the performance of trolley supply chain.

Per decision area criteria and sub-criteria have been designed, which are used in the sixth chapter to evaluate the improvement strategies. Therefore the following sections contain the decision areas and their improvement strategies with corresponding (sub-) criteria are described in detail.

4.1 Ownership of the trolley fleet strategies

The first strategic choice that has to be made is related to the ownership of the trolley fleet. Since 2009 the entire trolley fleet is leased. Before 2009 the trolleys were bought. The choice to lease the trolleys has a different impact on the operation and the management of the trolley fleet than when the trolley fleet is bought.

“When a firm buys an asset, it obtains both the right to the services of that asset over the period it is owned plus the right to sell that asset at any future date. With a lease, the firm acquires only the right to the asset’s services for a period specified in the contract” (Smith & Wakeman, 1985).

In general there are three options for the ownership of the trolley fleet: buy, lease and outsource the trolleys. As stated before the choice for one of the alternatives have a huge and diverse impact on the management of the trolley supply chain.

4.1.1 Buying trolleys

As stated above before 2009 KLM bought all their trolleys. This is compared to leasing cheaper, because you don’t have to pay interest. The disadvantage of buying trolleys that you have to pay the total purchasing value up front. The average price of a trolley is around 500 euro’s. So an order of 200 trolleys, which is normal, already mounts up to 100,000 euro. This can be a substantial amount of money if the company is performing not at an optimal level.

The strategic impact of the buy trolley alternative is captured in the fact that when KLM chooses this alternative it has to consider that the trolleys you buy now should also be able to serve the catering product of the future as of the 10 years lifetime. The strategic impact on contracts is minimized, because you only have to close a contract with the manufacturer and the repair company. This in contrary with the other variants.
The tactical impact of buying trolleys is mainly concerned with quantities and delivery schedule. This is less complex than the leasing alternative, because the outflow of trolleys is limited to leakage – scrapping and missing – and your flight schedule. The need calculations for trolleys is an important tactical aspect for all the alternatives. In case a new batch is received, the old batch should be disposed. This should be planned in advance and the sale must be announced to the employees. This is called a car trunk sale.

The operational impact of buying is that the registration in the ERP system, delivery in the warehouse, and planning for operation is arranged. In the unusual case that a whole batch of trolleys is taken out of service, the registration should be arranged in the ERP system as well. The preparation and executing of the car trunk sale is an operational aspect of the buy trolley alternative.

4.1.2 Leasing trolleys

The financial position of KLM was the last years far from optimal. Therefore, in 2009 the management of KLM has decided to lease the trolleys. Due to the interest payment leasing is in the end more expensive than buying trolleys. Especially if you take into account that the trolley lease was purely financial. This means that the lease is like a loan plus interest construction. The maintenance is also KLMs responsibility. It is not comparable to most car-lease deals. At the end of a lease agreement the lessee (KLM) has three options end the contract, extend the contract or take over ownership. When you end the contract all the trolleys has to be given back to the lessor (lease company). When not all the trolleys can be found and given back the lessee has to be pay a replacement value to the lessor. Which can go up to 50% of the purchasing value. If you take over the ownership the lessee also has to pay the replacement value.

The strategic impact of the lease contract alternative is among inter alia related to return procedure. The trolley supply chain should be designed in such a way the give-back procedure works smooth. In addition, the contracts and incentives with the lease company should be optimal. Optimal in a way that the replacement value is according to the market value of a trolley. In such a way that there are no big surprises at the end of a lease agreement. KLM should also take into account that in the current situation it is not able to give 100% of all the trolleys of a lease agreement.

The tactical impact of lease contract is related to the amount of trolleys to be procured. This impact also applies for the other alternatives. The amount to be procured is essential for KLM as too many trolleys is costly and too less trolleys would jeopardize the operation. Another impact relates to the repair of lease trolleys. The questions rises who will do the repair and who is paying for it? Also the decision at the end of a lease agreement is of tactical nature.

The operational impact of a lease contract relates to the registration of the trolley, communication to the stakeholders and the actual give-back of trolleys. The registration of entry, production and exit of a trolley should be registered in the ERP system. This to ensure the oversight of the current lease deals. When new trolleys arrive all the stakeholders should be informed to ensure the newest trolley is used and the old ones leave the system. When the
decision is made to give back the trolleys to the lease company an executing plan has to be set up. How many trolleys will be set up a pallet? How many trolleys per day will leave production? Which article numbers will be blocked in the ERP system? Who will inform all stakeholders? All these things are important for the give-back process of a trolley batch.

When the trolleys arrive in the warehouse they should be registered in the ERP system. This should be clear and understandable. This also applies in case the trolleys are bought, because adequate registration is a perquisite for insight in the trolley fleet.

When the trolleys at the end of the lease agreement have to be given back to the lessor, it is essential that the registration of the different batches in the ERP system is accurate. Otherwise it is almost impossible to find the entire batch. At the moment the process of the registration of trolleys is not optimal. Therefore, it is almost impossible to find the entire batch of trolleys. That is why the lessor and lessee agreed that also newer trolleys can be given back.

4.1.3 Outsourcing of trolley management
The last alternative is the complete outsourcing of the trolley management. This entails that the procurement, financing, maintenance and inventory management is executed by an external partner. The extra service is obviously not for free, but it provides control and insight into the trolley fleet and KLM can focus on the core business.

The strategic impact of the outsourcing alternative relates first to the contracts and incentives. The search for an outsourcing partner via a tender procedure should be set up. The contract and incentive in the contract should be very clear and should not leave any room for under performance. The fact to outsource entails that you give away responsibility and control. Therefore, it is very important to negotiate the terms in the contract. Also the location of the outsourcing company is very important, because this determines your trolley network design. By choosing this alternative the current network design – e.g. repair and inventory – needs to be adjusted.

The tactical impact still relates to the questions how many, when, and of which quality? The partner in this alternative can support this decision, but the main responsibility remains at KLM.

The operational impact of this alternative is minimized, because many responsibilities are shifted to the outsourcer. On the other hand this is not excuse for KLM to close their eyes. They should stay in close contact to ensure an accurate operation of the trolley supply chain. This alternative also entails the search for an outsource partner. This can be achieved through a tender procedure, with which KLM is already familiar.

4.1.4 Criteria
In order to evaluate the improvement strategies concerning the ownership of the trolley fleet the following criteria have been selected. The criteria have been selected by interviewing KLM personnel and a literature review. KLM has indicated that the following criteria are common in their organization cost, reliability, quality and flexibility.
Table 4 Criteria and sub-criteria ownership of the trolley fleet improvement strategies

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Sub-criteria</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1: Costs</td>
<td>Contract Costs</td>
<td>(Mollaghasemi, Pet-Edwards, &amp; Gupta, 1995)</td>
</tr>
<tr>
<td></td>
<td>Interest payment</td>
<td>(Kaplan &amp; Norton, 1996)</td>
</tr>
<tr>
<td></td>
<td>Cost transparency</td>
<td>(Basu, 2001)</td>
</tr>
<tr>
<td></td>
<td>Product price</td>
<td>(Tuzkaya, Gülşün, Kahraman, &amp; Özgen, 2010)</td>
</tr>
<tr>
<td></td>
<td>Spread of costs</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Maintenance costs</td>
<td>(Tuzkaya, Gülşün, Kahraman, &amp; Özgen, 2010) &amp; (Price &amp; Pilon, 2007)</td>
</tr>
<tr>
<td>C2: Reliability</td>
<td>Residual value of trolley</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Reputation</td>
<td>(Rezaei, Fahim, &amp; Tavasszy, 2014) &amp; (Nukala &amp; Gupta, 2007)</td>
</tr>
<tr>
<td></td>
<td>Financial position</td>
<td>(Rezaei, Fahim, &amp; Tavasszy, 2014)</td>
</tr>
<tr>
<td></td>
<td>Performance history</td>
<td>(Rezaei, Fahim, &amp; Tavasszy, 2014)</td>
</tr>
<tr>
<td></td>
<td>Correctness of inventory</td>
<td>(van Kleef, 2012)</td>
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<td></td>
<td>Correctness of delivery</td>
<td>(van Kleef, 2012) &amp; (Schönsleben, 2012)</td>
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<td></td>
<td>Complaint handling</td>
<td>(Rezaei, Fahim, &amp; Tavasszy, 2014)</td>
</tr>
<tr>
<td>C3: Quality</td>
<td>CSR Factors</td>
<td>(Rezaei, Fahim, &amp; Tavasszy, 2014)</td>
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<tr>
<td></td>
<td>Safety</td>
<td>(KLM Group, 2007)</td>
</tr>
<tr>
<td></td>
<td>Quality of supplier delivered products conform specs</td>
<td>(van Kleef, 2012)</td>
</tr>
<tr>
<td>C4: Flexibility</td>
<td>Flexibility of the contract</td>
<td>(Mollaghasemi, Pet-Edwards, &amp; Gupta, 1995)</td>
</tr>
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<td></td>
<td>Lead time of supply</td>
<td>(Schönsleben, 2012)</td>
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<td></td>
<td>Lead time to adjust trolley portfolio</td>
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<tr>
<td></td>
<td>Replace^1</td>
<td>(Mollaghasemi, Pet-Edwards, &amp; Gupta, 1995)</td>
</tr>
<tr>
<td></td>
<td>Terminate^2</td>
<td>(Mollaghasemi, Pet-Edwards, &amp; Gupta, 1995)</td>
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</tbody>
</table>

4.2 Enhancing traceability and identification strategies

The traceability and identification of a trolley or batch can be enhanced by technology – e.g. RFID, NFC, barcodes. The technology is able to contain technical and non-technical information about the trolley, e.g. brand, type, etc. In the future it will be possible to put even more information like the catering plan in such technologies.

In the production of KCS, but also caterers worldwide, every trolley is prepared manually. Changes in the loading plan have a large impact on the organization. Technology like RFID on a trolley can support the transition to more flexibility in the loading plan, because the manually production in KCS Centrum is now an obstacle.

The loading plan is currently made on simple consumption predictions. Therefore, half a year ago a pilot with a dynamic drinks loading plan is started on three Japanese destinations. The loading plan is created based on the PAX and the previous consumption. The caterers in Japan and KCS count the actual inflight consumption and register this on a website. The counted consumption forms together with the actual PAX the current loading plan for a specific flight. At this time, it is not possible to roll out a drink specific loading plan to all flights, because the production of the drink dynamic loading plan is executed manually. Therefore, it is too expensive. The first results indicates that there is a large weight saving potential.

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^1 To have the ability to replace assets due to obsolescence
^2 To have the ability to terminate the lease contract
In case you lease the trolley fleet or a part of it, it is desirable to enhance the tracking and identification because of return procedure at the end of the lease agreement. Technologies as described below can achieve this.

Enhanced traceability and identification is even more needed in case of safety issues. For example if a malfunction is detected in a specific batch, an airline must be able to immediately prevent the usage of this batch. Remember KLM slogan never comprise on safety!

At this moment the trolley only contains a metal plate with the technical specifications of the trolley on it. Due to wear and tear the metal plates are often not readable any more. Therefore, it is hard to find recognize a specific trolley batch. This information required to find a specific batch in case of the end of a lease agreement or safety issues.

Already in 1996 all the KLM trolleys were equipped with a tracker. KLM had put tracker readers at strategic points, like the washing machine, in KCS. The beginning of the project was promising, but in order to make the trolley tracker project successful additional investment had to be made. The management did not want to make this investment and cancelled the project. At that moment all the trolleys were already equipped with the trackers and a few scanners had been installed at KCS. Interviews with employees that were involved back in 1996, told the researcher that the placement of trackers within KCS is crucial for the success of such project. In addition, it is crucial to determine what you want to know, because otherwise you get an overload of information.

IATA conducted a study in 2007 to assess the benefits and challenges of tracking the trolley fleet with RFID. The study shows a potential yearly benefit of $292,000 and a one-off saving of $270,000 through stock reduction (Price & Pilon, 2007).

4.2.1 RFID
Radio Frequency Identification (RFID) is a tag that can be attached to an object and contains information. An active RFID tag makes it possible to scan a room within a second to determine which trolleys are present. In addition, it is possible to link RFID and the washing machine at KCS. Using software it is possible to tell the washing machine to not wash and shoot out a certain batch of trolleys. This would ease the shoot-out process. The advantage of RFID is the large range of the tag. Therefore, it might help other processes within KCS, like creating more flexibility in the loading plan. The disadvantage of RFID is that is the most expensive technology. Second, the organizational structure should be adjusted in order to make optimal use of RFID.

Radio Frequency Identification – RFID
In the literature a lot has been writing on the use of radio frequency identification (RFID) in the industry. Zhu et al. (2012) provide a literature review of RFID technology and point out the potential benefits RFID application delivers for the industry. The benefits only arise if the technology is properly used. Parlikad and McFarlane (2007) describe how to use of RFID can have a positive impact on the product recovery at the end-of-life. Bowman et al. (2009) write about the BRIDGE project, which is financed by the European Commission. In their report they link the Reusable Asset Management model and the use of RFID. Johansson & Hellström
(2007) point out by using the RFID use on RTIs at Arla Foods that someone in the organisation should be responsible for the RFID data. They state that via reduced attention on RFID data the benefits immediately reduced.

“Based on the ISO working document (ISO/FDIS 17364): “Supply chain applications of RFID – Reusable transport items (RTIs)” [17364], the term is formally defined as:

“This standard defines the requirements for RFID tags for Reusable Transport Items (RTI). RTIs are defined as all means to assemble goods for transportation, storage, handling and product protection in the supply chain which are returned for further usage, including for example pallets with and without cash deposits as well as forms of reusable crates, trays, boxes, roll pallets, barrels, trolleys, pallets collars and lids.” (Bowman, Ng, Harrison, & Illic, 2009)

<table>
<thead>
<tr>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Automatic Non-Line-of-Sight Scanning</td>
<td>Software and Equipment Upgrades</td>
</tr>
<tr>
<td>This means items do not require particular orientation for scanning, unlike barcodes.</td>
<td>The integration of RFID into existing practices requires considerable investment from organizations; reengineering the business and aligning the systems takes time. The process of implementing the technology will affect all facets of the organization, with the entire process expected to cost millions of dollars</td>
</tr>
<tr>
<td>Labour Reduction</td>
<td></td>
</tr>
<tr>
<td>Enhanced Visibility</td>
<td></td>
</tr>
<tr>
<td>Asset Tracking and Returnable Items</td>
<td></td>
</tr>
<tr>
<td>Item Level Tracking</td>
<td>“Data synchronization, integration, transformation, and communication are huge barriers in making the technology work for organizations</td>
</tr>
<tr>
<td>Traceable Warranties and Product Recalls</td>
<td>Quality Control and Regulation</td>
</tr>
<tr>
<td>Yard, Warehouse &amp; Factory Management</td>
<td>Reliability of the RFID tags might be an issue</td>
</tr>
<tr>
<td>Improved Inventory Management</td>
<td>Cost of Technology</td>
</tr>
<tr>
<td>Safety - RFID tags are virtually impossible to copy, making them suitable to security applications.</td>
<td>Interference and Reading Considerations</td>
</tr>
<tr>
<td>Ability to Withstand Harsh Environments</td>
<td>Privacy Concerns</td>
</tr>
<tr>
<td>Information Properties</td>
<td></td>
</tr>
<tr>
<td>Cost savings through RFID systems are derived through many of the areas already discussed in this paper, namely labour reduction, enhanced inventory management, advanced security and more efficient management of assets.</td>
<td></td>
</tr>
</tbody>
</table>

Table 5 Pros and cons of RFID in SCM in 2005

The table above shows the pros and cons by Michael and McCathie (2005). They recognize the huge potential of RFID in Supply Chain Management, but also make useful comments. Although their research dates back from 2005 and in the meantime the development of RFID continued, the first cons still applies. The implementation of RFID will affect the entire organisation and therefore the organisation first needs to be prepared in order for a successful RFID implementation.

In the same year Angeles (2005) emphasized the potential benefits of RFID technologies, but she outlined the following recommendations for a successful deployment of a RFID technology:

- Make the Return On Investment (ROI) Case for RFID.
- Choose the right RFID technology.
• Anticipate RFID technical problems.
• Manage the IT infrastructure issues.
• Integration with Back-End Applications.

Also more recent research by Sarac et al. (2010) emphasize the large potential of RFID technologies in Supply Chain Management, but they also make the following important remarks:

• Importance of reengineering the supply chain to gain more benefits from RFID technologies.
• Lack of international standards is another disadvantage. There are differences between the UHF frequency in Europe and USA.
• Various technical and economical obstacles. Metal and liquid environment can disturb reading performances of RFID technologies
• Choosing the right technology for an environment is a key decision factor for companies to gain the most out of RFID technologies. Analysing the environment and defining their objectives, constraints, strengths, weaknesses, opportunities, and threats are as important as analysing different RFID technologies in order to choose and implement the most efficient technology.

Leung et al. (2014) extensively reviewed six RFID implementation cases. They show that the implementation often is incorrect. Therefore, the use of RFID is not optimal despite the high potential of RFID technologies. They have the following three recommendations:

• Align the Supply Chain Strategy with RFID technologies.
• Evaluate the RFID applications available on the market and determine how their peers are using them.
• Organizations carefully consider whether the RFID application in question fits their needs.
• Organizations analyse the RFID application type that is suitable and feasible, in terms of complexity, SC partner involvement, and whether any organisational, tactical, strategic changes will be needed.
The figure above is adopted from Lim et al. (2013), because it is very nice visualisation of the RFID benefits and obstacles for a warehouse. This also very relevant for the research, because warehouses of the trolley supply chain are very important. You can learn from the above figure that there are many potential benefits, but also obstacles which should not be underestimated.

The literature shows that a successful implementation of RFID technologies takes a lot of time and care. The implementation of RFID technologies is not easy and requires a lot of effort and dedication from the entire organisation.

The IATA made a business case for RFID on catering trolleys in the airline industry. The pilot was conducted in cooperation with KLM Catering Services and KLM CityHopper (both private entities within the KLM group). The results show that immediate benefits could be derived from increased visibility and control of: (1) Trolley Tracking, (2) Trolley Contents, and (3) Trolley Maintenance (Price & Pilon, 2007). This will lead to the following reductions and improvements:

- Reduce maintenance costs
- Reduce inventories
- Reduce product shrinkage
- Trolley preventive maintenance
  - Improve safety
  - Minimize equipment inventory
- Asset inventory
  - Minimize equipment inventory
- Asset utilization
- Content inventory management
  - Improve on board sales control
  - Reduce product shrinkage
Improve customer service

In addition to the report of the IATA, the operational manager of KCS Centrum has given a presentation on the RFID pilot. He describes the following points how the catering airline operations can benefit from RFID: (van Gent, 2008)

- Internal Buffer control
- Elimination of hand scanning
- Production progress visible
- Complete check
  - No second deliveries
- Detect not loaded trolley’s at inbound gates
- Reduction searching for missing trolley’s

Both the IATA research and the RFID applications in other industries show that there is a lot of potential – e.g. reduce costs and improve performance – in the use of RFID in the trolley supply chain. Thereby, should be noted that the implementation process requires a lot of care from the entire organisation. A successful implementations requires time planning, effort, commitment and capital.

4.2.2 NFC

Near Field Communication (NFC) is a contactless communication method that is used in for example telephones. The average reach of NFC is approximately 10 centimetres. Due to the small reach it is necessary that the scanner comes very close to the NFC-chip. The advantage of NFC is that is less expensive as RFID and an active chip. In addition, it can support the desire to create more flexibility in the loading plan. The disadvantage is the small range of the chip. Second, the organizational structure should be adjusted to gain optimal usage from NFC. At the moment NFC is widely used in the telecom industry (Ondrus & Pigneur, 2009) (Mainetti, et al., 2013)

4.2.3 Barcode-printing – QR code

It is also possible to print a metal plate with a code on it which can be read by a (hand)-scanner. The Matrix 300 by Datalogic is an example of barcode printing method (Datalogic, 2014). This makes it possible to put all the technical specification of a trolley in the code. The advantage of this method that it is not that expensive compared to RFID and NFC. The disadvantage is that the reading of the code has to be performed manually.

4.2.4 Metal plate

At this moment a KLM trolley contains only a metal plate and year of construction. The year of construction eases to identify a trolley, but then certain knowledge of the different lease contracts is needed. The researcher had this knowledge and therefore the shoot-out process was easier, but when this knowledge is not present the shoot-out process is much harder.

The strategic impact of using technologies to enhance the traceability and identification is at first related to the network design of the scanners. If you opt for the use of technology every trolley will get a tag. The question remains where you will place the scanners, only at KCS or
at all caterers worldwide. If you have picked the locations it is necessary to design where in the buildings exactly the scanners will be placed. Another strategic impact of the use of technologies relates to the design of the organizational structure. Technology by itself will not improve the visibility of the trolley supply chain. The organizational structure must be adjusted and prepared in such a way that it can optimal make use of the technology. This is a perquisite to the success of all the technology alternatives.

Another strategic impact of technology is found in the contracts and incentives with outstations. Currently, it is not known where each trolley is, but the use of technology makes it possible to know exactly where each trolley is. In case an outstation is hoarding it can get fine or if they are very secure there could be an incentive in the contract to send back the excessive trolleys. The control on outstations could be improved by use of technology, but this should be included in the contracts.

The tactical impact of the use of technologies relates to the question about how many, when, and which quality? This is also what the operational manager of KCS pointed out in a private meeting. The lessons learned from a RFID pilot with KLM Cityhopper are the validation of technology – chips and scanners – and the network design.

The operational impact of the use of technologies relates to the actual planning of the implantation of the technology in the trolley supply chain. This covers the implementing of chips in the trolleys and scanners at the picked locations, but also the training of the organization and personnel.

Other division within the KLM group already make use of technology to track their products. The washing company Lamme and KCS use tags to track how many blankets and jackets are in the production. The Cargo division uses RFID tags on their equipment. Also in the baggage handling department at Schiphol, they make use of tags. In the baggage handling it currently works smoothly, but at the introduction there were a lot of problems. Because the employees in the baggage basement did not scan all the tags. That’s why after the introduction of the tags the system was not working smoothly. It was a great effort to resolve the problems and get optimal profit from the tag system. That’s why it is very important to give great care at the design and implementation of the use of tracking technology. On the other hand within other division is a large knowledge of tracking technology, this can be of great help in case a technology is picked.

4.2.5 Criteria

In order to evaluate the improvement strategies for enhancing traceability and identification the following criteria have been selected. The criteria have been selected by interviewing KLM personnel and a literature review. KLM has indicated that the following criteria are common in their organization cost, reliability, quality and flexibility.

<table>
<thead>
<tr>
<th>Criteria:</th>
<th>Sub-criteria:</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1: Cost/price</td>
<td>Purchase price</td>
<td>(Price &amp; Pilon, 2007) &amp; (Tuzkaya, Gülsün, Kahrman, &amp; Özgen, 2010)</td>
</tr>
<tr>
<td></td>
<td>Establishment costs</td>
<td>(Price &amp; Pilon, 2007)</td>
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<tr>
<td></td>
<td>Operating costs</td>
<td></td>
</tr>
</tbody>
</table>
In addition, to the four criteria the researcher has defined a fifth criterion namely ease. After defining the sub-criteria via reviewing the literature and interviewing KLM experts, the researcher concluded that the criterion ‘ease’ captures a part of the sub-criteria better.

### 4.3 Registration structure for movements and contracts strategies

There are different methods to register the movements of trolleys. This can be done by hand on a paper, or integrated in the current ERP system or in a separate program like Excel. The choice KLM makes concerning the financing and the technology of a trolley influences the registration choice. When a lease construction is chosen then there is the need to return the trolley at the end of the lease term. Therefore, there should be a return process in place.

The registration of trolleys can be specified in four general activities entry, usage, scrap and exit. Each activity should be registered and each activity should contain the right information. All the activities should be easy accessible, organized and complete.

#### 4.3.1 Current situation

An active article number is an article number that is used in the operation. An inactive article number is not used in the operation (any more). A lease number is an inactive article number only used for the registration of lease trolleys.

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3 Take in and book orders for all stakeholders; repair, KCS Warehouse, KCS Centrum, and outstations
The registration of entry trolleys – procurement – is currently done via two ways. The first way is the rebooking of trolleys via a lease number. The second way is the directly booking of an order on an active article number. The rebooking of trolleys entails that an order is placed via the lease number. When the trolleys are actual delivered at the KCS Warehouse, the trolleys will be rebooked to an active article number. This way you can see the quantities and date when trolleys enter the supply chain. The order does not contain any information on the contract terms. It only contains the date the order is placed, and received at the Warehouse and the quantity of the order.

The second way of registering the entry is place the procurement order directly on an active article number. This is done for example for the Marcel Wanders trolleys. Then when the trolleys arrive at the KCS Warehouse the order is booked and the trolleys can enter the operation. This way you can see the quantities and date when trolleys enter the supply chain. The order does not contain any information on the contract terms. It only contains the date the order is placed, and received at the Warehouse and the quantity of the order.

During operation it is most important that the right movement quantities and types are registered. This entails registration of all the flows in and out of the Warehouse, the outstations, Van Riemsdijk and KCS Centrum. Currently, the actual stock level compared to the SAP stock level of trolleys is not always equal. The outstations have in general more trolleys in their stocks than supposed. The scrapped trolleys are registered by Van Riemsdijk via the Portal.

The exit phase of trolleys entails the sale of KLM property trolleys at the KCS Warehouse and the return of lease trolleys to the lease company. The KLM property trolleys that were sold to KLM employees were not registered in SAP. The lease trolleys that returned to the lease company were also not registered in SAP.

4.3.2 Lease/SPACE number
The Lease/SPACE number is designed by the researcher and a NSM Supply Chain Specialist. This alternative is an extended version of the current situation. The lease number are inactive article numbers in SAP and the SPACE numbers are active article numbers. The name is SPACE is derived from the program that creates the loading plan for each flight. The SPACE program uses the active article numbers in SAP to create the loading plan. Therefore, it is essential to reduce the variety of active article numbers in SAP. SPACE requires that each article number contains only trolleys of the same type and weight. It is allowed to have different batches within one article number.
Figure 23 Example Lease/SPACE number registration

Every trolley order is booked via a unique lease number, the order contains besides the quantity and type also all the contract terms. Once an order is delivered at the KCS Warehouse the order is rebooked to a SPACE number – active article number – which has same type and weight characteristics. When a batch or a part of the batch is returned to the lease company the trolleys are rebooked to the original lease number. Subsequently, the actual return to the lease company is registered with a ‘Sales Order’. In this way the entry and exit of an order is registered in the SAP system, which is visible for all KLM employees. Therefore, at any time the amount of leased trolleys is visible in SAP system.

The disadvantage of this alternative is the creation of many lease numbers, which could make it confusing. In addition, it can sometimes be cumbersome with the rebooking of trolleys.

This method can also be applied to KLM property trolleys. Then the order is directly placed at the manufacturer and not at the lease company. When trolleys are sold, this is registered at the lease number. In case lease trolleys become KLM property at the end of the lease agreement. This can be registered as well. The trolleys are rebooked from the SPACE number to the original lease number and then rebooked to a new lease number. Subsequently, the trolleys are rebooked to the SPACE number.

The Lease/SPACE alternative is developed by the researcher and a KLM Supply Chain Specialists. For the verification and validation of this method the researcher initiated a workshop with two business analysts, the Supply Chain Specialist and the researcher. In the workshop the business analyst with a large experience in SAP suggested the use of batch management instead of the Lease/SPACE method. The Lease/SPACE method is a work around method in SAP, and the batch management method is integrated in SAP.
4.3.3 Batch management

Batch management (BM) is a method built-in SAP to register multiple batches under a single article number. At the moment BM is used for products with an expiry date, such as dairy and drinks. For trolleys, the expiry date could be the end date of the lease agreement. After that date it is no longer possible to pick those trolleys in the KCS Warehouse.

A batch represents in this case a trolley order. This can be lease or KLM property. Each batch contains a unique set of information. In this case all the information regarding the lease/procurement contract.

Every article number represents a specific weight and type of trolley. If a new order has a different weight or type than the article numbers at that moment active, a new article number is created. If a trolley is ordered by KCS, for example the Full Size. Then SAP allocates according to an algorithm a specific batch, for example the oldest or newest batch. For trolleys it is desirable that the newest batch is allocated, because they are used less intensive and therefore the maintenance costs will be lower.

It is also possible to block a specific batch for issue at KCS Warehouse, for example if the contract term has ended. At the moment the trolleys are stored just under their article number, but with BM it is required that a trolley is stored under his batch. Therefore, the KCS Warehouse has to be adjusted and the identification of a batch should be increased.

The operation at KCS Centrum is not influenced by BM, because KCS Centrum just orders a Full Size trolley. They are not interested in a certain batch. In addition, there is not a registered inventory at KCS Centrum. There is a registered inventory at outstations and Van Riemsdijk. For both inventories the choice can be made to let both partners register in batches or via the current way just article numbers.

![Figure 24 Example Batch Management registration](image-url)

The exit of trolley via scrap, sale or return lease company can be registered easily. If a trolley is scrapped than this has to be done at batch level. Sale of KLM property trolley should be registered by a ‘Sales Order’ movement also on batch level. The return to the lease company is also registered on batch level and will be a return manufacturer transaction.

A new article number with BM costs nothing. Change an already existing article number to BM costs €20’000, - per article number. Therefore, to implement BM it is necessary to create a total new set of article numbers. This should then be communicated to all the stakeholders...
and updated in all the software systems. The complexity of the BM introduction should not be underestimated.

### 4.3.4 Criteria registration of trolley movements

In order to evaluate the improvement strategies for the registration structure of movements and contracts the following criteria have been selected. The criteria have been selected by interviewing KLM personnel and a literature review. KLM has indicated that the following criteria are common in their organization cost, reliability, quality and flexibility.

<table>
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<td>Establishment costs</td>
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</tr>
<tr>
<td></td>
<td>Operating costs</td>
<td>(Tuzkaya, Gülşün, Kahraman, &amp; Özgen, 2010)</td>
</tr>
<tr>
<td></td>
<td>Maintenance costs</td>
<td>(Price &amp; Pilon, 2007) &amp; (Tuzkaya, Gülşün, Kahraman, &amp; Özgen, 2010)</td>
</tr>
<tr>
<td>C2: Reliability</td>
<td>Accurateness (Correctness) of inventories</td>
<td>(Gu, Goetschalckx, &amp; McGinnis, 2007)</td>
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<tr>
<td></td>
<td>Correctness of delivery to stakeholders</td>
<td>(Ledbetter &amp; Morgan, 2001) &amp; (van Kleef, 2012) &amp; (Kasi, 2005)</td>
</tr>
<tr>
<td></td>
<td>Correctness information trolleys in SAP</td>
<td>(van Kleef, 2012)</td>
</tr>
<tr>
<td>C3: Ease</td>
<td>Load-unload and usage easiness and speed</td>
<td>(Gu, Goetschalckx, &amp; McGinnis, 2007) &amp; (Tuzkaya, Gülşün, Kahraman, &amp; Özgen, 2010)</td>
</tr>
<tr>
<td></td>
<td>Supervision easiness</td>
<td>(Tuzkaya, Gülşün, Kahraman, &amp; Özgen, 2010)</td>
</tr>
<tr>
<td></td>
<td>Ease to track and trace a trolley in the operation</td>
<td>(Buchanan, 1994)</td>
</tr>
<tr>
<td>C4: Quality</td>
<td>Operational feasibility</td>
<td>(Tuzkaya, Gülşün, Kahraman, &amp; Özgen, 2010)</td>
</tr>
<tr>
<td></td>
<td>Quality of order picking</td>
<td>(Gu, Goetschalckx, &amp; McGinnis, 2007)</td>
</tr>
<tr>
<td></td>
<td>Usage of trolley fleet</td>
<td></td>
</tr>
<tr>
<td>C5: Flexibility</td>
<td>Operational flexibility</td>
<td>(Schönsleben, 2012) &amp; (Tuzkaya, Gülşün, Kahraman, &amp; Özgen, 2010)</td>
</tr>
<tr>
<td></td>
<td>Flexibility about future plans</td>
<td>(Tuzkaya, Gülşün, Kahraman, &amp; Özgen, 2010)</td>
</tr>
</tbody>
</table>

Table 7 Criteria and sub-criteria registration of movements and contracts improvement strategies

In addition, to the four criteria the researcher has defined a fifth criterion namely ease. After defining the sub-criteria via reviewing the literature and interviewing KLM experts, the researcher concluded that the criterion ‘ease’ captures a part of the sub-criteria better.

### 4.4 Communication and coordination strategies

This paragraph entails recommendations for a better communication and coordination structure for the trolley supply chain. This means that all the stakeholder have up-to-date information of the trolley portfolio. This is required for an optimal performance of the trolley supply chain.

There is currently no proper allocation of tasks within in the NSM department concerning the communication throughout the trolley supply chain. In the NSM department four business units are involved in the communication and control of trolley supply chain. This are the Central Planning, Area Planning, Contract Management and the Supply Chain Specialists.

The analysis of the trolley supply chain communication shows that the tasks and responsibilities are not clearly mapped. Therefore, there are three alternatives to solve this problem. The first alternative is to do nothing and let the situation continue. The second
alternative is the appointment of a trolley supply chain manager. The third alternative is the embedding of the responsibilities in the current organisational structure.

The tasks and responsibility concerning the trolley supply chain coordination in the current situation are not clearly described and embedded in the organization. This alternative should be taken into consideration, because NSM can has the choice to do nothing.

The second alternative is the appointment of a trolley supply chain supervisor. This person would be responsible for the entire communication and coordination of the trolley supply chain. The trolley supply chain supervisor. He is accountable to the manager operations.

The third alternative is the embedding of the communication and coordination in the current organizational structure. This alternative is an extension of the current situation in which the responsibilities and tasks are clearly described and embedded in the organization. This entails a close collaboration between the SCS, CM and the Central Planning.

The precise details of tasks and responsibilities regarding the communication and coordination of the trolley supply chain depends on the choice about financing, technology, and registration. Therefore, the alternatives are only specified in a generic way, but important aspects include detailed information about the trolley fleet such as:

- Details about batches; year build, type, quantity, warranty, brand, prices, contract terms;
- Registration of scrapped trolleys.
- Actual stock levels at KCS Warehouse, Outstations, and Repair.
- Up to date list of article numbers for every stakeholder
- Blocking of article numbers.
- Creating new article numbers.

### 4.4.1 Criteria

In order to evaluate the improvement strategies for the communication and coordination structure the following criteria have been selected. The criteria have been selected by interviewing KLM personnel and a literature review. KLM has indicated that the following criteria are common in their organization cost, reliability, quality and flexibility.

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<td></td>
<td>Operating costs</td>
<td>(Tuzkaya, Gülsün, Kahraman, &amp; Özgen, 2010)</td>
</tr>
<tr>
<td>C2: Reliability</td>
<td>Discrepancy between actual stock levels and SAP values</td>
<td>(van Kleef, 2012)</td>
</tr>
<tr>
<td></td>
<td>Accurateness of inventory</td>
<td>(van Kleef, 2012)</td>
</tr>
<tr>
<td></td>
<td>Accurateness of contracts overview</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Effectiveness of organisational structure</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Reliability of the trolley information</td>
<td>(Gunasekaran, Patel, &amp; Tirtiroglu, 2001)</td>
</tr>
<tr>
<td></td>
<td>Reliability of the organization</td>
<td>(Gunasekaran, Patel, &amp; Tirtiroglu, 2001)</td>
</tr>
<tr>
<td></td>
<td>Reliability of information for decisions</td>
<td>(Gunasekaran, Patel, &amp; Tirtiroglu, 2001)</td>
</tr>
<tr>
<td>C3: Ease</td>
<td>Ease to hand-over tasks and responsibilities</td>
<td>(Tuzkaya, Gülsün, Kahraman, &amp; Özgen, 2010)</td>
</tr>
<tr>
<td></td>
<td>Transparency allocation of tasks</td>
<td>(Tuzkaya, Gülsün, Kahraman, &amp; Özgen, 2010)</td>
</tr>
</tbody>
</table>
In addition, to the four criteria the researcher has defined a fifth criterion namely ease. After defining the sub-criteria via reviewing the literature and interviewing KLM experts, the researcher concluded that the criterion ‘ease’ captures a part of the sub-criteria better.

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Sub-criteria</th>
<th>Source(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supervision easiness</td>
<td></td>
<td>(Tuzkaya, Gülsün, Kahraman, &amp; Özgen, 2010)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(Buchanan, 1994)</td>
</tr>
<tr>
<td><strong>C4: Quality</strong></td>
<td>Operational feasibility</td>
<td>(Tuzkaya, Gülsün, Kahraman, &amp; Özgen, 2010)</td>
</tr>
<tr>
<td>Quality of the trolley information available</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>C5: Flexibility</strong></td>
<td>Flexibility to take over tasks</td>
<td>(Schönsleben, 2012)</td>
</tr>
<tr>
<td></td>
<td>Flexibility about future plans</td>
<td>(Tuzkaya, Gülsün, Kahraman, &amp; Özgen, 2010)</td>
</tr>
<tr>
<td></td>
<td>Time to reach all stakeholders</td>
<td>(Tuzkaya, Gülsün, Kahraman, &amp; Özgen, 2010)</td>
</tr>
<tr>
<td></td>
<td>Time to deliver overview trolley portfolio</td>
<td></td>
</tr>
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</table>

Table 8 Criteria and sub-criteria Communication and Coordination improvement strategies
4.5 Monitoring the performance of trolley supply chain strategies

KLM has indicated that they prefer to monitor the performance of the trolley supply chain via KPIs rather than BSC or SCOR methods, because the organisation is already familiar with working with KPIs.

For a managerial perspective it is desirable to construct KPIs that indicate the performance of the trolley supply chain. Although these KPIs must cover the entire trolley supply chain, the amount of KPIs must not be too extensive. Otherwise the overview of KPIs becomes too cluttered.

The following areas should be covered KCS Warehouse, KCS Centrum, Outstations, Scrap and Repair. If all the data – such as stock levels – is accurate better and more informed decisions can be made.

The first alternative is not to design any KPIs and maintain the current way of working. The other three alternatives depict a set of KPIs. The first set contains 5 KPIs, which are mainly strategic KPIs. This alternative is a so called executive dashboard.

The third alternative – second set of KPIs – is a more detailed set of 15 different KPI’s. This provides more information on the trolley supply chain, but it might also makes it more complicated. Besides the strategic KPIs, it also depicts tactical KPIs.

The last alternative comprises approximately 25 different KPIs, this alternative provides the most insight in the status of the trolley supply chain. It also reflects the operational aspect of the trolley supply chain. It entails much more detail then the other alternatives, which might be confusing.

In summary:

- **Alternative 1:** Current situation
- **Alternative 2:** 5 KPIs
- **Alternative 3:** 15 KPIs
- **Alternative 4:** 25 KPIs

The NSM department makes the choice for which set of KPIs they require in the day to day operation. It is essential for the DM to define the need for KPIs and to determine the information it needs. Therefore, the exact formulation of the KPIs and the measurement instruments should be determinant by KLM via a workshop. It is very important that there is support within the organisation and that the KPIs are adequately aligned with KLMs strategy (Alvandi, Fazli, Yazdani, & Aghaee, 2012) (Kaplan & Norton, 1996). Alvandi et al. (2012) provided a step-by-step approach to design the KPIs. In addition, Gunesekearan et al. (2001) point out that is important to make a distinction between strategic, tactical and operational KPIs or as they call it metrics. The Supply Chain Operations (SCOR) approach by the Supply Chain Council provides a set of metrics on strategic, tactical and operational level, which can support the design of KPIs for the trolley supply chain (Kasi, 2005) (Supply Chain Council, 2010).
Many performance measures for closed-loop supply chains are similar to those for open supply chains. More specific performance measures would typically be percentage of products collected, average quality of returned products, average collection costs and costs of processing a return (Flapper, van Nunen, & van Wassenhove, 2005).

Purposes of a performance measurement system according to Aykuz & Erkan (2010) and Gunasekaran & Kobu (2007):

- Identifying success.
- Identifying if customer needs are met.
- Better understanding of processes.
- Identifying bottlenecks, waste, problems and improvement opportunities.
- Providing factual decisions.
- Enabling progress.
- Tracking progress.
- Facilitating a more open and transparent communication and co-operation.

The trolley supply chain can be described as a sociotechnical system. It is a system in which a large part is determined by the many stakeholders (social part) involved and the technical part is determined by the many different nodes and flows such as KCS, outstations and aircrafts (Schönsleben, 2012).

In addition, performance measuring of a supply chain provides a firm insight and it offers a firm the opportunity to adjust and steer where needed. Many firms need a steering mechanism to control their supply chain. A proactive approach enhances a firms’ competitiveness and it provides financial benefits (Gunasekaran, Patel, & McGAughey, 2004).

Indicators should measure every aspect of a supply chain in order to define the overall performance. Therefore, overall supply chain performance measurement forms the basis for improvements via continuous process improvement (CPI) (Schönsleben, 2012). These indicators are called key performance indicators (KPIs) or key performance parameters (KPPs) (Parmenter, 2010). KPIs are widely used in the industry, to get a systemic or balanced performance measurement; often models such as Balanced Scorecards (BSC) and SCOR are used. The BSC method is first described in 1996 by Kaplan and Norton. Before this only the financial aspect of the performance was taken into account. Kaplan and Norton included the customer aspect, the internal business process aspect and the growth & learning aspect into the performance measurement (Kaplan & Norton, 1996) (Alvandi, Fazli, Yazdani, & Aghae, 2012).

Although the BSC and SCOR model are useful models, they are not able to improve the overall performance (Cai, Liu, Xiao, & Liu, 2009). Although the early statement of Cai et al. (2009) the BSC method could assist in the development of appropriate KPIs (Alvandi, Fazli, Yazdani, & Aghae, 2012), because it can server as source for potential KPIs. The book of Parmenter (2010) contains a detailed 12-Step approach to determine the KPIs.
Research shows that there already have been formulated KPIs that concern KLMs entire catering supply chain (van Kleef, 2012). These KPIs can be divided into three categories costs, quality and reliability. In addition, Schönsleben (2012) adds three other categories to the categories mentioned above namely Delivery, Flexibility and Primary Entrepreneurial Objective. Cai et al. (2009) also propose flexibility and add innovativeness.

Alvandi et al. (2012) have defined seven KPI characteristics:

1. Nonfinancial measures (not expressed in Dollars, Yen, Pounds, Euros, etc.)
2. Measured frequently (e.g., daily or 24/7)
3. Acted on by the CEO and senior management team
4. Understanding of the measure and the corrective action required by all staff
5. Ties responsibility to the individual or team
6. Significant impact (e.g., affects most of the core critical success factors [CSFs] and more than one BSC perspective)
7. Positive impact (e.g., affects all other performance measures in a positive way) (Parmenter, 2007).

Example of performance indicators by Schönsleben (2012)

“A performance indicator relates to a logistic object and thus becomes an attribute of that object – and sometimes it becomes a logistic object in its own right.”

A balanced set of global measures form the basis of a balanced scorecard. All indicators together form a set of measurements of performance and provide a basis on which company performance can be improved, via continuous process improvement (CPI).


Performance indicators in the Target Area of **quality**:  
- Scrap factor (or yield factor) -  
  - Number of scrapped trolleys divided by total number of trolleys  
- Complaint rate – #IFR/month

Performance indicators in the Target Area of **costs**:  
- Stock-inventory turnover  
  - Annual cost of trolley inventory issues divided by average trolley inventory

Performance indicators in the Target Area of **Delivery**:  
- Fill rate or customer service ratio  
  - Number of trolleys delivered on desired delivery date divided by number of trolleys ordered  
- Delivery reliability rate
- Number of trolleys delivered on confirmed date divided by number of confirmed trolleys
  - Response time
    - Time from order entry up to order preconfirmation divided by total lead time
  - Order confirmation time
    - Time from order confirmation up to order confirmation divided by total lead time

The SCOR model contains the following performance indicators in the area of delivery. The first concerns the goal of high delivery reliability rate and the second the goal of short lead times.

Performance indicators in the Target Area of **Flexibility**:

- Breadth of qualifications
  - Number of different operations that can be executed by an employee or a production infrastructure
- Temporal flexibility
  - Short-term possible percentage of deviation from an employee’s or a production infrastructure’s average capacity

Performance indicators of the **Primary Entrepreneurial Objective**:

- Return on net assets (RONA)
  - A measure of financial performance that takes the use of assets into account
    - (net income) / (fixed assets + net working capital)

A characteristic in planning & control in a supply chain is the sum of all values, that is, one value per feature in the morphological scheme. It relates to a product or product family.

**An example of KPIs for RTIs**

Bowman et al. (2009) have formulated the following key performance indicators for RTIs.

**Trolley utilisation KPI:**

- Total number of ordered trolleys
- Total number of issued trolleys

This indicates how efficient the trolleys are used by KCS.

**Out of stock situation KPI:**

- Total number of out of stock situations / total number of orders.

This KPI can be used to assess the trolley inventory levels at KCS Centrum. In addition, this KPI can be used to assess the out-of-stock situation at outstations.

**Product Quality KPI 1:**
- total number of damaged trolleys from an order / total number of delivered trolleys

This KPI can be applied on the delivery of new trolleys from the manufacturer. In addition, it can also be used by KCS Centrum to assess the quality of the delivered trolleys from the warehouse. It should be noted that this might be unrealistic, because delivered trolleys at KCS Centrum are immediately inserted in the operation.

**Product Quality KPI 2:**

- Total number of damaged trolleys in batch / total number of trolleys in batch.

This KPI measures the quality of a specific trolley batch.

**Trolley Management Metrics**

**Metrics required for managing trolleys**

**Trolleys Quality KPI:**

- Total number of damaged trolleys / total number of trolleys.

This KPI is used mainly to assess the quality of the trolleys.

**Trolley quality KPI**

- Rate of new trolley replenishment
- Rate of trolley lost or damaged
- Unaccountability rate of lost or damaged trolleys – (Shrinkage)
- Average trolley lifetime
- Rate of goods damaged by trolleys

**Trolley utilisation KPI**

- Trolleys Count in/out rate (daily / weekly / monthly / yearly)
- Rate or total number of trolleys in circulation
- Size of trolley buffer stock at a specific location
- Frequency/size of shortage or surplus of trolley (according to demand)
- Usage frequency per trolley (number of times trolley transported from one site to another - measure of durability)

**Trolley efficiency KPI**

- Average trolley cycle time
- Average trolley dwell time at a particular location
- Average time to transport trolley
- Average time to service repair
- Average time to supply new trolleys

**Trolley cost KPI**
- Average transportation cost per trolley
- Average cost of cleaning or repair per trolley
- Hidden labour costs
- Cost per trolley.

### 4.5.1 Criteria

In order to evaluate the improvement strategies for monitoring the performance of the trolley supply chain the following criteria have been selected. The criteria have been selected by interviewing KLM personnel and a literature review. KLM has indicated that the following criteria are common in their organization cost, reliability, quality and flexibility.

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Sub-criteria</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1: Cost/price</td>
<td>Operating cost</td>
<td>(Tuzkaya, Gülsün, Kahraman, &amp; Özgen, 2010)</td>
</tr>
<tr>
<td></td>
<td>Establishment costs for measuring</td>
<td>(Price &amp; Pilon, 2007)</td>
</tr>
<tr>
<td>C2: Reliability</td>
<td>Reliability of inventories</td>
<td></td>
</tr>
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<td></td>
<td>Reliability of the information for decision making</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Reliability of the KPIs</td>
<td></td>
</tr>
<tr>
<td>C3: Ease</td>
<td>Ease to generate KPIs</td>
<td>(Tuzkaya, Gülsün, Kahraman, &amp; Özgen, 2010)</td>
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<tr>
<td></td>
<td>(Buchanan, 1994)</td>
<td></td>
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<tr>
<td></td>
<td>Ease of traceability trolleys</td>
<td>(Tuzkaya, Gülsün, Kahraman, &amp; Özgen, 2010)</td>
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<td></td>
<td>(Buchanan, 1994)</td>
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<td></td>
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<td>C4: Quality</td>
<td>Quality of information to make decisions</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Quality of the KPIs</td>
<td></td>
</tr>
<tr>
<td>C4: Flexibility</td>
<td>Flexibility to adjust KPIs</td>
<td>(Tuzkaya, Gülsün, Kahraman, &amp; Özgen, 2010)</td>
</tr>
<tr>
<td></td>
<td>Time to generate KPIs</td>
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<tr>
<td></td>
<td>Time to understand KPI</td>
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</tbody>
</table>

Table 9 Criteria and sub-criteria performance measures criteria

In addition, to the four criteria the researcher has defined a fifth criterion namely ease. After defining the sub-criteria via reviewing the literature and interviewing KLM experts, the researcher concluded that the criterion ‘ease’ captures a part of the sub-criteria better.

### 4.6 Preliminary conclusion

This chapter provided insight in the five decision areas which can in the long-term improve the trolley supply chain and hence so secure the trolley decision-making process. In the previous chapter for each decision area improvement strategies have been designed. The main purpose of this chapter was to describe the improvement strategies in detail and select the criteria and sub-criteria, which will be used to evaluate the improvement strategies. The evaluation of the improvement strategies is described in chapter 6. Before the improvement strategies can be evaluated, the impact of the improvement strategies on the current processes of the trolley supply chain is described. The impact of the improvement strategies on the trolley supply chain processes is described in the following chapter.
5 Impact of improvement strategies on trolley supply chain processes

This chapter describes the impact of the improvement strategies on the trolley supply chain processes. EPC diagrams have been used to describe the trolley supply chain processes and the impact of the improvement strategies on them. The choice for EPC was made in cooperation with KLM, because they are familiar with this modelling technique and the alignment of EPC with SAP R/3. The following section entails a description of EPC modelling and subsequent the EPC diagrams are presented.

5.1 Event-driven Process Chain (EPC)

A useful tool for mapping a supply chain is via Event Process Chain (EPC) modelling. EPC enables a firm to model the dynamic behaviour of supply chain processes. By mapping the supply chain processes it visualises relationships and so bottlenecks (Van Der Vorst & Beulens, 2002). Furthermore, EPC modelling is supported by many tools such ARIS and SAP R/3 (TU Eindhoven, 2014) (Baureis, 2010).

The part below will describe the basic rules of EPC modelling according to Baureis (2010).

![Activity and Event EPC diagram]

Figure 25 Event and Activity EPC diagram

“An Activity (or Function) describes an incidental task that typically consumes time and resources. Therefore, it is an active component and has decision-making authority.

An Event describes, in accordance with DIN 69900, an occurred defined condition that causes a sequence of activities. Therefore the event is a passive component and may have no function in contrast to the decision-making authority. Events can trigger functions. Functions are triggered by events. Events describe an occurring condition” (Baureis, 2010).

In general you start an EPC model with an event, because an event has to trigger a predefined activity or function. An event can trigger one or more activities. An event or function can only have one outgoing flow. In case an event triggers two function a special building block has to be used. This will be explained in the part below. In addition, activities and events have to alternate. Therefore, it is not possible that one event can trigger another event directly.

Building blocks can connect multiple events or activities. There are three type of building blocks AND, OR, and XOR. Building blocks can either split a single flow into multiple flows, or it can combine (join) multiple flows into a single flow. Therefore, there is made a distinction in interpretation between splitting and joining building blocks.
Figure 26 Building blocks EPC diagrams

**AND**
- SPLIT: The processing steps that follow the rule occur in parallel and have to be performed.
- JOIN: All processing steps for incoming connections must be completed so that the processing steps that follow the rule can be performed.

**OR**
- SPLIT: At least one of the following rule processing steps (or even several or all processing steps) must be performed.
- JOIN: At least one processing step (or even several or all processing steps) must be completed, whereupon the processing steps that follow the rule can be performed.

**XOR**
- SPLIT: Exactly one of the following rule processing steps must be executed.
- JOIN: Only one of the processing steps for incoming connections may be completed so that the processing steps that follow the rule can be performed.

In general it possible to make all combinations as possible except for the following two type of configurations:

The combinations above are not allowed, because an event can only trigger one or all the subsequent activities.
5.2 EPC – Procurement & Tender process trolleys

![EPC Diagram]

Figure 27 EPC - Tender & Procurement process
The figure above describes the procurement of new trolleys at KLM. The first 5 events manufacturing in a batch, more intensive use of trolley, fleet extension, end-of-lease agreement and scrapped (shrinkage) of trolleys trigger the activity to make decision to procure new equipment. This activity can only have two outcomes procure new equipment or not. When the decision is made to procure new equipment KLM can start making a request for proposal. The request for proposal includes the requirements and need of the equipment. Subsequently, the proposal is send to potential vendors. This is the start of the tender procedure. When the tender procedure delivers a vendor the vendor will receive the final requirements and they can start make the design freeze. The design freeze has to be approved before the actual order can be send to the vendor. Parallel to this activity the question about ownership of the trolley fleet needs to be answered. This can be buying, leasing or outsourcing. When the design freeze is approved and the choice made for financing the order, the actual order can be send to the vendor. In case the ownership is outsourced the process ends here, because from this point the outsourcing partner takes over the process.
5.3 EPC – Trolley ordering process at manufacturer

This part describes the order processing of trolleys by means of Figure 28. The ordering process starts when the vendor, design and quantity are defined. The first activity is ordering a set of test trolleys. When that is done the order with test trolleys is placed at the manufacturer. Now the order receiving process can start. When the test trolleys are received in the Warehouse of KCS the test activity can start. At the moment the test is executed at KCS Centrum. The test trolleys are washed multiple times to see how it holds. In some occasions a third expert partner is invited to support the testing with data. When the testing activity is finished it can have two events the trolleys passed the test or they did not. When they did not passed the test, the trolleys will be send back to manufacturer and they have to adjust them.

The final order will be send to the manufacturer if the trolleys pass the test. The ordering activity creates an order in SAP and email to the manufacturer with the actual order. Now the waiting for the confirmation of the order starts. If there is no confirmation order send by the
manufacturer KLM will contact with manufacturer. If the order confirmation is received by KLM the transport to the warehouse can be arranged. The manufacturer is normally not able to deliver all trolleys in once, they will come smaller batches. Also the Warehouse is not always able to store an entire order. In the past an order existed out of 4000 half-size trolleys. When the transport is arranged the receiving of the trolleys can start. When all the trolleys are received in the warehouse the order is taken in by warehouse employees in SAP and the quality inspection and goods receive process can start.

The process of quality inspection can start when the trolleys are received at the KCS Warehouse. The activity conduct inspection is done by KLM employees and an external partner. The inspection can only have two outcomes the trolleys pass the inspection or not. When the trolleys did not pass the quality inspection the manufacturer will be contacted. The manufacturer will start to look for a solution for the problem. When it is not possible to find a feasible solution the manufacturer has to manufacture new trolleys. When a solution is found the trolleys can pass the quality inspection check. When the batch of trolleys passes the quality inspection check the trolleys are ready for operation. Then the process of shoot in the trolleys can start.
5.4 EPC – KCS Goods Receive Process at the Warehouse

The process of goods receives only applies in the current situation, but it does not apply if the improvement strategy outsourcing for the ownership of the trolley fleet is selected.

The diagram above describes the process of receiving goods at the KCS Warehouse. The process starts when a KLM driver or an external driver is offering his load at the dock.

Figure 29 EPC – Goods receive process at KCS Warehouse

The process of goods receives only applies in the current situation, but it does not apply if the improvement strategy outsourcing for the ownership of the trolley fleet is selected.

The diagram above describes the process of receiving goods at the KCS Warehouse. The process starts when a KLM driver or an external driver is offering his load at the dock.
When an external driver arrives at the dock, he/she has to check in at the driver’s desk. When the external driver is checked in or when a KLM driver is arrived at the dock, the drivers will unload their truck. The goods are placed in the entrance hall of the KCS Warehouse. The controller inbound (c.i.) checks if there is an order that corresponds with the packing list, when provided, to register the goods. There are now four events that can happen. First, there is no packing list, probably a KLM driver has delivered goods from KCS, and the c.i. will check if there is an open order. If there is no open order, the c.i. will contact the Central Planning (CP) to make an (retour) order. The c.i. is now able to book the goods. Second, the packing list is equal to the open order, then the c.i. can directly book the goods. Thirdly, the packing list is smaller than the open order. In this case the c.i. books the amount of the packing list and the order is partly booked. Finally, the packing list is larger than the open order. In this case the c.i. will contact the CP to increase the open order. In case the contract is expired the CP will contact Contract Management to increase the contract. Then the CP is able to increase the open order and the c.i. will book the goods.

If the goods are booked in SAP, the c.i. will print the labels with a location for the goods. The labels will be sticked on to goods. KCS employees can then see at which location in the warehouse they have to put the goods. In case RFID or any other technology is used on the goods the tags need to be scanned and the scanner shows the warehouse location. When the goods are placed at the location, the c.i. will scan the location tag and the system is updated. When the goods are at their location the employee will scan the label of the goods and the location and now the goods are registered at their location.

5.5 EPC – Order process for a trolley by KCS Centrum
In Figure 30 below the order process for a trolley by KCS Centrum is presented. There are two methods KCS Centrum can order a trolley. The normal method starts with the event that there is a need for trolleys. KCS Centrum will contact the CP to make an order in SAP. The CP creates the order in SAP and the ordering process at the KCS Warehouse is activated. When the latter process is completed the process transport truck is activated and when that is completed the trolleys are arrived at KCS Centrum. Subsequently, two events can happen or the trolleys are put in temporary storage or directly set into the operation.

The second method is a ‘loop-fax’ (LFI). This method enables KCS Centrum to directly place an order at the KCS Warehouse without interference of the CP. This is not the normal method, but it can only happen when the CP is not in the office for example during the weekend. When the order is placed at the KCS Warehouse the rest of the procedure is identical to the first method.

In case the ownership of the trolley fleet is outsourced the orders are sent by a system to the outsource company. This system can be an advanced ERP system like SAP or orders by email. If this solution is selected this one the issues that has to be resolved. A more detailed look into the different computer programs and its interfaces is described in Appendix D on page 149.
Order process KCS Centrum LR

- The need for a new equipment
  - Place a LFI order in BAAN
    - Order for equipment is placed
      - Order processing process at WH
        - Process transport truck
          - Make decision for storage location of equipment
            - XOR
              - Storage location is work floor
                - Bring equipment to the work floor
                  - Equipment is at the work floor
              - Storage location is inventory
                - Bring equipment to the inventory
                  - Equipment is in the inventory

Normal order process for equipment by KCS Centrum

- The need for a new equipment
  - Contact CP to place an order in SAP
    - CP is informed about the order
      - CP places order for equipment in SAP
        - Order is placed in SAP
          - Process transport truck
            - Make decision for storage location of equipment
              - XOR
                - Storage location is work floor
                  - Bring equipment to the work floor
                    - Equipment is at the work floor
                - Storage location is inventory
                  - Bring equipment to the inventory
                    - Equipment is in the inventory

Figure 30 EPC – Order a trolley for KCS Centrum operation
5.6 EPC – Process transport of trolley by truck/sea/air

![Process flow diagram for transporting a trolley by truck/sea/air](image)

Figure 31 EPC – Transport via a truck
Figure 32 EPC – Transport via sea
Goods can be transported by three ways by a truck, by a boat or by an aircraft. To start the process of a truck a driver has to be ready and there has to be an assignment. This is the
prerequisite for the driver to check the assignment. When the driver is informed he goes either
directly to the truck and drives to his destination with an empty truck or he has to load the truck
first and then drives to his destination. Subsequently, the driver will check in at his destination
and when he is checked in he will unload and load his truck or immediately load his truck – in
case arrived with an empty truck.

Depending on a subsequent destination the driver will go to this subsequent destination or head
back to the KCS Warehouse. In case the driver goes to a subsequent destination, the process is
the same as at the first destination. Subsequently, the driver might have another destination on
his assignment the process will be the same. This continues until the driver has to go to the
KCS Warehouse. When the driver parks the truck at the dock the process of goods receive at
the KCS Warehouse starts.

The process to send goods via boat to mostly outstations starts with an order provided by the
KLM Planning department. Subsequently, the process of order receiving by the KCS
Warehouse has to be completed, before the transport process by sea starts. The equipment is
picked and compiled in the main hall of the KCS Warehouse. When the entire order is picked
a 20 ft. or 40 ft. sea container is loaded. Subsequently, the 3PL partner, Kuehne & Nagel, will
transport the container to his destination. When the container has a delay, the container process
delay starts. The container delay process is described in the paragraph below. If there is no
delay the container arrives in time at his destination and can be unloaded by the outstation. The
outstation has to make a decision to put the equipment at the work floor or in the inventory.
Depending the outcome of the storage location decision the equipment is placed their and the
movement has to be registered in SAP.

When the event occurs a delay with a container, the 3PL Kuehne & Nagel will inform the
Customs & Distribution (C&D) department of KLM about the delay. There can be three forms
of information about the delay. First there is no information about the delay, C&D will contact
the Area Planning department with this information. Subsequently, the AP has to make a
decision to send extra equipment by air. When they make the decision to send extra equipment,
they create directly an order and then the process transport by air starts. When they decide to
wait for further information, the activity wait for further information about the delay starts.
They could decide to do nothing and see how the situation works out. Second, type of
information about the delay is that the delay is not significant. This means that the delay does
not jeopardize the operation. When the AP is informed, no action is needed and the waiting for
the container to arrive at his destination can start. Third, the delay can be significant. This
means that delay will jeopardize the operation. When the AP is informed the AP has to make
a decision to send extra equipment through via the air.

The last way to send an equipment to an outstation is via the air. This is the most expensive
mode of transport and therefore the least preferred mode. The process starts with an air
equipment order by the AP department. The order is handled via the order receiving process of
KCS Warehouse. The result of this is that all the equipment is picked. This triggers the activity
to prepare the air shipment at the main hall of the KCS Warehouse. When the air shipment is
prepared, it is transported to the KCS Centrum from where the shipment will be put on a KLM
flight to his destination. At the outstation the shipment has to be unloaded. The unloading is not always performed. Therefore, you see the two events ‘equipment is offloaded’ and ‘equipment is not offloaded’. When the equipment is offloaded, the outstation makes the storage location decision. This can either be in the normal inventory or at the work floor. Besides putting the equipment in the chosen location, the outstation has to register the movement via the Portal.

When the equipment is not offloaded at the outstation, the OS will inform the AP. When the AP is informed about the failure of the shipment, the AP will create a new order in SAP for a new shipment. The equipment that is not offloaded at the outstation will go back to Schiphol and then it will be unloaded by KCS. KCS Centrum will send the equipment back to KCS Warehouse, where it will go back into storage.

5.7 EPC – Request of a trolley by an outstation
This chapter describes the process of a request by an outstation for a trolley, but is also applicable for other equipment. The process starts with a request from an outstation for extra trolleys. The OS places the request via the Portal in SAP. The request in the portal is handled by the Area Planning department. They can either deny or approve the request. If the request is denied, the process ends. When the request is approved by the Area Planning, the AP will choose a mode of transport for the equipment. When the mode of transport is determined, the AP creates an order in SAP to send a trolley to the OS. When the order is created in the SAP system the order processing process at the KCS Warehouse starts. The equipment can either be send by sea or air. A shipment via the air is more expensive than via the sea, but the lead-time via air is much lower. Therefore, the mode choice to supply an outstation depends on the need of the outstation. If the need is not high and the equipment can go via the sea than this mode is chosen.
Figure 34 EPC – Request by an outstation for an extra trolley
5.8 EPC – Order receiving process by the WH for a trolley

The figure below shows the process of receiving of an order by KCS Warehouse. The process starts with the creation of order by for example the Area or Central Planning. The order has to be received by the KCS Warehouse ERP system. When the order is received in the SAP system, the system creates a picking list and books the order in SAP. When the picking list is created, the actual picking of the order starts. Finally, when the order is complete the process for transport by either sea, road or air starts.

Figure 35 EPC – Receiving a trolley order by the KCS Warehouse
This chapter describes the process at the end of a lease agreement. The lease agreement prescribes that three months before the end of the lease agreement, KLM must make a decision if it wants to extend the lease contract, take over ownership or serve out the lease agreement. When KLM decides to serve out the lease agreement, KLM has to inform the lease company. If the lease company is informed the shoot-out process of trolleys can start.

When KLM decides to extend the contract, the activity starts which entails the extension of the contract. The procurement department of KLM is responsible for the lease agreement extension negotiations. Subsequently, when the lease agreement is extended the process ends. In case, the decision is made to take over the ownership of the trolleys, the lease company has to be informed as well and pay the lease company the residual value.

In the current situation there is no registration of the decision made in the ERP system. There is no registration concerning the end of a lease agreement.

In the desired situation KLM still has to make the decision about what to do at the end of the lease agreement. But now the choice made is registered in the ERP system. When the contract is extended, two activities has to be completed. First the lease agreement has to be updated in SAP and second the extension of the lease agreement has to be negotiated with the lease company. When both activities are completed, the process ends. In case KLM decides to take over the ownership of the trolleys. First this must registered in SAP and second the decision should be communicated with the lease company.
The functions and events indicated by the green boxes are proposed solutions to register the shoot out of trolleys in SAP.

In the current situation there is no registration of trolleys that are given back to the lease company. When the decision is made to give back the trolleys the shoot-out process starts. The first activity to define the shoot-out process. This means make a schedule how many trolleys a week will be shot out, how many trolleys on a pallet, and delivery schedule with the lease company. When the operational process is defined preparations in SAP must be made and the process must be communicated to all the stakeholders. When both activities are completed the actual shoot out process can start. In the current situation KLM did not make any preparations in SAP.

When the shoot-out process starts, KLM makes an order for replacement trolleys, because it is not possible to extract trolleys out of the process they have to be replaced. With the normal order process the replacement arrive at KCS Centrum. Trolleys that are shot out will be...
replaced with the ordered trolleys. Via the transport process the shot out trolleys are transported to a storage in Nieuw-Vennep. When that is completed KLM checks if all the equipment is shot out. If this is not the case the decision has to be made to continue collecting the last part of the trolleys. If the decision is to continue collecting, the process starts over again. If KLM decides to stop looking for equipment or if all the equipment is collected, the shoot-out process continues.

It depends if all the equipment is retrieved or not. If not all the equipment is retrieved, then the lease company should be informed and when that is done the replacement should be defined. If the replacement is defined, it must be paid and the registration in SAP should be updated. The SAP registration is currently not done. If all the trolleys are retrieved the last steps are not applicable, but the final pick-up has to be arranged and a sales order in SAP has to be created. When the actual is arranged, the actual hand over of trolleys to lease company has to take place and the sales order has to be booked in SAP. When both activities are completed, the shoot-out process ends.

5.11 Preliminary conclusion

In this chapter the trolley supply chain processes are described using EPC diagrams. In addition, the impact of the designed improvement strategies is described. There is close link between the improvement strategies and the registration of certain actions in the SAP system. There should be noted that the success and therefore the impact is determined by the employees that enter the data. The impact assessment serves as support for the evaluation of the improvement strategies. In the next chapter we will evaluate the improvement strategies.
6 Evaluating the improvement strategies
In the previous chapters the improvement strategies have been designed, described and the impact on the trolley supply chain processes is assessed. This chapter contains the evaluation of the improvement strategies. Per subject KLM selects the best improvement strategies taken into account the criteria and sub-criteria, which are defined in chapter four. In this research we use a novel multi-criteria decision method: Best-Worst Method (BWM). The BWM is used, because this method requires less pairwise comparisons and it provides more reliable results. The BWM is developed by Rezaei (2014a) and the following section contains a detailed description of the BWM. In the subsequent sections the BWM is applied on each decision area of improvement strategies.

6.1 MCDM – Best-Worst Method
In order to rank multiple alternatives according to different criteria is not straightforward, as criteria costs and quality are not immediately comparable. Therefore, an adequate comparison method is needed to compare aspects such as quality and costs. Multi Criteria Decision Making (MCDM) methods are able to rank alternatives with different kind of criteria’s (Figueira, Greco, & Ehrgott, 2005).

A MCDM problem is normally presented in a matrix form, which is shown in Eq. 1. In the matrix represent \( \{a_1, a_2, \ldots, a_m\} \) a set of feasible alternatives, \( \{c_1, c_2, \ldots, c_n\} \) a set of decision-making criteria, and \( p_{ij} \) is the score of alternative \( i \) with respect to criterion \( j \). The overall goal is to select the alternative that is best.

\[
A = \begin{pmatrix}
  c_1 & c_2 & \cdots & c_n \\
  a_1 & p_{11} & p_{12} & \cdots & p_{1n} \\
  a_2 & p_{21} & p_{22} & \cdots & p_{2n} \\
  \vdots & \vdots & \ddots & \vdots \\
  a_m & p_{m1} & p_{m1} & \cdots & p_{mn}
\end{pmatrix}
\]

Eq. 2

The literature shows a wide variety of multi criteria decision methods. “Ranking is a kind of multi criteria decision making (MCDM) problem with different criteria and objectives“ (Alvandi, Fazli, Yazdani, & Aghaee, 2012). At the moment there is not a single best method. Every method has his benefits but at the same its limitations (Guitouni & Martel, 1998). As there is not a preferred method it’s advised to execute more than one method and interpret the different results.

Two common MCDM methods are the Analytic Hierarchy Process (AHP) and the Analytic Network Process (ANP) both are multi-criteria decision tools (Saaty, 2004). AHP was developed in 1977 by Thomas L. Saaty (Saaty, 1977). The ANP is a generalization of the AHP (Saaty, 2005). “ANP and AHP are theories of relative measurement of intangible criteria. With this approach to relative measurement, a scale of priorities is derived from pairwise comparison measurements only after the elements to be measured are known. The ability to do pairwise comparisons is our biological heritage and we need it to cope with a world where everything
is relative and constantly changing. In traditional measurement one has a scale that one applies to measure any element that comes along that has the property the scale is for, and elements are measured one by one, not by comparing them with each other. In the AHP paired comparisons are made with judgments using numerical values taken from the AHP absolute fundamental scale of 1-9. A scale of relative values is derived from all these paired comparisons and it also belongs to an absolute scale that is invariant under the identity transformation like the system of real numbers. The AHP/ANP is useful for making multi-criteria decisions involving benefits, opportunities, costs and risks. The ideas are developed in stages and illustrated with examples of real life decisions. The subject is transparent and despite some mathematics, it is easy to understand” (Saaty, 2005).

In addition, to AHP van Laarhoven and Pedrycz (1983) have developed a method which uses triangular fuzzy number. Chang (1996) has developed a new approach for handling fuzzy AHP by using triangular fuzzy numbers for pairwise comparison scale. Mikhailov and Tsvetinov (2004) have developed a fuzzy AHP which uses fuzzy preference programming. The fuzzy AHP by Mikhailov and Tsvetinov (2004) is an improved version of AHP. Rezaei et al. (2013) builds upon the method developed by Mikhailov and Tsvetinov and Rezaei et al. (2013) present an improved version of a fuzzy AHP method. The results of the improved fuzzy AHP method show that is a suitable method to tackle multi-dimensional, fuzzy, and perception-based constructs. The disadvantage of the improved fuzzy AHP method is that the in a comparison with four alternatives, you have to make 6 comparisons. Therefore, Rezaei (2014a) has proposed a new MCDM method called the Best-Worst Multi-Criteria Decision-Making, or in short BWM. The Best-Worst Multi-Criteria Decision-Making method is designed by Rezaei (2014a). In addition, to the first paper Rezaei (2014b) has published another paper on interval weight of the BWM MCDM.

Suppose we have \( n \) criteria and we want to execute a pair-wise comparison these criteria using a 1/9 to 9 scale. The resulting matrix would be:

\[
A = \begin{pmatrix}
    a_{11} & a_{12} & \cdots & a_{1n} \\
    a_{21} & a_{22} & \cdots & a_{2n} \\
    \vdots & \vdots & \ddots & \vdots \\
    a_{n1} & a_{n2} & \cdots & a_{nn}
\end{pmatrix}
\]  

Eq. 3

where \( a_{ij} \) shows the relative preference of criterion \( i \) to criterion \( j \). \( a_{ij} = 1 \) shows that \( i \) and \( j \) are of the same importance. \( a_{ij} > 1 \) shows that \( i \) is more important than \( j \) with \( a_{ij} = 9 \) showing the extreme importance of \( i \) to \( j \). In order for matrix \( A \) to be reciprocal, it is required that \( a_{ij} = 1/a_{ji} \) and \( a_{ii} = 1 \), for all \( i \) and \( j \). Considering the reciprocal property of matrix \( A \), in order to obtain a completed matrix \( A \), it is necessary have \( n(n-1)/2 \) pair-wise comparisons. The pair-wise comparisons matrix \( A \) is considered to be perfectly consistent if:
\[ a_{ik} * a_{ij} = a_{ij}, \forall i, j \]  

Eq. 4

It is possible to divide the pair-wise comparisons into two categories: (1) reference categories, and (2) secondary comparisons.

**Definition 1.** Comparison \( a_{ij} \) is defined as a reference comparison if \( i \) is the best element and/or \( j \) is the worst element.

**Definition 2.** Comparison \( a_{ij} \) is defined as a secondary comparison if \( i \) nor \( j \) are the best or the worst elements \( a_{ij} \geq 1 \).

In the BWM method you only compare the best with the others and the rest over the others. In case you have \( n \) criteria, this let you make \( 2n-3 \) comparisons. In case of fuzzy AHP you need \( n(n-1)/2 \) comparisons. Let’s assume \( n=5 \); then with BWM you need to make 7 comparisons and with fuzzy AHP you need to make 10 comparisons. We use the Best-Worst Method, because (1) it requires less comparison data, and (2) it results are more reliable.

In the next section the steps of the BWM are discussed.

6.1.1 Steps of BWM
In this section the seven steps of the BWM are described. The first 5 steps are derived from Rezaei (2014a), the last two step are derived from another working paper by Rezaei (2014b).

The **first step** is to define a set of decision criteria.

In this step, we consider the criteria \( \{c_1, c_2, \ldots, c_n\} \) that should be used to arrive at a decision. Let’s assume we buy a house, the decision criteria can be \{quality\( (c_1) \), price\( (c_2) \), surface\( (c_3) \), distance\( (c_4) \), neighbourhood\( (c_5) \)\}.

In the **second step** the DM defines the best and worst criteria. The criteria the DM prefers most and least prefers.

In this step, the decision-maker (DM) identifies the best and the worst criteria in general. No comparison is made at this stage. The DM in our example selects the quality \( (c_1) \) as the best criterion and selects distance \( (c_4) \) as worst criterion.

In the **third step** the DM compares the best criterion over all the other criteria. The DM defines his preference with a number between 1 and 9, where 1 indicates no preference between the criteria and 9 the most preference of the best criterion over the other criterion.

The resulting Best-to-Other vectors would be:

\[ A_B = (a_{B_1}, a_{B_2}, \ldots, a_{B_n}), \]

Where \( a_{Bj} \) indicates the preference of the best criterion \( B \) over criterion \( j \), it is clear that \( a_{BB} = 1 \). For our example, the vector shows the preference of quality \( (c_1) \) over all the other criteria.
In the fourth step the DM compares the other criteria over the worst criterion. The DM defines his preference with a number between 1 and 9, where 1 indicates no preference between the criteria and 9 the most preference of the best criterion over the other criterion.

The resulting Other-to-Worst vector would be:

\[ A_w = (a_{1w}, a_{2w}, \ldots, a_{nw})^T, \]

where \( a_{jw} \) indicates the preference of the criterion \( j \) over the worst criterion \( W \). It is clear that \( A_{ww} = 1 \). For our example, the vector shows the preference of all the criteria over distance (\( c_4 \)).

In the fifth step we calculate the \( \xi^* \) and the weights \( (w_1^*, w_2^*, \ldots, w_n^*) \) for each criteria.

The optimal weight for the criteria is the one where, for each pair of \( w_B / w_j \) and \( w_j / w_W \), we have \( w_B / w_j = a_{Bj} \) and \( w_j / w_W = a_{jw} \). To satisfy these conditions for all \( j \), we should find a solution where the maximum absolute differences \( \left| \frac{w_B}{w_j} - a_{Bj} \right| \) and \( \left| \frac{w_j}{w_W} - a_{jw} \right| \) for all \( j \) is minimized. Considering the non-negativity and sum condition for the weights that would result in the following linear programming problem:

\[
\begin{align*}
\min & \quad \xi \\
\text{s.t.} & \quad \left| \frac{w_B}{w_j} - a_{Bj} \right| \leq \xi, \text{ for all } j \\
& \quad \left| \frac{w_j}{w_W} - a_{jw} \right| \leq \xi, \text{ for all } j \\
& \quad \sum_j w_j = 1 \\
& \quad w_j \geq 0, \text{ for all } j
\end{align*}
\]

Eq. 5

By solving the problem above the weights \( (w_1^*, w_2^*, \ldots, w_n^*) \) and \( \xi^* \) are obtained.

The steps until here were derived from the first paper of Rezaei (2014a) on BWM. The following two steps are derived from the second paper of Rezaei (2014b) on BWM.

In the sixth step you calculate the interval weights for each criteria, while you keep the \( \xi^* \) constant.
In this step we try to find the intervals of the weights. In the previous step we have obtained the $\xi^*$, which we will use for obtaining the intervals. We will calculate the intervals according to the following linear programming problem:

$$\min w_j$$

s.t.

$$\left| \frac{w_B}{w_j} - a_{Bj} \right| \leq \xi^*, \text{ for all } j$$

$$\left| \frac{w_j}{w_w} - a_{jw} \right| \leq \xi^*, \text{ for all } j$$

$$\sum_j w_j = 1$$

$$w_j \geq 0, \text{ for all } j$$

$$\max w_j$$

s.t.

$$\left| \frac{w_B}{w_j} - a_{Bj} \right| \leq \xi^*, \text{ for all } j$$

$$\left| \frac{w_j}{w_w} - a_{jw} \right| \leq \xi^*, \text{ for all } j$$

$$\sum_j w_j = 1$$

$$w_j \geq 0, \text{ for all } j$$

Solving these two models for all criteria we can find the optimal interval weights of the criteria. In the next step present interval analysis is used to compare and rank the interval weights in case there is overlap between the intervals.

In the **seventh and last step** we rank the criteria based on their intervals.

In case there is an overlap between two intervals it is not evident which interval is better. Therefore, we use present interval analysis to calculate the best interval. Ranking a set of criteria with interval weights you need to calculate ‘matrix of degree of preference’ and the ‘matrix of preferences’. First the degree of preference of A over B has to be calculated.

The degree of preference of A over B (or $A > B$) is defined as:
\[
P(A > B) = \frac{\max(0, a_R - b_L) - \max(0, b_L - a_R)}{(a_R - a_L) + (b_R - b_L)}
\]

where \( A = [a_L, a_R] \) and \( B = [b_L, b_R] \) are two interval numbers. It is clear that \( P(A > B) + P(B > A) = 1 \) and \( P(A > B) = P(B > A) = 0.5 \) when \( A = B \), which means when \( a_L = b_L \) and \( a_R = b_R \).

If \( P(A > B) = P(B > A) \) (or equivalent \( P(A > B) > 0.5 \)), then \( A \) is said to be superior to \( B \) to the degree of \( P(A > B) \), denoted by \( A \succ B \); if \( P(A > B) = P(B > A) = 0.5 \), then \( A \) is said to be indifferent to \( B \); denoted by \( A \sim B \); if \( P(B > A) > P(A > B) \) (or equivalent \( P(B > A) > 0.5 \)), then \( A \) is said to be inferior to \( B \) to the grade of \( P(B > A) \) denoted by \( A \prec B \). The ‘matrix of degree of preference’ and the ‘matrix of preferences’ are calculated as follows:

\[
DP_{ij} = \begin{pmatrix}
A & B & \ldots & N \\
A & P(A > A) & P(A > B) & \ldots & P(A > N) \\
B & P(B > A) & P(B > B) & \ldots & P(B > N) \\
\vdots & \vdots & \vdots & \ddots & \vdots \\
N & P(N > A) & P(N > B) & \ldots & P(N > N)
\end{pmatrix}
\]

\[
P_{ij} = \begin{pmatrix}
A & B & \ldots & N \\
A & P_{AA} & P_{AB} & \ldots & P_{AN} \\
B & P_{BA} & P_{BB} & \ldots & P_{BN} \\
\vdots & \vdots & \vdots & \ddots & \vdots \\
N & P_{NA} & P_{NB} & \ldots & P_{NN}
\end{pmatrix}
\]

Where:

\[
p_{ij} = \begin{cases} 
1, & \text{if } P(i > j) > 0.5, \\
0, & \text{if } P(i > j) \leq 0.5, \ i, j = A, \ldots, N.
\end{cases}
\]

### 6.1.2 A numerical example

For buying a house, a buyer considers five criteria quality (c₁), price (c₂), surface (c₃), neighbourhood (c₄), and distance (c₅). The buyer provides the following pair-wise comparison vectors.

<table>
<thead>
<tr>
<th>Best-others</th>
<th>Quality</th>
<th>Price</th>
<th>Surface</th>
<th>Distance</th>
<th>Neighbourhood</th>
</tr>
</thead>
<tbody>
<tr>
<td>Best-criterion: quality</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>8</td>
<td>6</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Others-worst</th>
<th>Worst criterion: Distance</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Quality</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Price</td>
<td>6</td>
<td></td>
</tr>
</tbody>
</table>
Surface 5
Distance 1
Neighbourhood 3

Table 10 Best-others and others-worst pair-wise comparison vectors for buying a house

Solving this linear programming problem using the model described in step 6 will give you the following interval weights for the optimal value of $\xi^* = 1.1270$.

<table>
<thead>
<tr>
<th></th>
<th>$w_L$</th>
<th>$w_R$</th>
<th>center</th>
<th>width</th>
</tr>
</thead>
<tbody>
<tr>
<td>W1</td>
<td>0.3614</td>
<td>0.4399</td>
<td>0.4007</td>
<td>0.0393</td>
</tr>
<tr>
<td>W2</td>
<td>0.2119</td>
<td>0.3099</td>
<td>0.2609</td>
<td>0.0490</td>
</tr>
<tr>
<td>W3</td>
<td>0.1684</td>
<td>0.2664</td>
<td>0.2174</td>
<td>0.0490</td>
</tr>
<tr>
<td>W4</td>
<td>0.0396</td>
<td>0.0482</td>
<td>0.0439</td>
<td>0.0043</td>
</tr>
<tr>
<td>W5</td>
<td>0.0742</td>
<td>0.0903</td>
<td>0.0822</td>
<td>0.0081</td>
</tr>
</tbody>
</table>

Table 11 Results numerical example BWM

Looking at the intervals and at Figure 38 you can see that there is overlap between the intervals of the criteria price and surface. Therefore, we can’t visually rank the criteria. We have to calculate the degree of preference matrix and preference matrix:

$$DP_{ij} = \begin{pmatrix} 0.5 & 1 & 1 & 1 & 1 \\ 0 & 0.5 & 0.7218 & 1 & 1 \\ 0 & 0.2782 & 0.5 & 1 & 1 \\ 0 & 0 & 0 & 0.5 & 0 \\ 0 & 0 & 0 & 1 & 0.5 \end{pmatrix} \Rightarrow P_{ij} = \begin{pmatrix} 0 & 1 & 1 & 1 & 1 \end{pmatrix}_{4} \begin{pmatrix} 0 & 0 & 1 & 1 & 1 \end{pmatrix}_{3} \begin{pmatrix} 0 & 0 & 0 & 1 & 1 \end{pmatrix}_{2} \begin{pmatrix} 0 & 0 & 0 & 0 & 0 \end{pmatrix}_{0} \begin{pmatrix} 0 & 0 & 0 & 1 & 0 \end{pmatrix}_{1}$$

Now based on the sum of rows, we have the ranking of the criteria in the following order quality $\succ$ price $\succ$ surface $\succ$ Distance $\succ$ Neighbourhood.
6.1.3 Consistency Ratio

The consistency ratio is used to check if the judgements of the DM are consistent. Rezaei (2014a) uses the following definition for the consistency: A comparison is fully consistent when $a_{ Bj} \cdot a_{jW} = a_{BW}$, for all $j$, where $a_{ Bj}$, $a_{jW}$, and $a_{BW}$ are respectively the preference of the best criterion over the criterion $j$, the preference of criterion $j$ over the worst criterion, and the preference of the best criterion over the worst criterion.

However, it is possible for some $j$ not to be fully consistent, which is why Rezaei (2014a) proposes a consistency ratio to indicate how consistent a comparison is. Therefore, Rezaei (2014a) has defined the following consistency index, which is shown in Table 12.

<table>
<thead>
<tr>
<th>$a_{BW}$</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consistency Index (max $\xi$)</td>
<td>0.00</td>
<td>0.44</td>
<td>1.00</td>
<td>1.63</td>
<td>2.30</td>
<td>3.00</td>
<td>3.73</td>
<td>4.47</td>
<td>5.23</td>
</tr>
</tbody>
</table>

Table 12 Consistency Index (CI), adopted from Rezaei (2014a, p. 11)

We then calculate the consistency ratio, using $\xi^*$ and the corresponding consistency index, as follows:

$$\text{Consistency Ratio} = \frac{\xi^*}{\text{Consistency Index}}$$

In case of our example the CR ($a_{BW}$=8) = $1.1270 / 4.47 = 0.252$, which implies a good consistency.

6.2 Process of evaluation

The researcher is the moderator in the decision making process. The researcher has invited two business analysts and the manager Operations to participate in the decision-making process. The three specialists had to come to an agreement on all the weights and choices made in the BWM. At the start of the BWM the researcher explained the process of the Best-Worst Method, during the executing the researcher immediately entered the data into an excel file. Questions regarding the process and (sub)-criteria were answered by the researcher. The researcher did not influence any choice.

6.3 Results Best Worst Method

This section describes the evaluation results of the Best Worst Method. The BWM has been applied to the five decision areas in which the DM had to make a decision. The five decision areas are:

1. Ownership of trolley fleet.
2. Enhancing traceability and identification.
3. Registration structure for movements and contracts.
4. Communication and coordination structure.
5. Monitoring the performance of trolley supply chain.

The literature uses the term alternatives or A. In this paper we will use the term improvement strategy or IS, because it is in this case more suitable. In the following sections the results per decision area are presented. A more comprehensive overview of the BWM results is presented in Appendix F on page 150.
6.3.1 Results ownership of trolley fleet improvement strategies
The three improvement strategies (IS) that were designed to improve the ownership of the trolley fleet and now will be evaluated using the BWM were the following:

- IS1 Outsource everything
- IS2 Leasing
- IS3 Buying

In the figure above the criteria and sub-criteria are presented. These are used to evaluate the three improvement strategies. For each improvement strategy an interval is determined. If a comparison is executed with two or three criteria the weights are unique, which does not result in intervals. Although we have three improvement strategies, we have four criteria’s. Therefore, the global weights have interval data, which means that the final result contains interval data. The global weights are presented in table below. Subsequently, the global weights are multiplied with the unique weights of the comparisons of the improvement strategies and the sub-criteria. The latter contains unique weights because there are only three improvement strategies. Finally the lower and upper interval weights are added together into a lower and upper final weight per improvement strategy, which is shown in Table 14.

Figure 39 Hierarchy of criteria improvement strategies ownership of trolley fleet
### C2: Reliability
- Residual value of trolley: 0.0335, 0.0519, 0.0071, 0.0122
- Reputation: 0.0631, 0.1716, 1.7251, 0.3859, 0.0291, 0.0875
- Financial position: 0.0846, 0.1023, 0.0390, 0.0521
- Performance history: 0.0931, 0.2228, 0.0429, 0.1136
- Correctness of inventory: 0.3617, 0.4371, 0.1667, 0.2229
- Correctness of delivery: 0.1962, 0.3395, 0.0904, 0.1731
- Complaint handling: 0.0372, 0.0449, 0.0171, 0.0229

### C3: Quality
- Reputation: 0.1797, 0.2586, 0.8377, 0.2792
- CSR Factors: 0.1000, 0.1000, 0.4586, 0.1994, 0.0180, 0.0259
- Safety: 0.3541, 0.3541, 0.0636, 0.0916
- Quality of supplier delivered products conform specs: 0.5459, 0.5459, 0.0981, 0.1412

### C4: Flexibility
- Flexibility of the contract: 0.0728, 0.0746, 0.8377, 0.2792
- Lead time of supply: 0.4055, 0.4103, 0.5359, 0.1786, 0.0295, 0.0306
- Replace: 0.0620, 0.0628, 0.0045, 0.0047
- Lead time to adjust trolley portfolio: 0.2803, 0.2803, 0.0204, 0.0209
- Terminate: 0.0908, 0.0919, 0.0066, 0.0069
- Lead time of trolley portfolio: 0.1547, 0.1646, 0.0113, 0.0123

**Table 13 Comparison between sub-criteria and global weights financing alternatives**

<table>
<thead>
<tr>
<th>Intervals</th>
<th>Lower limit</th>
<th>Upper limit</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>IS1</td>
<td>0.2682</td>
<td>0.4938</td>
<td>0.3810</td>
</tr>
<tr>
<td>IS2</td>
<td>0.1717</td>
<td>0.2863</td>
<td>0.2290</td>
</tr>
<tr>
<td>IS3</td>
<td>0.3624</td>
<td>0.5593</td>
<td>0.4609</td>
</tr>
</tbody>
</table>

**Table 14 Final score ownership of trolley fleet improvement strategies**

In case there is an overlap of intervals the degree of preference of A over B has to be established, because it is not possible to immediately rank the improvement strategies in case there is an overlap. In this case the improvement strategies of IS3 and IS1 have overlapping intervals. Subsequently, the intervals of improvement strategies IS1 and IS2 are overlapping. The intervals are also graphically shown in Figure 40. Now the overlap is even more evident.
The degree of preference matrix and preference matrix for the ownership of trolley fleet improvement strategies are shown below.

![Final ranking ownership trolley fleet improvement strategies](image)

**Figure 40** interval range improvement strategies ownership of trolley fleet

So based on the sum of rows, for ranking we have IS3 $\succ$ IS1 $\succ$ IS2. This means that the DM prefers improvement strategy 3, which entails the buying as the ownership structure for the trolley fleet.

### 6.3.2 Results traceability and identification improvement strategies

The five improvement strategies (IS) that were designed to improve the traceability and identification of the trolley fleet and now will be evaluated using the BWM were the following:

- **IS1** Do nothing
- **IS2** RFID
- **IS3** NFC
- **IS4** Barcode printing - QR Code
- **IS5** Metal plate

\[
DP_{ij} = \begin{pmatrix} 0.5 & 0.9468 & 0.3110 \\ 0.0532 & 0.5 & 0 \\ 0.689 & 1 & 0.5 \end{pmatrix} \Rightarrow P_{ij} = \begin{pmatrix} 0 & 1 & 0 \\ 0 & 0 & 0 \\ 1 & 1 & 1 \end{pmatrix}
\]

So based on the sum of rows, for ranking we have IS3 $\succ$ IS1 $\succ$ IS2. This means that the DM prefers improvement strategy 3, which entails the buying as the ownership structure for the trolley fleet.
Figure 41 Hierarchy of criteria improvement strategies traceability and identification

In the figure above the criteria and sub-criteria are presented. These are used to evaluate the five improvement strategies. In this case it obvious that the results contain interval data, because there are five improvement strategies and five criteria. The global weights are presented in table below. Subsequently, the global weights are multiplied with the interval weights of the comparisons of the improvement strategies and the sub-criteria. Finally the lower and upper interval weights are added together into a lower and upper final weight per improvement strategy, which is shown in Table 16.

<table>
<thead>
<tr>
<th>Criteria</th>
<th>MIN</th>
<th>MAX</th>
<th>ξ</th>
<th>CR</th>
<th>#</th>
<th>Comparison between sub-criteria</th>
<th>Global Weights</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 C1: Cost/price</td>
<td>0.2072</td>
<td>0.2489</td>
<td>0.6277</td>
<td>0.2729</td>
<td>1 Purchase price</td>
<td>0.2025</td>
<td>0.2802</td>
</tr>
<tr>
<td>2 Establishment costs</td>
<td>0.2990</td>
<td>0.3412</td>
<td>0.0623</td>
<td>0.0850</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 Operating costs</td>
<td>0.1559</td>
<td>0.1822</td>
<td>0.0323</td>
<td>0.0454</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 Maintenance costs</td>
<td>0.0320</td>
<td>0.0374</td>
<td>0.0066</td>
<td>0.0093</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5 Inventory costs</td>
<td>0.2025</td>
<td>0.2802</td>
<td>0.0420</td>
<td>0.0698</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6 Conformance to specification</td>
<td>0.1825</td>
<td>0.1908</td>
<td>0.5359</td>
<td>0.1786</td>
<td>0.0623</td>
<td>0.0682</td>
<td></td>
</tr>
<tr>
<td>7 Average defect rate</td>
<td>0.1825</td>
<td>0.1908</td>
<td>0.0623</td>
<td>0.0682</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8 Sophistication</td>
<td>0.0409</td>
<td>0.0427</td>
<td>0.0140</td>
<td>0.0153</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9 Accurateness (Correctness) of inventories</td>
<td>0.2672</td>
<td>0.2794</td>
<td>0.0913</td>
<td>0.0999</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10 Performance history</td>
<td>0.0598</td>
<td>0.0626</td>
<td>0.0204</td>
<td>0.0224</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11 Accurateness (Correctness) of delivery</td>
<td>0.2336</td>
<td>0.2672</td>
<td>0.0798</td>
<td>0.0955</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 15 Comparison between sub-criteria and global weights enhancing the traceability and identification improvement strategies

<table>
<thead>
<tr>
<th>Intervals</th>
<th>Lower limit</th>
<th>Upper limit</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>IS1</td>
<td>0.1883</td>
<td>0.2592</td>
<td>0.2237</td>
</tr>
<tr>
<td>IS2</td>
<td>0.2324</td>
<td>0.3035</td>
<td>0.2679</td>
</tr>
<tr>
<td>IS3</td>
<td>0.1130</td>
<td>0.1600</td>
<td>0.1365</td>
</tr>
<tr>
<td>IS4</td>
<td>0.1237</td>
<td>0.1668</td>
<td>0.1453</td>
</tr>
<tr>
<td>IS5</td>
<td>0.2084</td>
<td>0.2900</td>
<td>0.2492</td>
</tr>
</tbody>
</table>

Table 16 Interval range traceability and identification improvement strategies

The intervals of IS1, IS2 and IS5 are overlapping. Subsequently, the intervals of IS3 and IS4 are overlapping as well, but they rank lower than the other improvement strategies. The interval ranges are visualized in Figure 42. Then it is obvious that IS1, IS2 and IS5 are overlapping and rank higher than IS3 and IS4.

![Final ranking traceability and identification improvement strategies](image)

Figure 42 Interval ranges traceability and identification improvement strategies

Due to the overlap, we need to calculate the matrix of degree of preference and the matrix of preferences to finally rank the improvement strategies, which is shown in the matrices below.
So based on the sum of rows, for ranking we have IS2 > IS5 > IS1 > IS4 > IS3. This means that the DM prefers IS2 above all the other improvement strategies, which entails the use of RFID to enhance the traceability and identification of the trolley fleet.

### 6.3.3 Results registration structure for movement and contracts improvement strategies

The three improvement strategies (IS) that were designed to improve the registration structure for movements and contracts and now will be evaluated using the BWM were the following:

- IS1 Do nothing
- IS2 Lease/SPACE
- IS3 Batch Management

In the figure above the criteria and sub-criteria are presented. These are used to evaluate the three improvement strategies. For each improvement strategy an interval is determined. If a comparison is executed with two or three criteria the weights are unique, which does not result in intervals. Although we have three improvement strategies, we have five criteria’s. Therefore, the global weights have interval data, which means that the final result contains interval data. The global weights are presented in table below. Subsequently, the global weights are
multiplied with the unique weights of the comparisons of the improvement strategies and the sub-criteria. The latter contains unique weights because there are only three improvement strategies. Finally the lower and upper interval weights are added together into a lower and upper final weight per improvement strategy, which is shown in Table 18.

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Comparison between sub-criteria</th>
<th>Global Weights</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1: Cost/price</td>
<td>Establishment costs</td>
<td>MIN</td>
</tr>
<tr>
<td></td>
<td>Operating costs</td>
<td>0.4877</td>
</tr>
<tr>
<td></td>
<td>Maintenance costs</td>
<td>0.3123</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.2000</td>
</tr>
<tr>
<td>C2: Reliability</td>
<td>Accurateness of inventories</td>
<td>0.5443</td>
</tr>
<tr>
<td></td>
<td>Correctness of delivery to stakeholders</td>
<td>0.1250</td>
</tr>
<tr>
<td></td>
<td>Correctness of trolleys in SAP</td>
<td>0.3307</td>
</tr>
<tr>
<td>C3: Ease</td>
<td>Load-unload and usage easiness and speed</td>
<td>0.0833</td>
</tr>
<tr>
<td></td>
<td>Supervision easiness</td>
<td>0.7113</td>
</tr>
<tr>
<td></td>
<td>Ease to track and trace a trolley in the operation</td>
<td>0.2053</td>
</tr>
<tr>
<td>C4: Quality</td>
<td>Operational feasibility</td>
<td>0.5348</td>
</tr>
<tr>
<td></td>
<td>Quality of order picking</td>
<td>0.2985</td>
</tr>
<tr>
<td></td>
<td>Usage of trolley fleet</td>
<td>0.1667</td>
</tr>
<tr>
<td>C5: Flexibility</td>
<td>Operational flexibility about future plans</td>
<td>0.2500</td>
</tr>
<tr>
<td></td>
<td>Flexibility about future plans</td>
<td>0.7500</td>
</tr>
</tbody>
</table>

Table 17 Comparison between sub-criteria and global weights registration alternatives

<table>
<thead>
<tr>
<th>Intervals</th>
<th>Lower limit</th>
<th>Upper limit</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>IS1</td>
<td>0.1868</td>
<td>0.2091</td>
<td><strong>0.1979</strong></td>
</tr>
<tr>
<td>IS2</td>
<td>0.2783</td>
<td>0.3081</td>
<td><strong>0.2932</strong></td>
</tr>
<tr>
<td>IS3</td>
<td>0.4933</td>
<td>0.5430</td>
<td><strong>0.5182</strong></td>
</tr>
</tbody>
</table>

Table 18 Intervals range registration alternatives

Based on the table above and Figure 44, that there is no overlap between the three improvement strategies.
Although, Table 18 and Figure 44 provided an evident ranking, the matrix of degree of preference and the matrix of preferences is created to verify the final ranking. The calculated matrices are presented below.

The sum of rows confirms the final ranking, that IS3 \( \succ \) IS2 \( \succ \) IS1. This means that the DM prefers the use of Batch Management for the registration structure of movements and contracts of the trolley fleet. In addition, the DM also prefers the use of Lease/SPACE above doing nothing at all.

6.3.4 Results communication and coordination improvement strategies
The three improvement strategies (IS) that were designed to improve the communication and coordination structure and now will be evaluated using the BWM were the following:

- IS1 Do nothing
- IS2 Embedded in organisation
- IS3 Trolley Manager
In the figure above the criteria and sub-criteria are presented. These are used to evaluate the three improvement strategies. For each improvement strategy an interval is determined. If a comparison is executed with two or three criteria the weights are unique, which does not result in intervals. Although we have three improvement strategies, we have five criteria’s. Therefore, the global weights have interval data, which means that the final result contains interval data. The global weights are presented in table below. Subsequently, the global weights are multiplied with the unique weights of the comparisons of the improvement strategies and the sub-criteria. The latter contains unique weights because there are only three improvement strategies. Finally the lower and upper interval weights are added together into a lower and upper final weight per improvement strategy, which is shown in Table 20.

<table>
<thead>
<tr>
<th>Criteria</th>
<th>MIN</th>
<th>MAX</th>
<th>$\xi$</th>
<th>CR</th>
<th>#</th>
<th>Sub-criteria</th>
<th>Comparison between sub-criteria</th>
<th>Global Weights</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1: Cost/price</td>
<td>0.3364</td>
<td>0.3817</td>
<td>0.6277</td>
<td>0.2729</td>
<td>1</td>
<td>Establishment costs</td>
<td>0.3333 0.3333 0.0000 0.0000</td>
<td>0.1121 0.1272</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Operating costs</td>
<td>0.6667 0.6667</td>
<td>0.2243 0.2545</td>
</tr>
<tr>
<td>C2: Reliability</td>
<td>0.1533</td>
<td>0.2267</td>
<td>0.6277</td>
<td>0.2729</td>
<td>2</td>
<td>Discrepancy between actual</td>
<td>0.1430 0.1448 0.2087 0.2087</td>
<td>0.0219 0.0328</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>stock levels and SAP values</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Accurateness of inventory</td>
<td>0.1430 0.1448</td>
<td>0.0219 0.0328</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Accurateness of contracts</td>
<td>0.1430 0.1448</td>
<td>0.0219 0.0328</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>overview</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Effectiveness of organisational</td>
<td>0.0799 0.0808</td>
<td>0.0122 0.0183</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>structure</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Reliability of the trolley</td>
<td>0.1430 0.1448</td>
<td>0.0219 0.0328</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>information</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Reliability of the organization</td>
<td>0.0799 0.0808</td>
<td>0.0122 0.0183</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Reliability of information</td>
<td>0.2562 0.2593</td>
<td>0.0393 0.0588</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>for decisions</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C3: Ease</td>
<td>0.1418</td>
<td>0.1609</td>
<td>0.6277</td>
<td>0.2729</td>
<td>10</td>
<td>Ease to hand-over tasks and</td>
<td>0.2000 0.2000 0.4384 0.8769</td>
<td>0.0284 0.0322</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>responsibilities</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
11 Supervision easiness 0.4877 0.4877 0.0692 0.0785 12 Transparency allocation of tasks 0.3123 0.3123 0.0443 0.0502 13 Operational feasibility 0.6667 0.6667 0.0000 0.0000 0.1405 0.1767 14 Quality of the trolley information available 0.3333 0.3333 0.0703 0.0883 15 Flexibility to take over tasks 0.1997 0.2233 0.8377 0.2792 0.0119 0.0151 16 Flexibility about future plans 0.0631 0.0706 0.0000 0.0000 0.0038 0.0048 17 Time to reach all stakeholders 0.2233 0.3055 0.0133 0.0207 18 Time to deliver overview trolley portfolio 0.4317 0.4828 0.0258 0.0327 19 Comparison between sub-criteria communication and coordination alternatives

<table>
<thead>
<tr>
<th>Intervals</th>
<th>Lower limit</th>
<th>Upper limit</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>IS1</td>
<td>0.2012</td>
<td>0.2430</td>
<td>0.2221</td>
</tr>
<tr>
<td>IS2</td>
<td>0.4880</td>
<td>0.6031</td>
<td>0.5456</td>
</tr>
<tr>
<td>IS3</td>
<td>0.2061</td>
<td>0.2616</td>
<td>0.2338</td>
</tr>
</tbody>
</table>

Table 19: Comparison between sub-criteria communication and coordination alternatives

The interval ranges are visualised in Figure 46. It can be seen that there is only an overlap between the IS1 and IS3 improvement strategies. Subsequently, IS2 out ranks the two other improvement strategies.

![Figure 46 Interval ranges communication and coordination improvement strategies](image)

Although, Table 20 and Figure 46 show the best the improvement strategy, the matrix of degree of preference and the matrix of preferences is created establish the ranking of the two other improvement strategies. The calculated matrices are presented below.

\[
DP_{ij} = \begin{pmatrix} 0.5 & 0 & 0.3792 \\ 1 & 0.5 & 1 \\ 0.6208 & 0 & 0.5 \end{pmatrix}, \quad \Rightarrow P_{ij} = \begin{pmatrix} 0 & 0 & 0 \\ 1 & 0 & 1 \\ 1 & 0 & 0 \end{pmatrix}
\]

The sum of rows shows that IS3 outranks IS1. Therefore, the final ranking of the communication and coordination improvement strategies is IS2 \(\succ\) IS3 \(\succ\) IS1. This means the
DM prefers that communication and coordination of the trolley supply chain will be embedded in the organization.

6.3.5 Results monitoring the trolley supply chain performance improvement strategies

The four improvement strategies (IS) that were designed to improve the monitoring of the performance of the trolley supply chain and now will be evaluated using the BWM were the following:

- IS1: Do nothing
- IS2: 5 KPIs
- IS3: 15 KPIs
- IS4: 25 KPIs

In the figure above the criteria and sub-criteria are presented. These are used to evaluate the five improvement strategies. In this case it obvious that the results contain interval data, because there are five improvement strategies and five criteria. The global weights are presented in table below. Subsequently, the global weights are multiplied with the interval weights of the comparisons of the improvement strategies and the sub-criteria. Finally the lower and upper interval weights are added together into a lower and upper final weight per improvement strategy, which is shown in Table 22.
Table 21 Comparison between sub-criteria and global weights performance measure alternatives

<table>
<thead>
<tr>
<th>Intervals</th>
<th>Lower limit</th>
<th>Upper limit</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>IS1</td>
<td>0.1760</td>
<td>0.2048</td>
<td>0.1904</td>
</tr>
<tr>
<td>IS2</td>
<td>0.1956</td>
<td>0.2189</td>
<td>0.2072</td>
</tr>
<tr>
<td>IS3</td>
<td>0.3320</td>
<td>0.3602</td>
<td>0.3461</td>
</tr>
<tr>
<td>IS4</td>
<td>0.2462</td>
<td>0.2662</td>
<td>0.2562</td>
</tr>
</tbody>
</table>

Table 22 Interval ranges monitoring the supply chain performance improvement strategies

As can be seen in the table above and in Figure 48 that only the intervals of IS1 and IS2 are overlapping. Improvement strategies 3 and 4 are not overlapping with any other interval range. Therefore, it can be stated that the DM prefers the IS3 above all other improvement strategies followed by IS4.

![Figure 48 Interval ranges monitoring the supply chain performance improvement strategies](image-url)
Although, Table 22 and Figure 48 show the best and second best improvement strategy, the matrix of degree of preference and the matrix of preferences is created establish the ranking of the two other improvement strategies. The calculated matrices are presented below.

\[
DP_{ij} = \begin{pmatrix}
0.5 & 0.1769 & 0 & 0 \\
0.8231 & 0.5 & 0 & 0 \\
1 & 1 & 0.5 & 1 \\
1 & 1 & 0 & 0.5
\end{pmatrix} \implies P_{ij} = \begin{pmatrix}
0 & 0 & 0 & 0 \\
1 & 0 & 0 & 0 \\
1 & 1 & 0 & 1 \\
1 & 1 & 0 & 0
\end{pmatrix}
\]

So based on the sum of rows, for ranking we have IS3 \succ IS4 \succ IS2 \succ IS1. This means the DM prefers 15 KPIs to monitor the performance of the trolley supply chain. It is also remarkable to state the improvement strategy with no KPI ranks worst. This indicates that the DM prefers the use of KPIs for the trolley supply chain.
6.4 Validation

As the BWM is a novel MCDM method validation tests are not too comprehensive. In his paper Rezaei (2014a) has developed a consistency ratio, which serves as validation check. Saaty (2005b) argues in his paper to use expert opinions for the validation of AHP models. Therefore, the results have been presented and discussed with the DM. The DM found it very interesting and useful method to select improvement strategies for the trolley supply chain.

<table>
<thead>
<tr>
<th>CR Range</th>
<th>Ownership</th>
<th>Traceability &amp; Identification</th>
<th>Registration Structure</th>
<th>Communication &amp; Coordination</th>
<th>Monitoring Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>0&lt;CR&lt;0.1</td>
<td>20.7%</td>
<td>0.0%</td>
<td>20.8%</td>
<td>10.7%</td>
<td>26.1%</td>
</tr>
<tr>
<td>0.1&lt;CR&lt;0.2</td>
<td>34.5%</td>
<td>38.7%</td>
<td>12.5%</td>
<td>7.1%</td>
<td>34.8%</td>
</tr>
<tr>
<td>0.2&lt;CR&lt;0.3</td>
<td>34.5%</td>
<td>29.0%</td>
<td>58.3%</td>
<td>71.4%</td>
<td>39.1%</td>
</tr>
<tr>
<td>CR&gt;0.3</td>
<td>10.3%</td>
<td>32.3%</td>
<td>8.3%</td>
<td>10.7%</td>
<td>0.0%</td>
</tr>
</tbody>
</table>

Table 23 Consistency ratio results for all subjects of alternatives

<table>
<thead>
<tr>
<th>CR Range</th>
<th>Ownership</th>
<th>Traceability &amp; Identification</th>
<th>Registration Structure</th>
<th>Communication &amp; Coordination</th>
<th>Monitoring Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>MIN</td>
<td>0.0000</td>
<td>0.1058</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.0000</td>
</tr>
<tr>
<td>MAX</td>
<td>0.6342</td>
<td>0.5611</td>
<td>0.8769</td>
<td>0.8769</td>
<td>0.2792</td>
</tr>
<tr>
<td>MEAN</td>
<td>0.2039</td>
<td>0.2573</td>
<td>0.2255</td>
<td>0.2649</td>
<td>0.1733</td>
</tr>
<tr>
<td>MEDIAN</td>
<td>0.1994</td>
<td>0.2729</td>
<td>0.2173</td>
<td>0.2681</td>
<td>0.1994</td>
</tr>
<tr>
<td>ST. DEV.</td>
<td>0.1483</td>
<td>0.1099</td>
<td>0.1713</td>
<td>0.1567</td>
<td>0.0854</td>
</tr>
</tbody>
</table>

Table 24 Minimum, maximum, mean, median and standard deviation of all consistency ratios per subject of alternatives

In Table 23 the CR results of all the comparisons are presented. Only for the traceability and identification ISs the CR 32.3% of the CR are above 0.3. For the rest of the CRs they are good. Table 24 shows the minimum, maximum, mean, median and standard deviation of all consistency ratios per decision area of improvement strategies. The highest CR is for both Registration structure and Communication & Coordination improvement strategies 0.8769, while the mean of both CRs is respectively good 0.2255 and 0.2649 with respectively low a standard deviation of 0.1713 and 0.1567. Therefore, we can conclude that the application of the BWM has passed the tests of validation.

6.5 Preliminary conclusion

In this chapter we have evaluated the designed improvement strategies. We used a novel multi-criteria decision making method: Best-Worst Method (BWM). We have used this method because it requires less comparison data than other MCDM methods and the BWM provides more reliable results. We had selected five decision areas for improvement and for each decision area we designed improvement strategies. The five decision areas are presented in Table 25 in the first column, the second column contains the best improvement strategy for that decision area.

<table>
<thead>
<tr>
<th>Decision areas</th>
<th>Best improvement strategy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ownership of trolley fleet</td>
<td>IS3 – Buying</td>
</tr>
<tr>
<td>Enhancing traceability and identification</td>
<td>IS2 – RFID</td>
</tr>
<tr>
<td>Registration structure for movements and contracts</td>
<td>IS3 – Batch Management</td>
</tr>
<tr>
<td>Communication and coordination structure</td>
<td>IS2 – Embedded in the organisation</td>
</tr>
</tbody>
</table>
Monitoring the performance of trolley supply chain  IS3 – 15 KPIs

Table 25 Best improvement strategy per decision area for improvement

Now that we have selected the best improvement strategy per decision area we can make recommendations on what the next steps are. In the next chapter recommendation for the implementation of the selected improvement strategies is provided.
7 Advice on implementation

In the previous chapter we have evaluated and selected the best improvement strategy per decision area. The table below shows the results of the evaluation in the previous chapter. This chapter describes the next steps to implement the chosen improvement strategies.

<table>
<thead>
<tr>
<th>Decision areas</th>
<th>Best improvement strategy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ownership of trolley fleet</td>
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<tr>
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<td>IS3 – Batch Management</td>
</tr>
<tr>
<td>Communication and coordination structure</td>
<td>IS2 – Embedded in the organisation</td>
</tr>
<tr>
<td>Monitoring the performance of trolley supply chain</td>
<td>IS3 – 15 KPIs</td>
</tr>
</tbody>
</table>

Table 26 Best improvement strategy per decision area for improvement

For all improvement strategies applies that support of organisation has to be created. In the case of the ownership of the trolley fleet and the traceability and identification decision area this is even more important, because the impact of these strategies is strategically-oriented. Furthermore, the impact of the latter two and the registration structure impacts the way the organisation is working. In addition, if there is no support it is almost impossible to successful implement the improvement strategies.

The next steps in implementing the chosen improvement strategy differ per decision area of course. The implementation of financing improvement strategy – buying – is not going to be easy, because the financial board of KLM needs to agree on this decision. They make in the end the final decision to buy or lease, because they oversee the entire financial position of KLM. An important decision criteria for the financial board is the cash flow of KLM. In case there is a low cash flow, then the financial board decides to lease the equipment. In case there is a high cash flow, then they might be open for NSM suggestions, such as buying. Therefore, the next in the realisation of the buying improvement strategy is to make a comprehensive business case. In which not only the financial consequences are discussed, but also the operational consequences. Thereby, must be realised that the financial board might reject the buying alternative and opts for leasing. Therefore, it is recommended to be prepared that the financial board decides to the lease the trolley fleet.

The next steps for the implementation of RFID as technology enhancing the traceability and identification of the trolley fleet are setting up a project team. The project team should consist of people of NSM, KCS and RFID experts. In addition, the project team should learn from other RFID experiences within KLM. The cargo division and the baggage handling already uses RFID. The project team should also contact partners of the SkyTeam, AirFrance, Etihad and Delta Airlines to learn from their trolley supply chain. For a successful implementation of RFID it essential to take a lot of care for the design process. This entails the technical design, but more important the organisational design needs be adjusted. Who is going analyse the data, and what will be the consequence if for example an outstation has too many trolleys and does not say anything. Therefore, contracts with outstations has to be adjusted. Furthermore, the ownership of the RFID data needs to be established.
Important milestone in the implementation process of RFID:

- Formation of project team with business analysts, KCS Centrum and Warehouse, Project Manager, and a Supply Chain Specialists.
- Commitment and approval of the management team.
- Design technical specifications
- Redesign organisational structure
- Learn from other KLM division and SkyTeam partners
- Pilot
- After a successful pilot, roll out RFID to the entire trolley operation

The next steps for the implementation of batch management as registration system in SAP are also setting up a project team consisting of NSM and KCS personnel. In order for batch management to work the RFID project has to be installed, because a trolley has to be identified by batch number. In addition, the storage location of the KCS Warehouse has to be adjusted and be prepared for batch management storage of trolleys. It is recommended for the batch management registration to combine it with the introduction of the new trolley in the end of 2015. At that moment new article numbers in SAP must be created anyways. It is very costly to enable batch management on an already active article number.

- Beginning of December 2014 commitment from management team for Batch Management.
- After commitment of MT formation of a project team with a Project Manager, KCS Warehouse representative, business analysts, Contract Management and Central Planning.
- Beginning of February commitment agreement of all stakeholders.
- Before the summer all the preparations in SAP are executed, because the first Atlas trolleys will arrive in September/October 2015.

The next steps for the implementation of communication and coordination is a meeting with the relevant NSM and KCS personnel to discuss everyone’s tasks and responsibilities. It is very important to first establish a clear list of all the tasks and responsibilities regarding the trolley supply chain communication and coordination. The determined tasks and responsibilities should be well documented and communicated to all stakeholders. It is advisable that the ‘Manager Operation’ and ‘Manager Regie’ both attend this at this meeting to ensure that the every hurdle is overcome. Important aspects that need to be divided:

- Owner the trolley contract overview and responsibly for adjustments.
- Monitoring the inventory levels and movements in SAP. Assuring accurate inventories and the administration of the plant REPA in SAP.
- Responsible for the shoot-out of trolleys that return to the lease company.
- Storage of repair certificates. These certificates need to be stored for three years.
- Place orders for new trolleys.
- Create/change or block trolley article numbers in SAP
• Communication with …
  o Area Planning for which trolleys they can send to the outstations
  o KCS Centrum which trolleys they have to order.
  o KCS Warehouse which article numbers need to be blocked
  o Checking that the above actors also do what they are instructed.
• Responsible for defining the trolley need.
• Initiating decisions regarding end of lease agreement.

The next steps for the design of the 15 KPIs is to set up a workshop to determine the exact KPIs. Then, the way of measuring and reporting needs to be determined. Finally, the actual measuring of the KPIs needs to be put in place. It is recommended for the design of KPIs to support the workshop with relevant literature to find the optimal KPIs. The implementation of the above improvement strategies should be reflected in the KPIs. Data from RFID can be an input for the KPIs.
8 Conclusion & Recommendations & Reflection

This chapter describes the conclusion, recommendations, reflection and suggestions for future research. In the conclusion we will first answer the research questions. Subsequently, we draw the final conclusion with respect to the main research question. In the reflection part the researcher will reflect on all the aspects of the research project and highlight the limitations of the research. We end this chapter with suggestions for future research.

8.1 Conclusion

First the conclusion with respect to the research questions are described and subsequently the final conclusion regarding the main research question is described.

8.1.1 Conclusions with respect to the research questions

In this section the research questions are answered. The research questions support to answer the main research question, which is answered in the subsequent section.

What does the closed-loop trolley supply chain of KLM entail in terms of flows and nodes?

In section 2.2 the entire trolley supply chain with all its processes is described in detail. The central hub of the trolley supply chain is KCS Centrum from here the trolleys go to an outstation and back. The KCS Warehouse is the central warehouse for all the trolleys and it is located 6 kilometres from KCS Centrum. The NSM department is located at Schiphol-Oost, which is 3.8 kilometres from the KCS Warehouse. The NSM is responsible for the all the decisions regarding the trolley fleet. They monitor the stock levels here at Schiphol, but also the stock levels of the outstation.

The outstation, which are foreign caterers, have a single set of trolley, which are between 20 and 60 trolleys, at their disposal. Therefore, the trolley supply chain has besides the KCS Warehouse 69 small trolley inventories around the world.

All the physical movement of trolleys are registered in SAP – the ERP system of KLM. Therefore, it is very important that all movements are registered in order to maintain insight. The inflow of trolleys is provided by the manufacturer, then the trolleys are used in the operation, finally the trolleys leave the system. The outflow or shoot-out of trolleys is a very important process, because the trolleys are currently leased, the trolleys have to be returned to the lease company at the end of the contract. Therefore, a specific trolleys needs to be find and returned.

How did the literature contribute in solving the problem?

The literature review showed that there is nothing scientific written about equipment in the airline catering industry. The only available direct literature is a master thesis report from Van Kleef (2012) his report focusses on the Redesign of the Control Model of the Catering Distribution Network of KLM. In addition, the trade association of airlines IATA has published an interesting business case on the use of RFID for track and trace of catering trolleys.
The literature review showed that trolleys can be allocated in the category of Reusable Article and to be more specific into Returnable Transportation Items (RTIs). The literature showed that there are general two types of supply chains regarding RTIs open-loop or pooling supply chains and closed-loop or exchange supply chains. The catering supply chain of KLM can be allocated in a closed-loop supply chain, because a trolley leaves its homebase Schiphol, arrives at an outstation and then returns to the homebase. The literature showed that common problems with RTIs are lack of visibility, significant investments and fleet shrinkage. All three problems also apply on the KLM trolley supply chain. However, the trolley supply chain is a special case of a closed-loop supply chain, because the return to homebase is already arranged via the home flight. Therefore, you assume that all the trolleys in the end will return to the homebase. Unfortunately this is not always the case.

Carrasco-Gallego & Ponce-Cueto (2010) have made recommendations on the management aspects of reusable articles in Closed-Loop Supply Chains. The first one is very interesting for this case, which is define the fleet size dimension.

In order to evaluate the improvement strategies the literature provided a method to rank the improvement strategies based on their sub-criteria. The establishment of the criteria and sub-criteria is done based on the literature. As the sub-criteria were so diverse, the need for a Multi-Criteria Decision Making method became evident. AHP, fuzzy AHP and BWM showed to be suitable methods to find the best improvement strategy, because they use pair-wise comparison judgements. In addition, it was not possible to quantify all the sub-criteria this limited the amount of MCDMs. The most suitable ranking method was found to be the novel BWM, because it uses less pair-wise comparisons than the other two methods and it leads to more consistent comparisons. The latter means that it produces more reliable results.

What are appropriate improvement strategies to improve the current decision-making process?

The conclusion can be drawn that it was impossible to make any decision regarding the trolley fleet. Especially decisions regarding the end of the lease agreement, even while the contracts were already ended KLM did had made any decision about returning the trolleys or keeping them. This was mainly caused by the lack of visibility and partly by a manufacturing defect in a batch full size trolleys. Due to the manufacturing defect NSM waited on a plan to repair the batch.

The following issues have been identified for faltering the decision-making process:

- The departure of key staff. The involved Project Manager and Buyer moved to another role within KLM. The transfer of trolley knowledge has failed. Furthermore, nobody in the NSM organisation dared to tackle the trolley project, because you can only fail was the general believe.
- The inadequate registration of trolley movements and contracts. Not all the trolley movements are registered in SAP. Therefore, the inventory level at the repair company is not known. The contract of each trolley batch is not registered in SAP. There are some printed overviews in circulation but it is not up to date.
• Lack of communication and coordination throughout the entire trolley supply chain. Trolleys that were blocked for usage and were supposed to return to the lease company were used to send catering products to outstations. In addition, KCS Centrum had no up-to-date trolley fleet information. Therefore, KCS Centrum ordered the oldest trolleys while the newest trolleys were still in the packing.
• The control of the 69 outstations is an issue, due to faults in the loading it is possible for outstation to hoard equipment. There is a presumption of trolley hoarding at outstations.

As we have identified the issues that falter the decision-making process the design of improvement strategies starts. There is concluded that the repair flow of trolleys is not registered in SAP. We can conclude that a Portal access for Van Riemsdijk (VRR) is at the moment the best method to register the flow of damaged and repaired trolleys. The Portal access solution is supported by all the involved stakeholders. The support was established in a meeting initiated by the researcher. In that same meeting we emphasized the importance of accurate trolley inventory levels in SAP.

It should be noted that VRR currently registers the inflow of damaged trolleys. This situation is not desirable, because VRR is an external partner in the trolley supply chain. Unfortunately KCS Centrum is at the moment not capable of registering the flow of damaged trolleys to VRR. In the past (5 – 7 years ago) KCS Centrum did register the flow of damaged trolleys, but there were problems with every shipment. Therefore, KLM stopped registering the repair flow.

Furthermore, we can conclude that the overview of lease contracts on page X enabled the decision-making process regarding the return of leased trolleys. The overview is created by interviewing former staff and a desk research of internal documents and invoices. In addition, we assured accurate inventory levels in SAP.

Subsequently, we can conclude that counting the entire trolley fleet at KCS Centrum really supported the investment decision for new trolleys. The counting results gave KLM an insight in how many trolleys are actually in the operation. The counting results supported the theoretical calculation of the order size.

Furthermore, we conclude that the outstations have more trolleys in their inventories than supposed. The outstations had to count their entire inventory. The results shown in section 2.2.4 indicate that the outstations have approximately 34% more trolleys in their inventory than supposed. That’s about 1000 trolleys, which is worth around €500,000.-.

What are appropriate improvement strategies to improve the performance of the trolley supply chain in the future?

We can conclude that there are five more decision areas which can further improve the performance of the trolley supply chain. Three of them focus on increasing the visibility of the trolley supply chain, one focusses on improving the ownership structure (cost reduction) of the trolley fleet, and the last focusses on continuously monitoring the performance of the trolley
supply chain and thereby ensuring the continuity of the trolley supply chain, which is the main objective of NSM.

For each decision area we have designed several improvement strategies, which are presented in Table 27. We have designed three appropriate improvement strategies for the ownership structure of the trolley fleet. That are buying, leasing and outsourcing.

<table>
<thead>
<tr>
<th>DECISION AREAS</th>
<th>IS1</th>
<th>IS2</th>
<th>IS3</th>
<th>IS4</th>
<th>IS5</th>
<th>FOCUS</th>
</tr>
</thead>
<tbody>
<tr>
<td>OWNERSHIP</td>
<td>Outsource</td>
<td>Leasing</td>
<td>Buying</td>
<td></td>
<td></td>
<td>Cost reduction</td>
</tr>
<tr>
<td></td>
<td>everything</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Visibility</td>
</tr>
<tr>
<td></td>
<td>Do nothing</td>
<td>RFID</td>
<td>NFC</td>
<td>Barcode</td>
<td>Metal plate</td>
<td>Visibility</td>
</tr>
<tr>
<td>TRACEABILITY &amp; IDENTIFICATION</td>
<td>Do nothing</td>
<td>Lease/SPACE</td>
<td>Batch Management</td>
<td></td>
<td></td>
<td>Visibility</td>
</tr>
<tr>
<td>REGISTRATION</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Visibility</td>
</tr>
<tr>
<td>STRUCTURE</td>
<td>Do Nothing</td>
<td>Embedded in organisation</td>
<td>Trolley Manager</td>
<td></td>
<td></td>
<td>Visibility</td>
</tr>
<tr>
<td>COMMUNICATION &amp; COORDINATION</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Visibility</td>
</tr>
<tr>
<td>PERFORMANCE MEASURES</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Performance</td>
</tr>
<tr>
<td></td>
<td>Do Nothing</td>
<td>5 KPIs</td>
<td>15 KPIs</td>
<td>25 KPIs</td>
<td></td>
<td>Performance</td>
</tr>
</tbody>
</table>

We can conclude that the traceability and identification of a trolley can be enhanced by RFID, NFC, Barcodes and metal plates. RFID is the most advanced technology, which entails the most potential benefits and risks. A metal plate on the front or a barcode is much cheaper, but provides less benefits.

Furthermore, we can conclude that there are two appropriate improvement strategies for the registration structure of trolley movements and contracts namely Lease/SPACE and Batch Management. Lease/SPACE is developed by the researcher and a KLM Supply Chain Specialist. Batch Management is recommended by two business analysts, who have a large SAP knowledge.

The communication & coordination structure also has been identified to be further improved. We can conclude that there are two improvement strategies namely embed the tasks and responsibilities in the organisation or hire a trolley manager who is responsible for all the managerial aspects regarding the trolley fleet.

Finally, we can conclude that KLM values the use of KPI instead of other performance measures. Therefore, we have designed three sets of KPIs that differ in size. The largest set contains the most detailed information, but requires more measurements and it might become cluttered. The set with the least amount of KPIs contains only the most important KPIs, this is called the executive dashboard.

What is the scientific, managerial and societal contribution of this research?

Scientific contribution

The scientific contribution of this research is captured in applying a novel multi-criteria decision making method – The Best Worst Method by Rezaei (2014a) – for selecting improvement strategies that optimize the performance of the trolley supply chain. Furthermore, we can conclude that the BWM is a useful MCDM method.
The literature review showed that there has not been writing about trolley management in the airline catering industry. This research also provides a scientific contribution on catering trolley management in the airline industry. In the current literature there has been writing about other examples of closed-loop supply chains. This research provides another example of closed-loop supply chains and its characteristics and issues. In addition, it provides improvement strategies to improve the overall performance of the closed-loop supply chain.

Furthermore, the criteria and sub-criteria for the trolley supply chain that are selected using the scientific literature are a scientific contribution. There has nothing yet been written on criteria and sub-criteria in the airline catering industry.

**Managerial contribution**

The managerial contribution relates to the contribution of this research for KLM. KLM contributes by gaining insight and control over their trolley supply chain. To be more specific they will have knowledge about the current fleet of trolleys that is in their loop. In addition, the registration of all flows is no implemented in SAP. The knowledge provided by this research will also enabled the decision making concerning the procurement of new equipment which will enter the trolley fleet in the end of 2015. Furthermore, KLM receives recommendations for improving their current trolley supply chain in order to maintain the insight and control that is provided by this research.

Furthermore, we have provided KLM a Multi-Criteria Decision Making method that is easy in use and enables them to select a best alternative. This is useful in case there is no obvious best alternative. This is not only restricted to decision regarding the trolley fleet, but it can also be used for decision regarding the entire catering product portfolio.

**Societal contribution**

The societal contribution is captured in the fact that KLM at the moment has no insight in their current trolley fleet. This research contributes to increase the insight and control over the trolley fleet, which is a prerequisite for other measures such as abandonment of the in-balance principle, to reduce the inflight weight and waste. The societal relevance is captured in the reduction of the inflight weight and waste, because this will reduce the fuel consumption which is beneficial for the society.

Furthermore, increasing the insight and control might lead to reducing the trolley fleet costs, which in the end is beneficial for the passenger.

**8.1.2 Final conclusions regarding the main research question**

The main research was formulated as follows:

*What are the best improvements strategies that enable the current trolley decision-making process and improve the performance of the closed-loop trolley supply chain at Cabin Inflight Management, taking into account that the proposed improvement strategies must meet KLM’s criteria cost, reliability, quality, and flexibility?*
The best improvement strategies that enabled the current decision-making process and have been implemented are the following:

- Registration of the repair loop via Van Riemsdijk. The Portal access for Van Riemsdijk.
- Overview of all the trolley procurement contracts since 2007.
- Counting the trolley inventories at KCS Warehouse and the outstations.
- Counting all the trolleys at KCS Centrum for three weeks.

The improvement strategies listed above enabled the current decision-making process at Cabin Inflight Management. CIM was able to make decisions regarding the return of leased trolleys and the procurement of new trolley fleet. All these improvement strategies were developed in close cooperation with CIM and therefore the improvement strategies were supported by all the stakeholders.

We can conclude that there are five areas which can improve the performance of the trolley supply chain. For each decision area we have developed multiple improvement strategies. In order to select the best improvement strategy per area we developed criteria and sub-criteria to evaluate the improvement strategies. Subsequently, we used a novel MCDM method – The Best-Worst Method – to select the best improvement strategy per decision area. The result is that

We conclude that the best improvement strategies are buying trolleys, use RFID technology to enhance traceability and identification, use Batch Management for the registration of trolley movements and contracts, embed in the organisation the task and responsibilities for the communication and coordination of the trolley supply chain, and define a set of 15 KPIs to monitor continuously the performance of the trolley supply chain. The best improvement strategies are depicted in the table below.

<table>
<thead>
<tr>
<th>Decision areas</th>
<th>Best improvement strategy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ownership of trolley fleet</td>
<td>IS3 – Buying</td>
</tr>
<tr>
<td>Enhancing traceability and identification</td>
<td>IS2 – RFID</td>
</tr>
<tr>
<td>Registration structure for movements and contracts</td>
<td>IS3 – Batch Management</td>
</tr>
<tr>
<td>Communication and coordination structure</td>
<td>IS2 – Embedded in the organisation</td>
</tr>
<tr>
<td>Monitoring the performance of trolley supply chain</td>
<td>IS3 – 15 KPIs</td>
</tr>
</tbody>
</table>

Table 28 Best improvement strategy per decision area

8.2 Recommendations
This part provides recommendations for KLM on the already implemented improvement strategies, and the five decision areas for which we have selected the best improvement strategy.

8.2.1 Recommendations regarding implemented improvement strategies
This research increased the visibility of the trolley supply chain to such level that it stopped the faltering of the trolley decision-making process. Therefore, it is recommended to take the following points into account:
• Keep the overview of lease contracts updated. This is also part of the communication and coordination structure, but give some in the NSM organisation the responsibilities over the contracts overview. Communicate this to all stakeholders, that in case there are adjustments the person responsible can update the overview.

• Train KCS Centrum and KCS Warehouse staff to recognize the different types of trolleys. This will prevent wrong entries in SAP. The KCS Centrum staff entails the planning department and the staff responsible for the assembly of the damaged trolleys. The KCS Warehouse staff entails the persons who are responsible for the receiving and storing of trolleys.

• In the current solution for registering the repair flows the external party Van Riemsdijk registers the inflow. This means that there is no control over his entries. There no signals that VRR is adjusting the entries, but KLM would like to be in control. Therefore, it is recommended to train KCS Centrum personnel, but more important to prepare the SAP that KCS Centrum can create an order for damaged trolleys to VRR. In contrast the registering process is now working so should we really change process and except the fact that we can’t control the outflow of damaged trolleys?

• A major part of the visibility of the trolley supply chain is determined by accurate trolley movements and so inventory levels in SAP. Therefore, it is highly recommended for the Planning department of NSM to closely monitor the movements of trolleys and check if outstanding orders are taken. If outstanding orders are not taken and the trolleys did enter the KCS Warehouse the inventory level is not correct any longer.

• The inventory levels of the outstations are an important determinant of the trolley supply chain. Therefore, it is recommended to let the outstations count their trolley stock every month. Note that KCS Centrum has to count the inventory of all catering products for China Southern every two weeks. This can prevent the hoarding of trolleys and other catering products.

• Currently, the cooperation on operational level between the NSM and KCS Centrum is minimal. In the researchers opinion it is recommended that the NSM and KCS cooperate more closely. NSM is owner of the trolley fleet and contains all the knowledge, while KCS Centum is the operator. Knowledge could be exchanged prior to flight schedules changes, which occur every half year. In the current situation NSM defines the trolley need, a cooperation with KCS Centrum might optimize the trolley need.

• It is recommended for the management team to create an environment where the staff does not hesitate to be in charge of the trolley fleet. The current staff does not like to be responsible for the trolley project, because it is complicated and it is almost impossible to do well.

• It is recommended to create the awareness that visibility depends mostly on the registration of actions by personnel. This means that you can have such a good process and registration system, the success depends on the entry of the personnel. Therefore, it is recommended for the management team to create this awareness otherwise every solution will be a failure. Therefore, it is recommended to register in SAP all the trolleys.
that are returned to the lease company. The researcher has initiated the registration, but it is highly recommended to keep registering it.

- It is recommended to involve the KCS Centrum employees, who are working on the floor, in the design process for new trolleys. I noticed that many employees are working over 10 years on the work floor. These persons have a large knowledge about what good characteristics are for a trolley, because they handle every day hundreds of trolleys.

### 8.2.2 Recommendations regarding the ownership of the trolley fleet

For the implementation of the improvement strategy buying of the trolley fleet it is recommended to have very solid business case. At the moment this is already required, but this could be extended with the advantages of the buying instead of leasing or outsourcing. The final decision regarding the ownership structure of the trolley fleet is determined by the financial board. Therefore, it is recommended to extend the business case with the operational and other benefits of buying the trolley fleet.

### 8.2.3 Recommendations regarding the traceability and identification

It is recommended for NSM to gain commitment of the management team in order to successful implement RFID. If the management team is not committed, the realization will probably not succeed.

The commitment of the management team can be achieved by devolving a solid business case. Therefore, it is recommended to assign a project team with the goal to design a very comprehensive business case. It is highly recommended to take a deeper look in the potential obstacles of RFID in the supply chain, many of which can be found in section 4.3.1.

It is recommended to make use of the RFID opportunity to have a critical look at the organisational structure of NSM. The management of the RFID technology needs to be incorporated in the organisational structure, because who is going to analyse the data for example? In addition, the Arla Foods example showed that reduced attention on RFID data reduced immediately the benefits of RFID.

Furthermore, it is recommended to rely on already available hardware and software. This to prevent excessive development costs and the failure risk. If you decide to develop your own software it is a risk that you make the software too comprehensive, because you like to measure everything and you want to be flexible to future developments. Therefore, it is recommended to use already proven RFID software and hardware. Contact your partners in the SkyTeam and learn from their trolley supply chain. In addition, keep it simple that’s already complex enough.

It is also recommended to revise the contract with outstation when RFID is used, because then it is possible to track each trolley and in case an outstation is hoarding it gets a fine or there is an incentive to return excess trolleys.
8.2.4 Recommendations regarding the registration of trolley movements and contracts

It is recommended for the batch management registration to combine it with the introduction of the new trolley in the end of 2015. At that moment new article numbers in SAP must be created anyways. It is very costly to enable batch management on an already active article number. In addition, start very early in getting commitment of KCS Warehouse, because they have to adjust their storage plan.

In first instance it is recommended to gain the support of the management of KCS Warehouse, because the implementation of Batch Management affects heavily their operation. KCS Centrum has to adjust their inventory plan, because the trolleys will be stored based on their batch number and not on the more general article number. Therefore, it is recommended to lay out a solid implementation plan.

Furthermore, it is recommended to assess if Batch Management is only implemented at KCS Warehouse, but also at the outstations and at Van Riemsdijk. It is recommended that Van Riemsdijk also will use Batch Management, because they can scrap trolleys. In the researcher opinion there is no need for the outstations to use BM, because the inventories are so small and will they do it correctly remains the question.

Finally it is recommended to only implement BM for new article numbers, because if you would like to apply BM on existing article number (in SAP) then it’s very expensive. For new article numbers it is free.

8.2.5 Recommendations regarding the communications and coordination structure

For embedding the communication and coordination plan it is recommended to embed the tasks and responsibility in the organisation as soon as possible. In addition, it is recommended that the ‘Manager Operation’ and ‘Manager Regie’ both attend this at this meeting to ensure that the every hurdle is overcome.

It is recommended to embed the tasks and responsibilities in the following four functions:

- Central Planner, who is responsible for the trolleys.
- Contract Manager, who is responsible for the contracts with the lease company, repair company, manufacturer and KCS.
- Supply Chain Specialist, who is responsible for calculating the demand for trolleys and is responsible for the reverse logistic activities.
- Project Buyer, who actually procures the trolleys.

8.2.6 Recommendations regarding the monitoring of the trolley supply chain performance

It is recommended to use for example to reflect the data from the RFID and Batch Management in the yet to be established KPIs.
Furthermore, KPIs are a nice way to reflect the performance of the trolley supply chain, but it is recommended to once in a while work along in the operation to really get the ins and outs. In addition, there is a lot to learn from working along in the operation.

Furthermore, it is recommended to take the time for the establishment of the KPIs and align the KPIs with the CIM strategy, because if there is a misalignment then the management steers on the wrong KPIs. In addition, it is recommended to involve all kind of NSM staff in the establishment, because KPIs might reflect the work they do. Involving them in the beginning will justify it later to steer on the KPIs.

In addition, it is recommended for the design of KPIs to support the workshop with relevant literature to find the optimal KPIs.

8.3 Reflection
This section reflects on the research approach, the research results and includes a personal reflection.

8.3.1 Reflection on the research approach
In the research approach we exclude improving the performance of outstations, while they are an important part of the trolley supply chain. The fact that the outstations are external partners and they are located outside Europe makes it a very complex problem. Therefore, the outstations still remain part of the unobservable part of the trolley supply chain. In this research we have asked the outstations to count their entire trolley inventory. Not all the outstations had submitted the counting’s therefore we extrapolated the results. Therefore, the results presented in section 2.2.4 might not be over or underestimated.

In this research we have only used one MCDM method to rank the improvement strategies. For scientific reasons it would be better to also use another MCDM model such as (fuzzy) AHP, this to confirm that the BWM leads to more consistent data. In addition, more participants in the BWM might also increase the credibility of the results. For example if every NSM manager made the BWM on his own, the results can be used to finalise important decisions. Every persons can make different accents in the BWM.

We have disregard the interdependency between the improvement strategy decision areas. This allowed us the find the best improvement strategy per decision area and did we not have generate many scenarios and combine them. This is a limitation of this research.

Furthermore we disregard other performance measures than KPIs, while there might be other metrics that could useful. For example, the methodology proposed by Nukala and Gupta (2007) especially designed for closed-loop supply chains might be very interesting to apply here. This might be a missed opportunity.

8.3.2 Reflection on the research results
In general the results of the Best-Worst MCDM method were satisfying the client. Looking at the latest news regarding the financial position of KLM the hard times are not yet over. Therefore, you can assume that the financial position of KLM will not be much better the
coming years and that the motto ‘cash is king’ remains. Therefore, it might not be possible to
convince the financial board to buy instead of lease or outsource the trolley fleet. The NSM
should be aware of this situation, and prepare for all kind of scenarios and the commissioning
of the processes.

You could ask yourself do the benefits from RFID compensate the financial and organisational
investments. RFID is a very sophisticated technique and it perfectly fits in the paradigm of the
Internet of Things (IoT) in which all products are connected with each other. Nowadays
everything is connected companies like XeroX, Siemens and Samsung are devoting many
resources in creating products that can communicate with each other and therefore support the
consumer in satisfying it needs. For example, the refrigerator that ‘sees’ that the milk is empty
and therefore orders new milk at the supermarket which delivers it at a time when you are at
home, because the refrigerator knows your agenda. So from the Internet of Things perspective
RFID is a must have in every supply chain, but the airline catering industry is not sophisticated.
The airline catering industry is the opposite. You as a consumer can’t order what you want, we
as airline define your meal choice and quantity. And do we really need RFID, because is closely
monitoring of the outstations, KCS Warehouse and KCS Centrum not enough? The
implementation requires a lot of resources in the form of capital, staff and commitment. Might
it be better to first control current processes and then propose the use of RFID technology? As
stated before RFID has many potential benefits, but it also requires many resources. So is the
NSM able to realise the benefits?

In general will NSM really implement the selected improvement strategies or will they switch
to the order of the day. Maybe therefore small improvements like embedding communication
& coordination structure are much effective then recommending huge changes such as RFID.
In addition, the smaller improvements enabled the decision-making process and might that be
the most important thing for managers?

8.3.3 Personal reflection
In the beginning of my graduation internship when I told that my subject was trolley
optimization colleagues at KLM said sarcastically: “Good luck”. This made me realize that
it was a topic that nobody dared to touch. This didn’t scared me, because I thought it cannot be
that difficult. Now looking back it was very interesting, and too fully understand the trolley
supply chain and its processes it takes time. After five months it became clear how everything
was working with the processes, but also with SAP and understand what all the SAP data
meant. This is one the reasons why I didn’t finish my master thesis project in time.

Executing the research project in a graduation internship was very instructive for me. This was
my first time a conducted an internship in a large company. Instructive because it made realize
what kind of job I want to pursue after I’m graduated. I really liked the combination of working
in the catering factory and linking the results I have seen there to the management team.
Through my trolley fleet knowledge I was asked to provide input on decision making issues as
the procurement of 14.000 trolleys and what to do at the end of the lease agreement. The
overview of lease contracts which I made really helped the decision making process.
In the beginning I struggled to combine the question of KLM, which is rather practice-oriented, with scientific-oriented purpose of a master thesis. This was also caused because in the beginning I could not oversee the complexity of the trolley supply chain, which complicated the alignment of the goals of KLM and the TU Delft.

Another point of reflection is my time management. I noticed that when I had strict deadlines I was working towards those deadlines and that work I produced then was way more than when there were no deadlines. This is also one of the reasons that I didn’t finish my master thesis project in time. For me it is essential in the future that I should be setting my own deadlines to get work done in time.

KLM gave me a lot of responsibility and freedom during my internship to set up my research, for which I’m grateful. For example I have organized a meeting and workshop to register the repair loop in SAP. In this meeting the people from KCS and KLM were presented. I thought it was a very nice experience, but also strange. Strange because I’m officially an intern who is still in university and those people are already working years at KLM. I had prepared a presentation for this meeting and discussed the topic with some attendees. The results was overall a good meeting. The only thing that could be improved was that I expected something from someone, and I assumed that he would do that, but he did not. Although it sounds as a cliché, but never assume things but be sure and ask them. Otherwise I might become an uncomfortable moment.

My first presentation for the management team of KLM I totally underestimated. The structure and content was totally wrong. Bastiaan really helped me to structure my presentations and tell the right story, and to beware of the audience. Although this are simple and normal rules for presentations, I tend sometimes forget to take a step back from the subject. I’m too caught up in the subject that I assume that everyone has at the same knowledge level. Therefore, I should realize to always realize who my audience is and better assume that they do not know anything.

8.4 Suggestions for future research
Future research is divided into two areas. The first area of future research relates to the trolley supply chain of KLM. The area of future research focusses on the Best-Worst Method.

As already mentioned in the recommendations the implementation of RFID must be further developed. The research on RFID implementation should focusses on the technical, financial, organisational, and process aspect. The technical aspect encompasses the choice for hardware, software and locational design. The financial aspect entails a detailed cost benefit analysis. The organisational aspect entails who is going to be responsible for analysing the data. In addition, who will be the owner of the data? The process aspect entails what the steps of the implementation of RFID will encompass. This means when to involve certain stakeholder, when to start testing the technology, etc.

Another area for future research within KLM is how to handle the work floor inventory at the outstations. At the moment KLM has no insight in the work floor inventory. KLM does have insight in the normal inventory, but the most of the trolleys are located on the work floor. The complexity of the problem is captured in the fact that there are 69 outstations worldwide with
cultural differences, the wide variety of trolley article numbers in SAP, the lack of knowledge on the trolley fleet at outstations, and the lack of urgency of outstations because it is only flight a day.

Another interesting topic for future research is the implementation process of the entire new trolley fleet in 2015. At this moment the trolley fleet has the KSSU standard (size dimensions), in the 2015 KLM will start using the Atlas standard. Because of this the entire trolley will be replaced. During approximately half a year both standards will be in operation. Although the differences between the two standards are minimal – see Appendix H – the trolleys cannot be exchanged. In addition, the 14,000 new trolleys will arrive almost all in once. Therefore, the process of the Atlas introduction needs to be designed and management.

In this research we used a Delphi method derive the pair-wise comparisons judgements. Future research could focus on gaining more participants and so collecting more reliable data.
Bibliography


Appendices

APPENDIX A – List of persons interviewed
The following people have been interviewed:

- Manager NSM
- Manager Operations
- Manager Contract Management outstations
- Buyer of trolleys
- Contract Manager lease company
- Former Project Manager trolleys
- Supply Chain Specialists
- Manager Planning
- Central Planner
- Area Planner
- Business Analysts
- SAP specialists
- Operational Manager Warehouse
- Operational Manager KCS
- Unit managers ICA, Europe and NFB KCS
- Manager equipment maintenance KCS
- Various people within KCS
- Owner Van Riemsdijk
- Owner lease company
APPENDIX B – Organogram KLM Inflight Services

CIM stands for Cabin and In-flight management. This organization is responsible for designing, planning and enabling the delivery of the service provided to passengers on-board of KLM aircraft (Osorio, 2010).

![Organogram EVP Inflight](image)

CIM consists of product management, network supply management, inflight management, and operations and products to the crew. The CIM organization was created in 2004, by clustering a collection of individual organizational entities throughout KLM and was placed within the division of In-flight services.

![Organogram VP CIM](image)

One of the departments of CIM is NSM (Network Supply Management) which was created on July 2009, by clustering a collection of individual organizational entities within CIM. As a result, a large number of processes are expected to be integrated to reach synergies and efficiencies within the CIM organization but also with external parties such as KCS, and AirFrance.

The main roadmap for the integration of these processes is the strategic plan of the organization which is the responsibility of the management of the CIM organization. The manager of CIM (Els Polhuijs) started her assignment from January 2010, and one of her first goals is to formulate the strategic plan of CIM.

Even though KLM and Air France agreed on preserving their individual brand identities, the business vision of CIM has to be aligned with the counterpart of CIM organization in Air France: Direction Logistique de Produit Vol (DLPV). The alignment between CIM and DLPV is expected to yield the maximum synergies for the Air France-KLM group. During the “colouring process” (decision regarding leadership in the joint business domains of AirFrance-
KLM) that catering was going to be a light blue domain, meaning that KLM would have the leadership in this domain. AirFrance has since then waited for KLM to take the initiative and formulate a joint business vision.

**NSM optimizes and directs the global KLM catering supply chain and realizes daily over 1500 products to our customers in a reliable, efficient, and flexible way.**

**KLM Catering Services – KCS**

KCS is a daughter company of KLM. It used to be a department of KLM and currently it is a subsidiary company owned entirely by KLM. However, the relationship between KLM and KCS has been marked by a tension between a need for closer cooperation, the desire for independence by KCS and the desire of KLM of being able to contract other caterers. Currently, the future of the relationship between KLM and KCS is clearly defined but is going through a period of redefinition.
KCS is the main caterer of KLM at Schiphol Airport. KCS is in charge of the meal production and the uplift and offload of trolleys to/from the aircraft. The main facilities of KCS are located in Schiphol-Noord (where the warehouse and the former kitchens are located) and Schiphol-centrum (where the meal assembly takes place and the trucks for uplift and offload are loaded and unloaded). KCS serves other airlines like Northwest, Etihad, China Eastern, and Kenya Airways. However since the take-over of Northwest by Delta, Northwest is catered by Gate gourmet. Currently, the main customer of KCS is KLM group.
APPENDIX C – Problem tree

Figure 53 Problem tree comprehensive
APPENDIX D – IT landscape KLM and KCS

<Not attached due to confidentiality reasons.>
APPENDIX E – Inventory detail KCS Warehouse and Van Riemsdijk

<Not attached due to confidentiality reasons.>
### APPENDIX F – Detailed results Best Worst Method

**Decision Area: Ownership structure trolley fleet**

#### Comparison between criteria

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Table 29 Comparison between criteria financing alternatives

#### Comparison between sub-criteria

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Table 31: Comparison between sub-criteria and alternatives financing alternatives

Table 32: Global weights multiplied by the sub-criteria vs alternative intervals financing alternatives
### Decision Area: Enhancing traceability and identification

#### Comparison between criteria

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Table 33 Comparison criteria enhancing the traceability and identification improvement strategies

#### Comparison between sub-criteria

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Global Weights
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<td>Load-unload and usage easiness and speed</td>
<td>0.1506</td>
<td>0.1594</td>
<td>0.4932</td>
<td>0.5219</td>
<td>0.0460</td>
<td>0.0487</td>
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</tr>
<tr>
<td></td>
<td>13</td>
<td>Supervision easiness</td>
<td>0.2834</td>
<td>0.3047</td>
<td>0.0687</td>
<td>0.0770</td>
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<td>0.0537</td>
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<td>0.0435</td>
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<td>0.2221</td>
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<tr>
<td>C4: Quality</td>
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<td>Accuracy forecast trolley need</td>
<td>0.0620</td>
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<td>Quality of supplier delivered products conform spec</td>
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<td>0.1248</td>
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<td>CSR Factors; Safety</td>
<td>0.0502</td>
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</tr>
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<td>C5: Flexibility</td>
<td>18</td>
<td>Operational flexibility</td>
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<td>0.4020</td>
<td>0.0544</td>
<td>0.0568</td>
<td>0.0544</td>
<td>0.0568</td>
<td>0.0873</td>
</tr>
<tr>
<td></td>
<td>19</td>
<td>Flexibility about future plans</td>
<td>0.3752</td>
<td>0.4020</td>
<td>0.0544</td>
<td>0.0568</td>
<td>0.0544</td>
<td>0.0568</td>
<td>0.0873</td>
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</table>

Table 34 Comparison between sub-criteria and global weights enhancing the traceability and identification improvement strategies
<table>
<thead>
<tr>
<th>Criteria</th>
<th>#</th>
<th>Sub-criteria</th>
<th>Global Weights multiplied by the sub-criteria vs alternatives score</th>
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</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>A1 MIN</td>
</tr>
<tr>
<td>C1: Cost/price</td>
<td>1</td>
<td>Purchase price</td>
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<td>2</td>
<td>Establishment costs</td>
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<td></td>
<td>3</td>
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<td>0.0004</td>
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<td>5</td>
<td>Inventory costs</td>
<td>0.0023</td>
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<tr>
<td>C2: Reliability</td>
<td>6</td>
<td>Conformance to specification</td>
<td>0.0150</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>Average defect rate</td>
<td>0.0156</td>
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<td></td>
<td>8</td>
<td>Sophistication/innovativeness</td>
<td>0.0007</td>
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<td></td>
<td>9</td>
<td>Accurateness (Correctness) of inventories</td>
<td>0.0045</td>
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<tr>
<td></td>
<td>10</td>
<td>Performance history</td>
<td>0.0026</td>
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<tr>
<td></td>
<td>11</td>
<td>Accurateness (Correctness) of delivery</td>
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<td>Load-unload and usage easiness and speed</td>
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<td></td>
<td>13</td>
<td>Supervision easiness</td>
<td>0.0371</td>
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<td></td>
<td>14</td>
<td>Ease to track and trace a trolley in the</td>
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<tr>
<td>C4: Quality</td>
<td>15</td>
<td>Accuracy forecast trolley need</td>
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</tr>
<tr>
<td></td>
<td>16</td>
<td>Quality of supplier delivered products</td>
<td>0.0200</td>
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<tr>
<td></td>
<td>17</td>
<td>CSR Factors; Safety</td>
<td>0.0039</td>
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<tr>
<td>C5: Flexibility</td>
<td>18</td>
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<tr>
<td></td>
<td>19</td>
<td>Flexibility about future plans</td>
<td>0.0092</td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>Lead time to adjust trolley portfolio</td>
<td>0.0060</td>
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<td></td>
<td>Terminate</td>
<td>0.0017</td>
<td>0.0019</td>
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<td>-----------</td>
<td>--------</td>
<td>--------</td>
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<tr>
<td>Total score per alternative</td>
<td></td>
<td>0.1883</td>
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</tbody>
</table>

Table 36 Global weights multiplied by the sub-criteria vs alternative intervals technology alternatives
### Decision Area: Registration of movements and contract structure

#### Comparison between criteria

<table>
<thead>
<tr>
<th>Criteria</th>
<th>MIN</th>
<th>MAX</th>
<th>ξ</th>
<th>CR</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1: Cost/price</td>
<td>0.2072</td>
<td>0.2489</td>
<td>0.6277</td>
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<td>C2: Reliability</td>
<td>0.3416</td>
<td>0.3574</td>
<td>0.6277</td>
<td>0.2729</td>
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<td>C3: Ease</td>
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<td>0.2397</td>
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<td>0.2729</td>
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<tr>
<td>C4: Quality</td>
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<td>0.6277</td>
<td>0.2729</td>
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<tr>
<td>C5: Flexibility</td>
<td>0.0607</td>
<td>0.0635</td>
<td>0.6277</td>
<td>0.2729</td>
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Table 37 Comparison between criteria registration alternatives

#### Comparison between sub-criteria and global weights registration alternatives

<table>
<thead>
<tr>
<th>Criteria</th>
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<th>Sub-criteria</th>
</tr>
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<tbody>
<tr>
<td>C1: Cost/price</td>
<td>1</td>
<td>Establishment costs</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Operating costs</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Maintenance costs</td>
</tr>
<tr>
<td>C2: Reliability</td>
<td>4</td>
<td>Accurateness (Correctness) of inventories</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>Correctness of delivery to stakeholders</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>Correctness information trolleys in SAP</td>
</tr>
<tr>
<td>C3: Ease</td>
<td>7</td>
<td>Load-unload and usage easiness and speed</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>Supervision easiness</td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>Ease to track and trace a trolley in the operation</td>
</tr>
<tr>
<td>C4: Quality</td>
<td>10</td>
<td>Operational feasibility</td>
</tr>
<tr>
<td></td>
<td>11</td>
<td>Quality of order picking</td>
</tr>
<tr>
<td></td>
<td>12</td>
<td>Usage of trolley fleet</td>
</tr>
<tr>
<td>C5: Flexibility</td>
<td>13</td>
<td>Operational flexibility</td>
</tr>
<tr>
<td></td>
<td>14</td>
<td>Flexibility about future plans</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Criteria</th>
<th>MIN</th>
<th>MAX</th>
<th>ξ</th>
<th>CR</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1: Cost/price</td>
<td>0.4877</td>
<td>0.4877</td>
<td>0.4384</td>
<td>0.8769</td>
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<tr>
<td>C2: Reliability</td>
<td>0.5443</td>
<td>0.5443</td>
<td>0.3542</td>
<td>0.2173</td>
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<td>C3: Ease</td>
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<td>0.0833</td>
<td>1.5359</td>
<td>0.4118</td>
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<td>C4: Quality</td>
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<td>0.5348</td>
<td>0.2087</td>
<td>0.2087</td>
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<tr>
<td>C5: Flexibility</td>
<td>0.2500</td>
<td>0.2500</td>
<td>0.0000</td>
<td>0.0000</td>
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</table>

Table 38 Comparison between sub-criteria and global weights registration alternatives
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<thead>
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<th>Criteria</th>
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<th>Sub-criteria</th>
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<th>Global Weights multiplied by the sub-criteria vs alternatives score</th>
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<tr>
<td></td>
<td></td>
<td></td>
<td>A1</td>
<td>A2</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>MIN</td>
<td>MAX</td>
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<tr>
<td>C1: Cost/price</td>
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<td>Establishment costs</td>
<td>0.5746</td>
<td>0.5746</td>
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<tr>
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<td>3</td>
<td>Maintenance costs</td>
<td>0.1111</td>
<td>0.1111</td>
</tr>
<tr>
<td>C2: Reliability</td>
<td>4</td>
<td>Accurateness (Correctness) of inventories</td>
<td>0.0833</td>
<td>0.0833</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>Correctness of delivery to stakeholders</td>
<td>0.1667</td>
<td>0.1667</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>Correctness information trolleys in SAP</td>
<td>0.0769</td>
<td>0.0769</td>
</tr>
<tr>
<td>C3: Ease</td>
<td>7</td>
<td>Load-unload and usage easiness and speed</td>
<td>0.4615</td>
<td>0.4615</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>Supervision easiness</td>
<td>0.0833</td>
<td>0.0833</td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>Ease to track and trace a trolley in the operation</td>
<td>0.0769</td>
<td>0.0769</td>
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<tr>
<td>C4: Quality</td>
<td>10</td>
<td>Operational feasibility</td>
<td>0.6000</td>
<td>0.6000</td>
</tr>
<tr>
<td></td>
<td>11</td>
<td>Quality of order picking</td>
<td>0.1429</td>
<td>0.1429</td>
</tr>
<tr>
<td></td>
<td>12</td>
<td>Usage of trolley fleet</td>
<td>0.1000</td>
<td>0.1000</td>
</tr>
<tr>
<td>C5: Flexibility</td>
<td>13</td>
<td>Operational flexibility</td>
<td>0.1250</td>
<td>0.1250</td>
</tr>
<tr>
<td></td>
<td>14</td>
<td>Flexibility about future plans</td>
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</table>

Table 39: Comparison between sub-criteria and alternatives registration alternatives
Table 40 Global weights multiplied by the sub-criteria vs alternative intervals registration alternatives

### Decision Area: Communication and Coordination structure

#### Comparison between criteria

<table>
<thead>
<tr>
<th>Criteria</th>
<th>MIN</th>
<th>MAX</th>
<th>ξ</th>
<th>CR</th>
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</thead>
<tbody>
<tr>
<td>C1: Cost/price</td>
<td>0.3364</td>
<td>0.3817</td>
<td>0.6277</td>
<td>0.2729</td>
</tr>
<tr>
<td>C2: Reliability</td>
<td>0.1533</td>
<td>0.2267</td>
<td>0.6277</td>
<td>0.2729</td>
</tr>
<tr>
<td>C3: Ease</td>
<td>0.1418</td>
<td>0.1609</td>
<td>0.6277</td>
<td>0.2729</td>
</tr>
<tr>
<td>C4: Quality</td>
<td>0.2108</td>
<td>0.2650</td>
<td>0.6277</td>
<td>0.2729</td>
</tr>
<tr>
<td>C5: Flexibility</td>
<td>0.0598</td>
<td>0.0678</td>
<td>0.6277</td>
<td>0.2729</td>
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</table>

#### Comparison between sub-criteria

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Sub-criteria</th>
<th>MIN</th>
<th>MAX</th>
<th>ξ</th>
<th>CR</th>
<th>MIN</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1: Cost/price</td>
<td>Establishment costs</td>
<td>0.3333</td>
<td>0.3333</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.1121</td>
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<tr>
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<td>Operating costs</td>
<td>0.6667</td>
<td>0.6667</td>
<td>0.2243</td>
<td>0.2545</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C2: Reliability</td>
<td>Discrepancy between actual stock levels and SAP values</td>
<td>0.1430</td>
<td>0.1448</td>
<td>0.2087</td>
<td>0.2087</td>
<td>0.0219</td>
<td>0.0328</td>
</tr>
<tr>
<td></td>
<td>Accurateness of inventory</td>
<td>0.1430</td>
<td>0.1448</td>
<td>0.0219</td>
<td>0.0328</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Accurateness of contracts overview</td>
<td>0.1430</td>
<td>0.1448</td>
<td>0.0219</td>
<td>0.0328</td>
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<td></td>
</tr>
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<td>Effectiveness of organisational structure</td>
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<td>0.0122</td>
<td>0.0183</td>
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<td></td>
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Table 42 Comparison between sub-criteria communication and coordination alternatives

<table>
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<th>Criteria</th>
<th>Sub-criteria</th>
<th>Comparison sub-criteria vs alternatives</th>
<th>( \xi )</th>
<th>CR</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>C1: Cost/price</strong></td>
<td>1 Establishment costs</td>
<td>MIN 0.5447 0.5447 MAX 0.3720 0.3720</td>
<td>MIN 0.3720 0.3720</td>
<td>MAX 0.0833 0.0833</td>
</tr>
<tr>
<td></td>
<td>2 Operating costs</td>
<td>MIN 0.1818 0.1818</td>
<td>MAX 0.7273 0.7273</td>
<td>MIN 0.0909 0.0909</td>
</tr>
<tr>
<td><strong>C2: Reliability</strong></td>
<td>3 Discrepancy between actual stock levels and SAP values</td>
<td>MIN 0.1000 0.1000</td>
<td>MAX 0.6000 0.6000</td>
<td>MIN 0.3000 0.3000</td>
</tr>
<tr>
<td></td>
<td>4 Accurateeness of inventory</td>
<td>MIN 0.1000 0.1000</td>
<td>MAX 0.6000 0.6000</td>
<td>MIN 0.3000 0.3000</td>
</tr>
<tr>
<td></td>
<td>5 Accurateeness of contracts overview</td>
<td>MIN 0.0909 0.0909</td>
<td>MAX 0.2875 0.2875</td>
<td>MIN 0.6216 0.6216</td>
</tr>
<tr>
<td></td>
<td>6 Effectiveness of organisational structure</td>
<td>MIN 0.0909 0.0909</td>
<td>MAX 0.6216 0.6216</td>
<td>MIN 0.2875 0.2875</td>
</tr>
<tr>
<td></td>
<td>7 Reliability of the trolley information</td>
<td>MIN 0.0769 0.0769</td>
<td>MAX 0.6154 0.6154</td>
<td>MIN 0.3077 0.3077</td>
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<tr>
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<td>8 Reliability of the organization</td>
<td>MIN 0.0769 0.0769</td>
<td>MAX 0.6154 0.6154</td>
<td>MIN 0.3077 0.3077</td>
</tr>
<tr>
<td></td>
<td>9 Reliability of information for decisions</td>
<td>MIN 0.0769 0.0769</td>
<td>MAX 0.6154 0.6154</td>
<td>MIN 0.3077 0.3077</td>
</tr>
<tr>
<td><strong>C3: Ease</strong></td>
<td>10 Ease to hand-over tasks and responsibilities</td>
<td>MIN 0.0769 0.0769</td>
<td>MAX 0.6154 0.6154</td>
<td>MIN 0.3077 0.3077</td>
</tr>
<tr>
<td></td>
<td>11 Supervision easiness</td>
<td>MIN 0.0769 0.0769</td>
<td>MAX 0.3077 0.3077</td>
<td>MIN 0.6154 0.6154</td>
</tr>
<tr>
<td></td>
<td>12 Transparency allocation of tasks</td>
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<td>MAX 0.6154 0.6154</td>
<td>MIN 0.3077 0.3077</td>
</tr>
<tr>
<td><strong>C4: Quality</strong></td>
<td>13 Operational feasibility</td>
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<td>MAX 0.4615 0.4615</td>
<td>MIN 0.0769 0.0769</td>
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</tbody>
</table>

Table 42 Comparison between sub-criteria communication and coordination alternatives
### Table 43 Comparison between sub-criteria and alternatives communication and coordination alternatives

<table>
<thead>
<tr>
<th>Criteria</th>
<th>#</th>
<th>Sub-criteria</th>
<th>A1 MIN</th>
<th>A1 MAX</th>
<th>A2 MIN</th>
<th>A2 MAX</th>
<th>A3 MIN</th>
<th>A3 MAX</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>C1: Cost/price</strong></td>
<td>1</td>
<td>Establishment costs</td>
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<td>0.0693</td>
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<td>Operating costs</td>
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<td>0.1631</td>
<td>0.1851</td>
<td>0.0204</td>
<td>0.0231</td>
</tr>
<tr>
<td><strong>C2: Reliability</strong></td>
<td>3</td>
<td>Discrepancy between actual stock levels and SAP values</td>
<td>0.0022</td>
<td>0.0033</td>
<td>0.0132</td>
<td>0.0197</td>
<td>0.0066</td>
<td>0.0098</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>Accurateness of inventory</td>
<td>0.0022</td>
<td>0.0033</td>
<td>0.0132</td>
<td>0.0197</td>
<td>0.0066</td>
<td>0.0098</td>
</tr>
<tr>
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<tr>
<td></td>
<td>6</td>
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<td>0.0017</td>
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<tr>
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<tr>
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<td>0.0014</td>
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<td>0.0045</td>
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<td>0.0121</td>
<td>0.0181</td>
</tr>
<tr>
<td><strong>C3: Ease</strong></td>
<td>10</td>
<td>Ease to hand-over tasks and responsibilities</td>
<td>0.0022</td>
<td>0.0025</td>
<td>0.0175</td>
<td>0.0198</td>
<td>0.0087</td>
<td>0.0099</td>
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<tr>
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<td>0.2616</td>
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Table 44 Global weights multiplied by the sub-criteria vs alternative intervals communication and coordination alternatives
**Decision Area: Monitoring the performance of the trolley supply chain**

### Comparison between criteria

<table>
<thead>
<tr>
<th>Criteria</th>
<th>MIN</th>
<th>MAX</th>
<th>ξ</th>
<th>CR</th>
</tr>
</thead>
<tbody>
<tr>
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<td>0.2306</td>
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<td>0.1994</td>
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Table 45 Comparison between criteria performance monitoring improvement strategies

### Comparison between sub-criteria and global weights

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Table 46 Comparison between sub-criteria and global weights performance measure alternatives
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<th>A3</th>
<th>A4</th>
<th>ξ</th>
<th>CR</th>
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</tr>
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Table 47: Comparison between sub-criteria and alternatives performance measure alternatives
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<th>Sub-criteria</th>
<th>C1: Cost/price</th>
<th>C2: Reliability</th>
<th>C3: Ease</th>
<th>C4: Quality</th>
<th>C5: Flexibility</th>
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</table>

Table 48: Global weights multiplied by the sub-criteria vs alternative intervals performance measure alternatives
APPENDIX G – Atlas & KSSU standard

In 2015 KLM will receive the Boeing 787 (“Dreamliner”) which uses a different equipment standard than the current fleet. Atlas is the new standard that is installed on the 787, while the current fleet has the KSSU standard. This entails that KLM has to procure new equipment; because KSSU equipment won’t fit in Atlas galleys [A galley is a kitchen inside the aircraft, which stores the trolleys, containers and other equipment]. Figure 54 shows the differences between Atlas and KSSU standards. This will result in a transition process from KSSU trolleys to Atlas trolleys. The transition process from KSSU to Atlas is left out of the scope of this research, but the Atlas transition process is suitable for future research.

Besides the question to buy or lease the new trolleys also the decision about the implementation process has to be made. Currently different scenarios are developed and investigated. A decision about the process has not yet been made.

Because it is not possible to adjust all airplanes at the same moment the Atlas standard will be introduced in phases. There is currently project running to find the best solution concerning the phased introduction of Atlas equipment. So, there hasn’t been made any decision yet about how the transition from KSSU to Atlas will be organized. At the moment several scenario have been evaluated.

The implementation of the Atlas standard is a huge opportunity for KLM to reorganize the entire trolley supply chain, because the introduction of the Atlas standard entails the replacement of the entire trolley portfolio. Besides opportunities the introduction of the atlas standards entails risks as well and costs. The Atlas introduction offers also a great opportunity to adjust the values of the KPI’s, because you know than exactly what you lay out on your outstations and what you pro-vide KCS for the operation.

The future of the loading equipment is characterized by the introduction of the Atlas equipment and CIMplify. The introduction process of the Atlas equipment will not be in the scope of this research, but it is important to keep in mind. The analysis of the current situation of the trolley supply chain and the insights this research has
provided, will be used by KLM for the decision concerning the procurement of the new Atlas standard equipment.