Integration of the airmail and equation operations at the KLM Cargo terminal

Determining the effects of the integration of the airmail and EQ departments on the overall performance of the physical KLM Cargo operations in FB1 by means of discrete simulation in Arena

Schiphol, 15 June 2009

Name:	Gijs van Amstel
Student number:	1104292
Company:	KLM Cargo
University:	Delft University of Technology
Faculty:	Technology, Policy and Management
Chair:	Transport, Infrastructure and Logistics

Master thesis committee

Professor:	Prof. dr. G.P. van Wee	TU Delft
Graduation supervisor:	Prof. dr. ir. A. Verbraeck	TU Delft
Graduation supervisor:	Ir. T.C.A. Mensch	TU Delft
External graduation supervisor:	Drs. S. Bhalla	KLM Cargo
External graduation supervisor:	G. Bergkamp	KLM Cargo

Preface

The integration project of mail and EQ was underway for some time when I started my master thesis at KLM Cargo. In an interview at KLM Cargo for another potential master project, I mentioned discrete simulation as a tool used during my bachelor and master at the TU Delft. This was the start of my master thesis for KLM Cargo. I agreed to work out the unanswered questions regarding the future performance in FB1.

At the start all activities in the freight building seemed relatively straightforward, but every time the amount of details and exceptions were surprising. Almost everything took longer than expected because of this, from data collection, to building the simulation model. Therefore I think my project had all the characteristics of a normal master thesis project.

I would like to thank KLM cargo for the opportunity to perform this research at the terminal at Schiphol. I appreciated the freedom I was given to perform this study according to my own ideas. My colleagues at KLM were very helpful, certainly when you consider that I certainly was not the first to work on this project, probably asking the same questions again. I would like to thank my supervisors of the TU Delft for their constructive criticism on my work.

Gijs van Amstel

Delft, Huize in den Pluym
June 2009

Executive summary

Immediate cause for the integration of Airmail and Equation

After the merger of KLM and Air France, the airlines induced the exchange of best practises. A study on the integration of the Airmail and equation (EQ) department at freight building 1 (FB1) at Schiphol was started in 2006. EQ is an express cargo product, with a high service level and guaranteed booking on a flight. The airmail product is not booked on a specific flight and has a lower priority than EQ. In FB1, KLM Cargo is receiving and sorting export, transit and import airmail and EQ.

Proposed Integration

After the proposed integration, the **small** EQ shipments will use the mechanized conveyor belt with manual sorting at the mail department. This implies both airmail and **small** EQ are sorted via the same conveyor belt system in the future. The handling of large and/or heavy EQ shipments will not change, nor will the handling of import EQ. The proposed integration includes changes to the lay-out of FB1 and extension of the conveyor belt system.

The expected benefits of the integration are: reduction of the labour costs, improvement of customer service, increased load factor of departing planes due to the FIFO-principle, the possibility to test the integrated operation prior to the movement of the freight buildings of KLM cargo to another location at Schiphol (the JUMP) and reduction of the required space for the operations of mail and EQ.

Problem specification

KLM Cargo is facing two problems, one short-term (ST) and one long-term (LT) problem:

- ST: It is uncertain what effects the integration will have on the performance of the airmail and EQ operations, therefore it is not possible to determine whether the benefits of the integration until the JUMP, justify the required investments.
- LT: KLM Cargo would like to integrate the EQ and mail department after the JUMP. At the new terminal, KLM Cargo can design a new tailor-made process for the combined operation. The changes due to the JUMP would be very large and KLM Cargo wants to prepare the movement and gain experience with the integrated situation to identify potential bottlenecks beforehand.

Research goal and methodology

An integral approach is used to determine the effects of the integration, which gives due weight to the interrelations between variables. The goal of this research is:

Determining the effects of the integration of the airmail and EQ departments on the overall performance of the physical KLM Cargo operations in FB1

The effects of the integration are evaluated on the following four performance areas in this research: resource utilization, handling times, number of re-bookings and space requirements. Discrete simulation in Arena is used to quantify the effects of the integration. The current situation is modelled first and the corresponding simulation results are used as a base case when calculating the future effects. This base model will be expanded step-by-step in order to isolate the effects of different causes of uncertainties.

Results

The simulation outcomes of the current situation, the integrated situation excluding new processes and the integrated situation including new processes lead to the following main results.

Resource utilization

The simulation results show a higher efficiency of the combined operations of the mail and EQ initially. The total number of working hours required for the same production decrease with 8%. The addition of new processes however will undo almost all gained efficiency again.
The removal of temporary storage shows an important reduction in the workload at EQ, because double handling for one shipment is prevented in the new situation. Applying the FIFO-principle at EQ makes the removal of the temporary storage possible.

Handling times

Average handling times are a good indicator of the quality of the operation. The integration will improve the handling times in FB1 for all EQ shipments. However the integration will be more beneficial for large EQ shipments than for small EQ shipments.
The introduction of the FIFO-principle and the increased flexibility with regard to the booking of EQ make early departures possible which reduce the average turnaround times with more than 5 hours.

Number of re-bookings

The total number of mailbags missing their initial flight is reduced considerably when the moment of collection is advanced to 90 minutes before flight departure.
The total number of EQ shipments missing their flight will increase by the integration. Simultaneously almost 17% of all EQ shipments will leave Schiphol prior to their booked flight.

Space requirements

The simulation results together with the composed tree diagram prove that the required space along the carousels is larger than the available capacity after the integration. This proves not all small EQ shipments can be sorted via the conveyor belt after the integration and therefore the efficiency gain will become smaller than the expected 8%. The introduction of the FIFO principle will reduce the required number of belly wagons at the EQ storage yard by more than 50%.

Advice to KLM Cargo

The results of this thesis give no reason to assume large efficiency gains can be realized by the integration of the physical operation of airmail and EQ. This contradicts the expectations of the initial business case on the integration. The expected financial benefits of the integration will therefore be much smaller than assumed by KLM Cargo until now.
The NPV analysis shows that the Capex in the physical operation cannot be earned back by the lower Opex in the physical operation the coming five years. This proves the integration of the physical operation should not be executed for financial reasons. Only in case the investment is required to create possibilities to gain other financial benefits outside the physical operation, KLM Cargo should consider the investment in the conveyor belt.
The simulation of the current situation with a new operational setup has indicated possibilities to realize advantages of the integration without investments in new infrastructure. KLM Cargo is advised to: make all departing flights accessible for both mail and EQ, introduce the FIFO principle at EQ, advance the collection of mail to 90 minutes before flight departure, remove the temporary storage at EQ and open belly wagons for a destination at the EQ storage yard only when actual cargo has arrived. The improved performance could improve the competitive position of KLM Cargo, in case the customers are willing to accept the FIFO principle. This new setup creates the possibility for the operational workforce of KLM Cargo to get used to some aspects of the integrated operation, which will result in valuable knowledge and experience for the JUMP. KLM Cargo is advised to postpone the investment in the extension of the conveyor belt system in FB1, adjust the current operational setup and proceed with the integration outside the physical operation.

Table of contents

Glossary and terminology

Available seat-kilometres (ASK)
The number of seats on an airplane multiplied by the number of kilometres flown by the airplane.

ATA and ATD
The actual time of arrival (ATA) and the actual time of departure (ATD) of planes at the airport.

Air Waybill (AWB)
Type of bill of lading that serves as a receipt of goods by an airline (carrier) and as a contract of carriage between the shipper and the carrier. It includes conditions of carriage that define (among other terms and conditions) the carrier's limits of liability and claims procedures, a description of the goods, and applicable charges. The airline industry has adopted a standard format for AWB which is used throughout the world for both domestic and international traffic. Unlike a bill of lading, an AWB is a non-negotiable instrument, does not specify on which flight the shipment will be sent, or when it will reach its destination. (www.businessdictionary.com, 11-2-2009)

Cargo
Used as general term for all product types of KLM Cargo. Cargo is often used to represent multiple product types simultaneously in this thesis.

Collo and colli
Collo is used to identify one piece of airmail or equation. Colli is the plural form**.**

EQ
Equation is the express product of Air France-KLM Cargo

FB
Freight building of KLM Cargo at Schiphol. KLM Cargo operates three freight buildings: FB1, FB2 and FB3.

FLT
Forklift truck

General cargo
General cargo is the basic cargo product of KLM. EQ and Airmail are special product types.

Integrator
Companies which offer all services in the air cargo supply chain under one roof, they vertically integrated the supply chain (Forster and Regan, 2001)

JUMP
The JUMP is the synonym for the movement of the KLM Cargo buildings to another location at Schiphol airport premises.

Lateral cargo
Lateral cargo is the cargo, which is transported between FB1 and FB2 & 3. The lateral cargo leaving FB1 towards FB2 & 3 is general cargo broken down at the EQ department. The lateral cargo coming towards FB1 from FB 2 & 3 is general cargo which will be transported as bulk cargo in the belly of the departing planes.

Liberalization
The removal or reduction in government-imposed regulation of the market for air services. Also known as deregulation.

Load factor
The load factor indicates the use of flight capacity. The number of fare-paying passengers divided by the total number of seats on that flight or the weight of fare-paying cargo divided by the maximum weight for cargo on that flight.

M21 & M25
M21 is the product code used by KLM Cargo for small Equation shipments. M25 is the product code used by KLM Cargo for exceptional heavy or large Equation shipments.

RIM
Register Incoming Mail by communication between the employee scanning along the input belt and an employee in the office, which registers the data manually in Trips

RPK
Revenue passenger-kilometres. The number of fare-paying passengers multiplied by the number of kilometres they fly (i.e., airline traffic).

Shipment
A shipment is the collection of all packages belonging to one AWB (EQ) or one dépêche number (mail) send by a shipper. A shipment can contain one or more collo.

Sorting/switching
The process of sorting out the cargo to different carousels is described as "switching" as well as "sorting" in this thesis. The whole operation in FB1 can be described as one sorting process, therefore "switching" is used in some cases to emphasis sorting at the sorting table at the mail department is mend.

STA and STD
The scheduled time of arrival (STA) and the scheduled time of departure (STD) are derived from the planning of the flight schedule. The actual times will often differ from the scheduled time.

Trips
Trips is the software package of the Universal Postal Union used by KLM Cargo. It has features for documentation, registration, coordination, electronic data interchange, tracking and tracing and planning (http://www.ptc.upu.int/ps/ips_trips.shtml).

T-ULD
A unit load device (see ULD) which is prepared by the forwarder in such a way that it can be considered one large package. At the KLM terminal export T-ULDs can be transported to the airside directly after arrival at export acceptance without further handling. The transit T-ULDs can remain at the airside between arrival and departure at the KLM terminal, because no handling is required.

ULD
A unit load device, or ULD, is a pallet or container used to load luggage, freight, and mail on wide-body aircraft and specific narrow-body aircraft. It allows a large quantity of cargo to be bundled into a large unit (http://en.wikipedia.org/wiki/Unit_Load_Device)

Yield
Revenues divided by revenue passenger-kilometres (i.e., the money received by an airline for each kilometre flown by each passenger).

Company profile

The royal Dutch airline KLM (Koninklijke Luchvaart Maatschappij) was founded in 1919. Schiphol international airport in Amsterdam has always been KLM's home base, Schiphol functions as the passenger and cargo hub in the KLM network.
KLM is operating passenger and cargo flights worldwide. The KLM Group does include Transavia and KLM Cityhopper besides KLM. In the nineties KLM teamed up with Northwest Airlines during the first episode of consolidation in the airlines business. In May 2004, KLM Merged with Air France, which resulted in the entry of KLM, Northwest and Continental to the SkyTeam alliance, an international alliance between Air France, Delta Air Lines, Alitalia, Korean Air, ČSA Czech Airlines and Aéro Mexico. KLM Cargo and Air France Cargo have achieved substantial integration since October 2005.
KLM Cargo operates 3 freighters and 109 combined passengers and cargo aircrafts. Of these 109 combi-planes, 59 are long-haul planes. Around 30% of the airfreight is carried by KLM's full freighter aircrafts, and the remainder is carried aboard the Boeing 747-400 Combi-aircraft and in the holds of KLM full-passenger aircrafts.
KLM has one of the largest combi-fleets in the world. This enables KLM Cargo to offer freight capacity to destinations where other carriers can only offer belly space for loose cargo. Together with partners, KLM Cargo can ship goods to around 545 destinations worldwide.
In fiscal year 2007/2008, the KLM Group transported more than 23.4 million passengers and 657,022 tons of cargo. The total performance of the cargo division in that year was 4947 million ton freight-kilometre (KLM, 2008a). KLM's cargo activities at Schiphol, account for 60% of all airfreight carried in and out of the Netherlands, making it a cornerstone of Amsterdam's mainport status (KLM, 2008a).

Air France Cargo KLM Cargo

1 Introduction

Increased competition between airlines has induced a wave of consolidation in the airline industry. High fuel prices, extra security measures and competition on tariffs demand a continuous attention for costs. Environmental regulations and price- and quality-conscious customers require high investments in new and state of the art equipment and advanced computer systems. When keeping up with these developments it is advantageous to have a larger size of operations (KLM, 2007). Together, airlines are able to offer the same service level and larger network with fewer flights, while reducing operational costs by sharing facilities on airports. Thus, consolidation can realize economies of scale and this will improve the competitive strength of both airlines.
In May 2004 two large European airliners KLM and Air France merged. This resulted in the world leader in terms of international passenger traffic and air cargo activity, excluding integrators (www.airfranceklm-finance.com). Alignment of the separate operations of both airlines after the merger ensures offering the same service level to their customers and makes exchange of best practices possible.
This merger will also have impact on the operations at KLM Cargo. The need to align the operations of KLM and Air France and the expected benefits on operational performance initiated a business case study on the integration of the handling processes of airmail and Equation (EQ) products in freight building 1 (FB1) at Schiphol airport. At Charles de Gaulle airport the two product flows are already successfully integrated by Sodexi, a subsidiary company of Air France-KLM.

At this moment KLM Cargo has three freight buildings at the Schiphol terminal. The layout of freight building 1 is product oriented. The layout of Freight building 2 and 3 is destination oriented (see Figure 1).

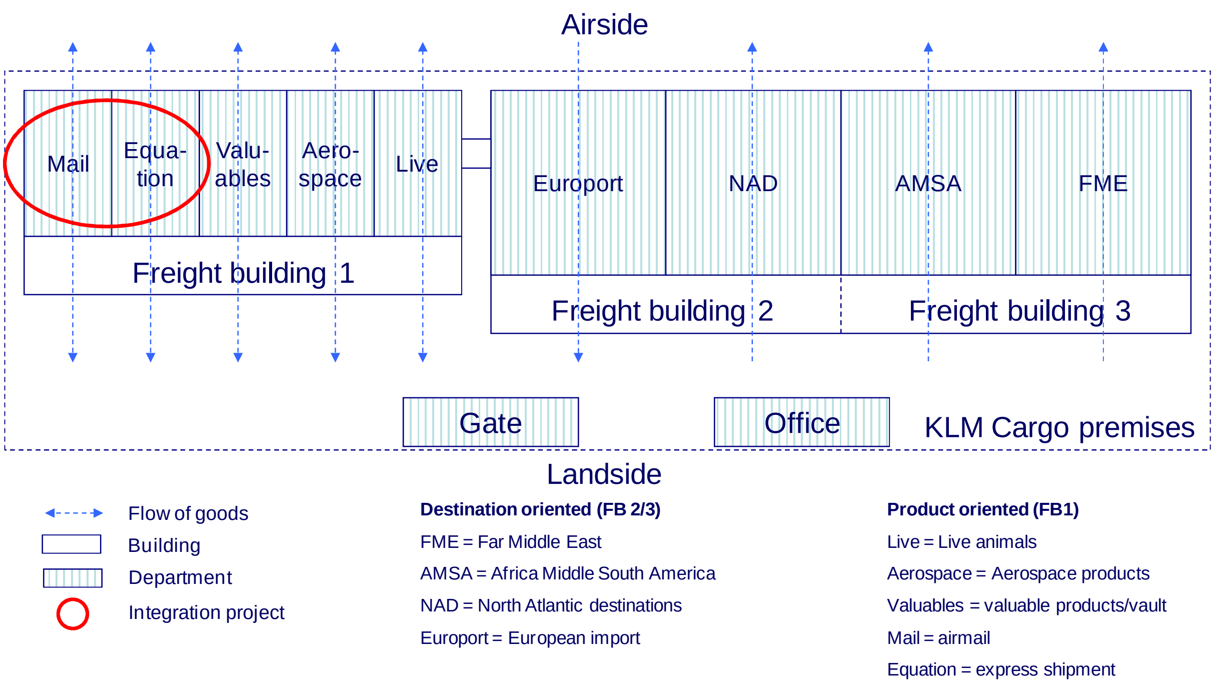


Figure 1: Layout KLM Cargo premises

EQ is an express service for cargo accompanied with a high service level. Last-minute access to capacity and guaranteed loading (within 90 minutes) on a specific flight (shipment are booked on a flight) are important services for the EQ product. This results in guaranteed delivery with the

booked flight and the fastest possible arrival at destination for urgent and important cargo shipments.
The conventional airmail product has a lower priority, for all mailbags the first in first out (FIFO) principle is applied. When the available capacity on a flight is not sufficient mail will be put on the next flight (except EMS & Priority airmail). EQ yields higher margins, but is accompanied by the obligation to meet the higher standards.

Although mail and equation are different products and require different treatment in parts of the handling process, a substantial overlap exists as well. KLM Cargo expects this overlap to grow in the future due to the increasing demand for air transport for small parcels, which show more resemblance with mailbags and mailboxes.

A business case study was initiated with the belief that integration of the two flows will have three mayor benefits:

- Reduction of the labour costs
- Improved customer service
- Increased load factor of departing planes

The first expected benefit will be a reduction of the number of full-time equivalents (FTE's) for the same performance, due to the realisation of synergy effects. When operations are combined resources can be shared and will be used more efficient. On the management level this effect will also take place, the joint operation will reduce the workload for managing and will make some management functions superfluous

The second expected advantage is an improvement of the customer service. The integrated operation will have an advantage for customers of both types of products.
For EQ packages the introduction of the FIFO-principle will decrease the times between the acceptance of cargo on landside and the departure by plane on the airside. This benefit will apply for the EQ packages, which will be transported on a flight prior to the booked flight. The actual booking will be used as deadline in the future, instead of an obligation to ship the cargo on that specific flight.
Postal companies transporting airmail with KLM want to receive more information on the location of their mail than they did in the past. The facilities to track and trace EQ packages will have to be present at the mail department after the integration, because EQ packages have to be registered. The expansion of these facilities towards track and trace for mailbags will be relatively easy.

The third expected benefit of the integration is an increase of the load factor of departing airplanes due to sorting and loading according to the FIFO- principle. A higher load factor can be obtained because all available EQ at the terminal, which possibly is booked on a later flight, can be used to fill up departing flights.
The capacity on the later flight can now be released for transport of other cargo again and the capacity offered to customers for future flights is increased, which in turn could attract new loads to KLM. The average load factor of the flights will only increase in general when KLM Cargo is able to attract new loads.

Beside the mayor benefits of the project two minor benefits are identified as well:

- The possibility to test the integrated operation before the movement of the freight buildings of KLM cargo (the JUMP)
- Reduction of the required space for the operations of airmail and EQ

The planned movement of all freight buildings (the JUMP) to a location at Schiphol Zuidoost (figure 2, red arrow) influences the decision whether or not to integrate mail and EQ on a short term. Fast integration would make it possible to gain experience with the joint operation. Testing the joint operation would generate valuable knowledge for the design of the new cargo terminal.

The initial capital expenditure should be earned back by the lower operational expenditure after the integration. The period to earn back the initial investment is limited to the period until the JUMP. In the business case the required investment to change the infrastructure in FB1 was estimated on approximately 0.9 million EUR.

Space is a scares resource and therefore an expensive resource on the airport grounds. Combining mail and EQ could reduce the required amount of space used for the two operations, because the mail and EQ ready for departure in a belly wagon can be stored together. The FIFO-principle will reduce the time cargo is stored at the terminal and therefore reduce the required amount of space for the storage of cargo as well.

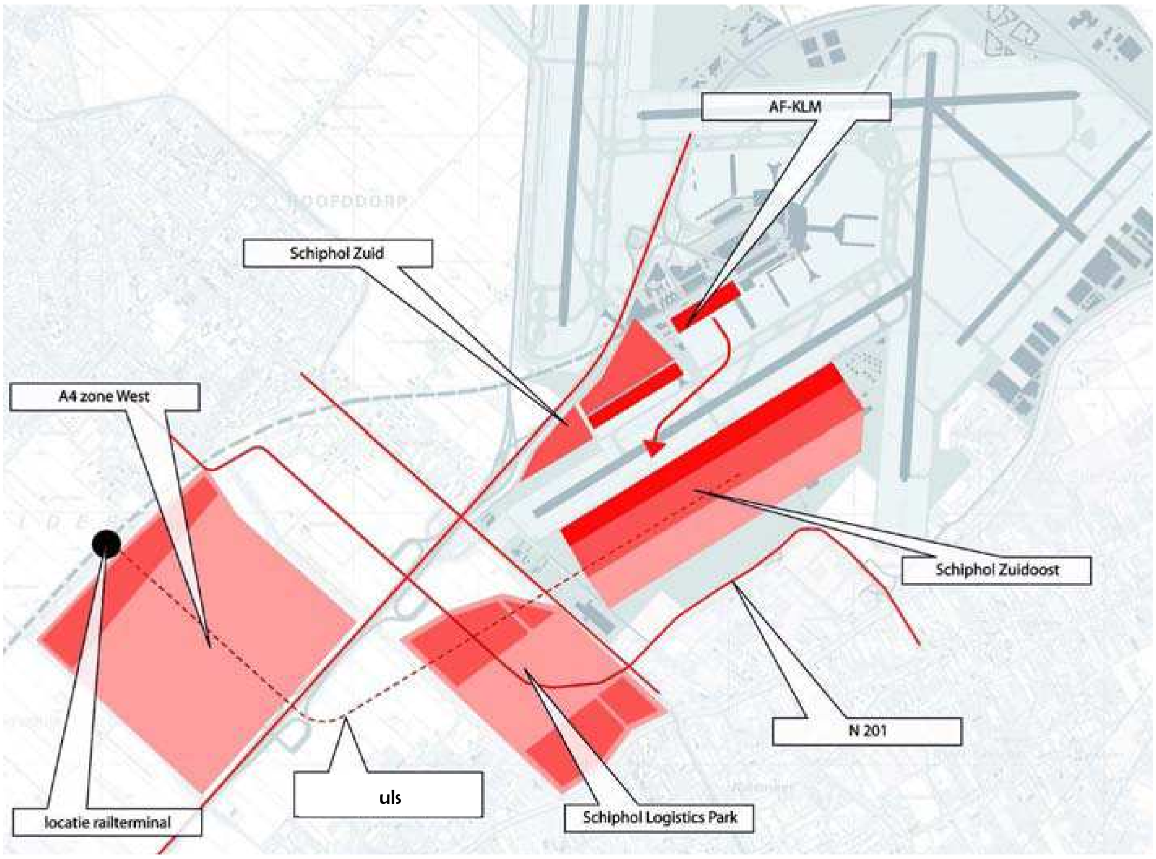


Figure 2: Spatial plan Schiphol, which illustrates the JUMP of AF/KL Cargo as well (Schiphol, 2007a)

1.1 Problem specification

KLM cargo has the believe that the integration of the airmail and EQ department will increase the competitive power of the joint Air France-KLM operation and will prepare the company for the future, maybe even a future at a new location.

Although the business case confirmed KLM's expectations and resulted in a positive cost-benefit analysis (KLM Cargo and M3 Consultancy, 2006), the trust in the integration is not shared by all decision makers. The results of previous calculations did not convince the KLM management. The results did still incorporate too much uncertainty and none of the calculations have been able to incorporate all the different aspects of the integrated process to their full extend. In appendix A the important causes of the persisting uncertainty are enumerated.

These limitations of previous analyses of KLM Cargo have induced the demand for research on the integrated operations. This research should take uncertainties and interdependencies between changing processes at both departments into account, when determining the future operational performance. KLM Cargo's problem can be divided into a short-term and long-term problem.

Short-term problem
It is uncertain what effects the integration will have on the performance of the airmail and EQ operations, therefore it is not possible to determine whether the benefits of the integration until the JUMP, justify the required investments

Long-term problem
KLM Cargo would like to integrate the EQ and mail department after the JUMP. At the new terminal, KLM Cargo can design a new tailor-made process for the combined operation. Nevertheless the changes at the movement are great and KLM wants to prepare for the movement and gain experience with the integrated situation to identify potential bottlenecks beforehand.

Four factors contribute in particular to the uncertainty around the total performance of the integrated situation:
1. The integration will change the current flow of EQ shipments through FB1. Relatively small EQ shipments will be sorted for a possible subsequent flight via the conveyor belt at the mail department. Due to this partial change of the flow of EQ shipments, the division of the workload will change. The consequences on the performance at both departments are unknown (explained in paragraph 6.5.1).
2. New processes will be implemented in the operation simultaneously with the integration. Some new processes are required to make the integration possible. Other processes will be implemented because changes are made anyhow and it is easier to make them all at once. (explained in paragraph 6.5.2)
3. There are still choices to be made for the new operational setup. It is unclear if the number of locations for belly wagons along the carousels is sufficient in the integrated situation.
   The criterion to decide whether a shipment is to be considered "large" is not determined considering the implications for the physical processes. Nevertheless the consequences of the large shipment criterion on the division of work are expected to be large. Therefore it is worthwhile to evaluate operational setup (explained in paragraph 6.5.3).
4. Software alterations are required, because at this time the two departments are using different software programs to support the operations (clarified in paragraph 1.3)

The division between these four subjects is maintained in this report and is displayed in Figure 3. In a later stage, the first three causes of uncertainty are subdivided again. The effects on existing processes will exist out of the change in the processed quantity by both departments, the transportation of small EQ to the mail carousel and the combined security check of both airmail and EQ. The new processes will entail the labelling of all packages without a label coming in, an entry scan for small EQ packages and the exit scan after a package is taken off the carousel. The new organizational setup will exist out of the belly wagon organisation and the criterion whether a shipment has to be considered "large".

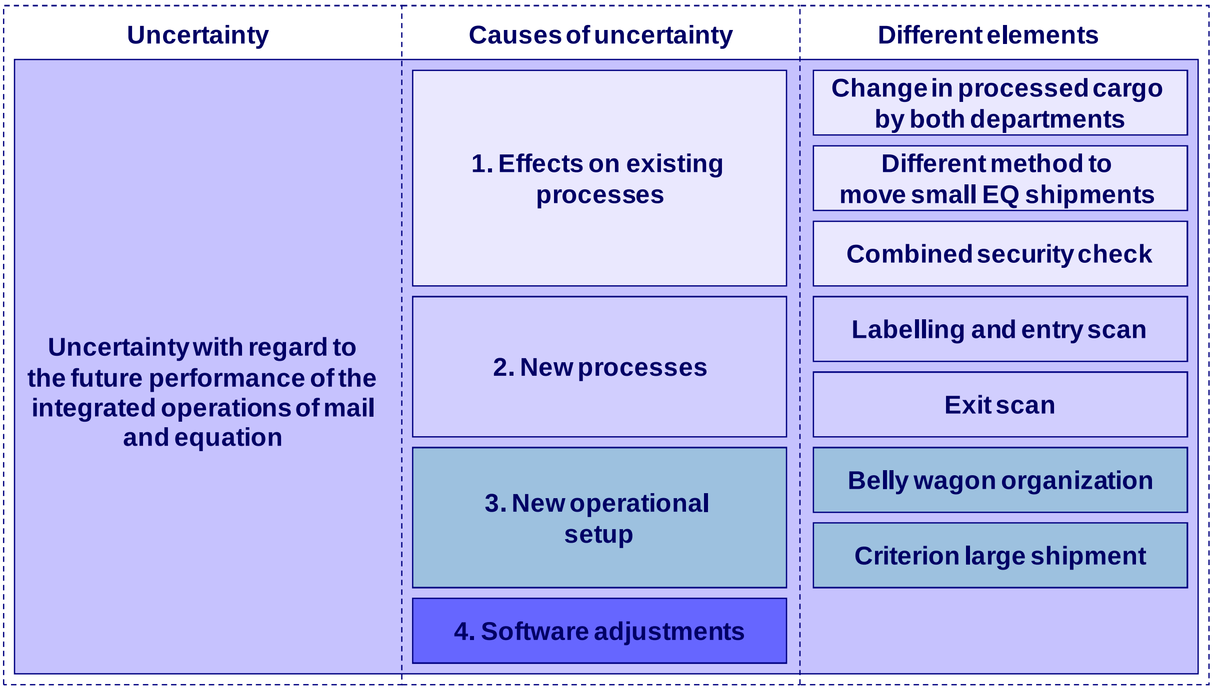


Figure 3: Composition of the uncertainty related to the future performance

It is expected that the operational performance will be influenced significantly by changed existing processes, new processes, the new operational setup and the software adjustments. It is even possible that the performance of the mail or/and the equation process will be worse after the integration. The following performance areas are relevant when evaluation the effects of the integration:

- Resource utilization
- Handling times at the airmail and EQ department
- The required number of belly wagons locations around the carousel
- The share of all cargo that can be transported by an earlier flight due to the FIFO-principle, or the share of cargo that will miss their initial flight due to delays in the operation. This will be summarized as the "number of re-bookings" from here for both mail and EQ.

In paragraph 4.2 these performance areas will be further decomposed to specific performance indicators. These indicators will be derived with the enhanced knowledge on KLM Cargo's commercial environment (chapter 2) and of the operations (chapter 3).

1.2 Research goal

Three of the four identified causes of uncertainty (Figure 3) will be of influence for the physical operation: effects on existing processes, the addition of new processes and the new operational organization. In order to deliver reliable estimates of the future performance of the combined operations, this research should provide an integral approach, which incorporates the uncertainty and interdependencies between processes. The estimates should be compared to the performance of the existing operations to determine the effect. Without an integral approach the results will be destined to be non-convincing in the decision making process. Therefore the goal of this research is:

Determining the effects of the integration of the airmail and EQ departments on the overall performance of the physical KLM Cargo operations in FB1

The results of the business case can be updated with the new estimates. This information is useful when deciding whether or not KLM Cargo should proceed with the integration.
Although the focus of the research will be the future operations in FB1, it might be possible to reflect on the impact of the JUMP based on the results of the integration at FB1. In this way the research could be valuable for the period after the JUMP as well.

1.3 Preliminary demarcation

The focus on the physical process in FB1 results in the following demarcation.

Location
Only the operations in FB1 related to the airmail and EQ department are taken into account. This implies that all activities from the acceptance or the release of mail and EQ on the landside, to the delivery or acceptance of mail and EQ in belly wagons at the transportation department at the airside are relevant for this research.

Employees
Only the employees directly involved in the physical flow of belly wagons, mailbags or EQ products are subject to this research. The effects of the integration on jobs supporting and coordinating these activities are outside the scope of this research.

Software
The required software alterations are outside the scope of this research, as mentioned previously. The software should support the combined operation of EQ and airmail, therefore different elements of the strictly separated software packages of airmail and EQ have to be combined.
The software alterations are the responsibility of a separate project team. This team will work on the software alterations parallel to this research. Regular meetings with this team will ensure that requirements for the physical processes deriving from the software alterations are communicated.

1.4 Research questions

In this paragraph the main research question and the sub-questions of this master thesis are formulated.

1.4.1 Main research question

The main research question will be derived from the research goal. The main research question will concentrate on the performance of the integrated operations of the airmail and EQ department.

MQ: What is the effect of the integration of the airmail and EQ departments on the overall performance of the KLM cargo operations in FB1?

Before it is possible to answer the main research question the organization of the combined operational processes will have to be worked out in detail. The method used to answer the main question has to give due weight to the interdependence of the different processes in FB1.
A quantitative method will be used to calculate the future performance of the operation of EQ and airmail. A clear view on the current performance of KLM Cargo operation in FB1 is required in order to compare this with the future situation.

1.4.2 Sub-questions

To answer the main research question, the three remaining uncertainties identified in the problem specification (paragraph 1.1) should be further investigated. Prior to dealing with the uncertainties of the integration project it is necessary to completely understand the air cargo industry and the involved stakeholders.

KLM Cargo's commercial environment

The integration of the two cargo departments at FB1 of KLM Cargo seems a relatively straightforward company decision. Nevertheless the decision is partially inspired by external influences. In order to understand all motives for the integration one has to understand the KLM Cargo's commercial environment.

SQ1: What external forces have influenced KLM Cargo's decision to integrate the airmail and EQ department?

In order to answer this first research question industry supply chain, stakeholder and demand analyses will be carried out in chapter 2.

Effects on existing processes

The answer to the second sub-question will capture the pure effect of the shift in workload between the EQ and airmail when integrated. No new processes are added and only the minimum required changes are made to make the integration possible when answering this question.

SQ2: What is the effect of the integration on the performance of the existing processes at the airmail and EQ department?

With this question the effects of the pure integration are isolated, because the changes to the operation are restricted to a minimum. KLM Cargo's expected advantages of the integration project should come to light when answering this first question. From this point only more processes will be added to the operation, which are expected to undo a part of this initial gain.

New processes

The next step will be calculation of the effects of the addition of new processes. The new processes are: attaching labels with barcodes when necessary, making an entry scan and performing the exit scan when cargo is taken off the carousel and placed in a belly wagon. The situation including the new processes will be compared to the answer of the previous sub-question.

SQ3: What is the effect of the addition of new processes on the integrated performance?

New operational setup

In paragraph 1.1 the uncertainty related to new operational setup is divided into two elements: the large shipment criterion and the belly wagon organization.
In first instance the large shipment criterion from the sales department will be used, but there is no reason to assume this criterion will lead to desirable result in the operation. Therefore the sensitivity of a change in the criterion on the performance will be interesting to research.
The demand for space, for each destination location[1] along the carousels and at the EQ storage yard, will be determined to find a possible organizational setup of belly wagons for the integrated situation. These two uncertainties will be taken into account when answering the following sub-question, SQ4.

---

[1] The location to store all cargo for a certain destination along the carousel is described as "destination location" from here

SQ4: What are the effects of refining the operational setup of the combined operation?

The research approach used to retrieve the answer to the different research questions are discussed in the next paragraph.

1.5 Systems engineering as research approach

In this paragraph the choice for the research approach is explained. Systems engineering is a human, organizational and technology-based effort that is inherently multidisciplinary in nature. Often the studied systems are large in scale and in scope. The system will exist out of many parts and these can be related to each other in a sometimes complicated way [Sage et al., 2000]. SE considers the systems as a whole rather than focusing on the individual components [Pielage, 2005].
System engineering will fit the specified problem at KLM Cargo. The specified problem will require the design of alternatives regarding human, technological and organizational aspects. Numerous aspects have to be taken into account, which at the same time will influence each other. All characterizations of systems engineering will necessarily involve three logical steps [Sage et al., 2000, p.54]:

- formulation of the SE problem under consideration
- analysis to determine the impacts of alternatives and interpretation of these impacts in accordance with the value system of the decision maker(s)
- selection of an appropriate plan of action to continue the effort

The next paragraph will explain what research methods were used to make these steps.

1.6 Research Methods

The methods used to answer the research questions of this research will be described in this sub-paragraph, the division of the system engineering steps will be maintained.

1.6.1 Formulation of the problem

At the start of this thesis project, different methods were used to gain knowledge on the operation in FB1 and on the commercial environment of KLM Cargo. The following activities enlarged the relevant knowledge considerably:

- Engaging in project team meetings and IT-team meetings.
- Literature study of scientific research as well as internal project related material. This resulted in a supply chain analysis, an actor analysis and a demand analysis.
- Interviewing sales managers and operational managers (appendix R). A sales manager will take the customer perspective into account. The operational manager will primarily look at the stakes of the employees and possible bottlenecks in the new situation.
- Visit to the terminal of Sodexi at Charles de Gaulle airport in Paris, France. This operation is an example for the integrated situation in FB1.
- Observing the operation in FB1 and asking explanations of employees why certain activities are performed the way they are performed.

1.6.2 Analysis steps by means of simulation in Arena

The analysis steps involve the evaluation of the specified alternatives on the objective measures from the value system design.
Discrete simulation has been used to quantify the effects of the proposed integration. Discrete simulation models make it possible to determine the effects on the integrated operations for all alternatives. The decision to use discrete simulation was made for several reasons:

- The mail and EQ products are discrete entities. Each product has its own characteristics, which will influence the processes in their own way (e.g. size, destination, weight, shipment)
- Simulation gives due weight to the interdependencies between the different processes in the FB1.
- Various interrelated processes in the operation have a stochastic character in reality. Discrete simulation can incorporate the stochastic character of these elements (e.g. process times, inter-arrival times etc.)
- It will be relatively simple to experiment with different alternatives and compare and rank the alternatives on basis of the results of the simulation.
- Animation could be used to improve the understanding of in the integration and the selected alternatives.

The insights from the animation or the analysis of the results could give reason to refine the alternatives.

Simulation program
The simulation software package of Rockwell software will be used, which is called "Arena". Arena has the possibility to visualize the integrated operation and the accessibility of the program is relatively high, because no specific programming language has to be learned to use it.

1.6.3 Interpretation steps

During the interpretation stage the effects of the integration will be determined for various performance indicators. The differences between these performance indicators of the different model configurations are tested on significance with a paired Student t-test. A net present value analysis is used to evaluate the changes in efficiency.
The results will be communicated to KLM Cargo's management clearly. The deliverables exist out of this thesis report and (interim) presentations. The simulation model will be too complex to hand over as a deliverable.

1.7 Report outline

A pure simulation study has a specific approach (Verbraeck and Valentin, 2005, p.9). The sequence of the step-by-step analysis of a simulation study (Figure 4) is used to structure this report, although a systems engineering approach is taken for this research. This is possible because the step-by-step analysis and system engineering approach show resemblance. A thorough understanding of the problem is required before a simulation model can be build. The situation at hand is analysed with the simulation model, which can be refined based on analyses of earlier results. The simulation results are used to compare and rank different alternatives in the end. These stages in the simulation study overlap with the formulation, analysis and interpretation steps of the systems engineering approach. The specific report outline of this thesis will be described below and is based on Figure 4.

Chapter 1 has introduced the integration project and specified the problems of KLM Cargo. The problem specification leads to the main research question and four sub-questions. Systems engineering is chosen as a research approach and discrete simulation will be used as main research method.
Chapter 2 will describe the commercial environment of KLM Cargo and answers the first sub-question of this research. The chapter contains a supply chain analysis, stakeholder analysis and a reflection on the air cargo demand.
Chapter 3 explains the general goal of the activities in FB1 and describes the current airmail and EQ processes separately. Although the products have mutual characteristics, differences are present as well. These differences should be taken into account in the design of the integrated

situation. Afterwards the descriptions of the operations in FB1 are used to compose the conceptual models. The conceptual models will be used as the basis for the simulation model.

In chapter 4 the transformation from the descriptions of the operations in the previous chapters towards the simulation model is made in different steps. First the goal of the simulation model and the performance indicators for the evaluation are stated. The transformation from the conceptual models towards the simulation model description with a certain required output and input is explained subsequently. The verification and validation of the simulation model is the subject paragraph 4.7 and the last paragraph of chapter 4 contains the results of the sensitivity analysis of the simulation of the current situation.

Chapter 5 discusses the results of the simulation of the current situation in FB1. First, experimental design used to run the model is explained in paragraph 5.1. Followed by the description of the results of the simulation for the current situation for all four performance areas.

The integration proposal will be the subject of chapter 6. First the project objectives, constraints and requirements are enumerated. Afterwards the relevant observations from a visit to Sodexi in Paris will be discussed. Subsequently the integration proposal is explained and the elements which are still causing uncertainty related to the integration are discussed. Chapter 6 concludes with a quantitative data analysis of the integrated situation.

The results of the experiments with the simulation model of the integrated situation will be discussed in chapter 7. These results will be compared to the results of the base case derived in chapter 635. With the results of the simulation it will be possible to refine the integration proposal. Chapter 8 contains the conclusions based on the results discussed in chapter 7, which lead to an advice for KLM Cargo. Afterwards recommendations can be made for further research and for the situation after the JUMP. Finally the limitations of this research are discussed at the end of this chapter.

The epilogue will form the last chapter of this master thesis and will contain an academic and personal reflection.

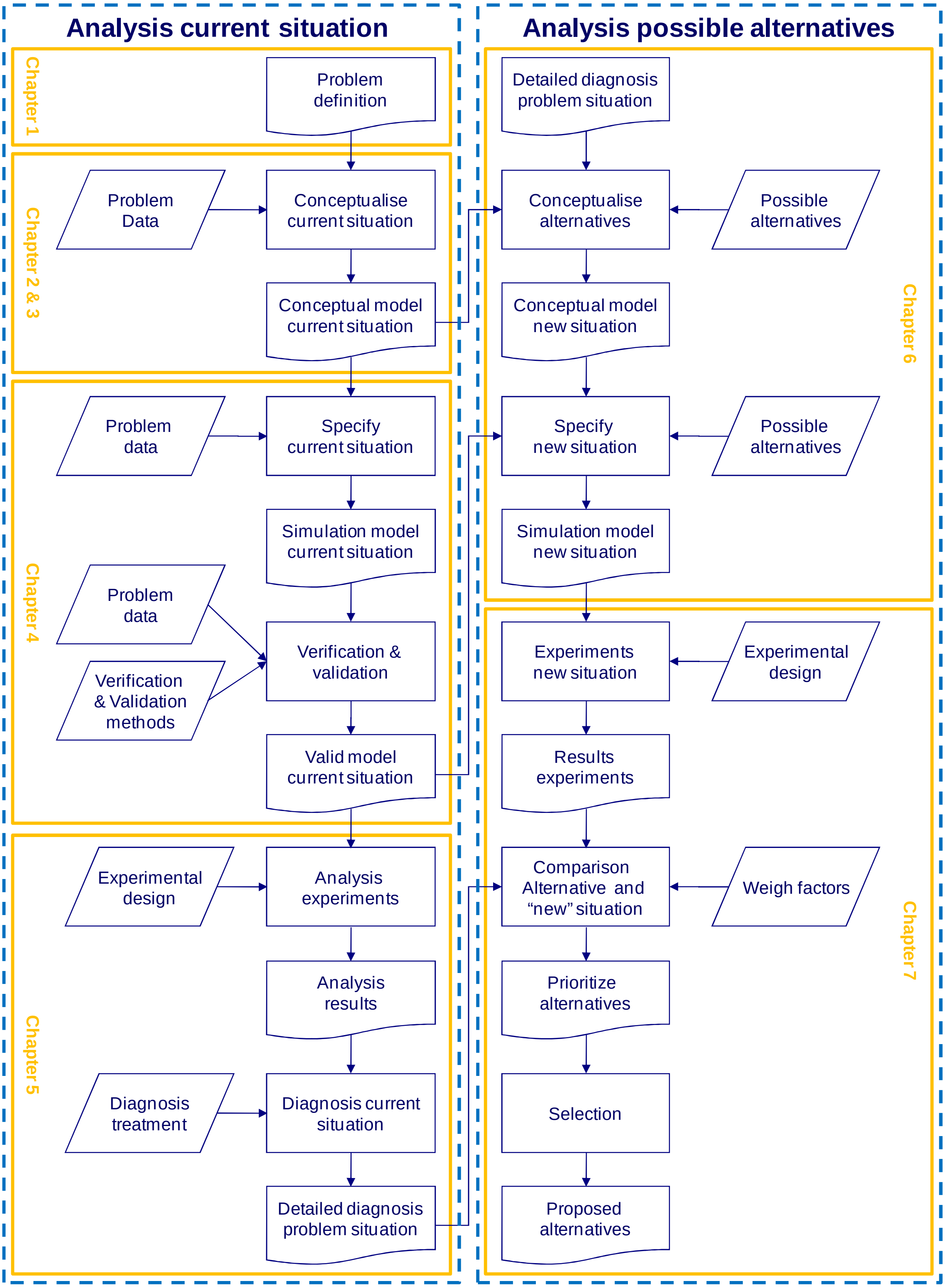


Figure 4: Step-by-step analysis of a simulation study (Verbraeck and Valentin, 2005, p. 9)

2 KLM Cargo's commercial environment

KLM Cargo operates within an industry with specific characteristics and various involved stakeholders. Paragraph 2.1 summarizes the detailed industry supply chain analysis (appendix B) and will describe the position of KLM Cargo in the air cargo industry. Subsequently the summary of the stakeholder analysis (appendix C) is placed in paragraph 2.2. Paragraph 2.3 will describe the composition of the demand for air cargo (summary of appendix D).
The analyses in this chapter should result in the answer to the first sub-question of this thesis.

2.1 KLM Cargo position in the air cargo supply chain

Liberalization and deregulation has increased competition, which forced down the profit margins. The low profit margins, together with the capital-intensive and demand-sensitive character of the airline industry, make it hard to survive in the airline business. As a result a wave of consolidations has gone through the airline industry (KLM, 2007), which has changed the composition of the airline industry during the last decade.
The traditional supply chain (Figure 5) will cover the transport of goods from the shipper to the consignee. In between the forwarders are responsible for the coordination of the transportation, performed by the ground service provider at both airports and the airline carrier between airports.

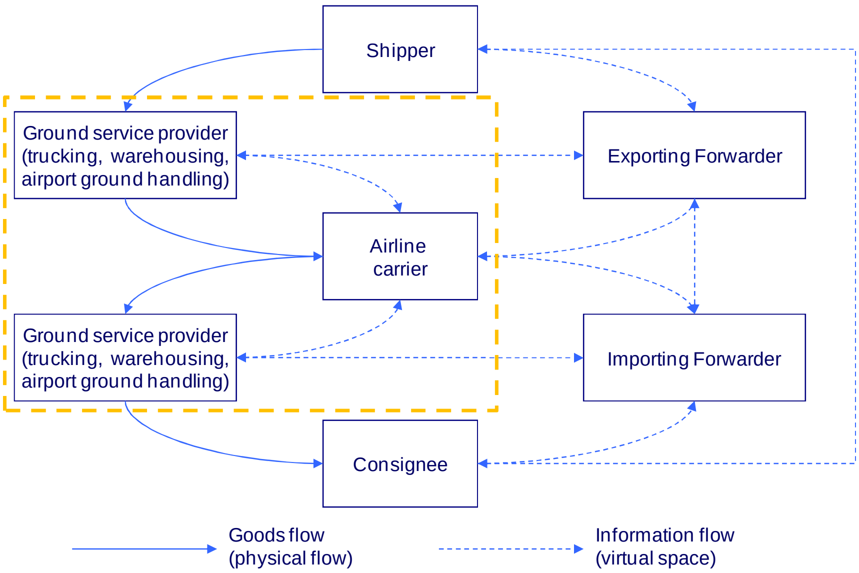


Figure 5: Traditional air cargo supply chain (Schwarz, 2005)

KLM Cargo combines the traditional separated functions of the airline carrier and the ground service provider (Figure 5, orange square). The transport to and from the plane is the responsibility of KLM Cargo at Schiphol, as well as the sorting and warehousing of import and export cargo in the freight buildings. Only the road transport to and from the freight buildings is not the responsibility of KLM Cargo. KLM only offers door-to-door responsibility for one product type, Cohesion. For transit cargo an additional trip by plane could be added to this traditional supply chain.
Liberalization created possibilities for horizontal and vertical integration within the highly fragmented air cargo supply chain. The air cargo industry consolidated on three levels: between airlines (by mergers and alliances), between forwarders and by companies vertically integrating all activities in the supply chain, the so called integrators.

Integrators pursued innovative strategies for infrastructure, product and information technologies. They focus on high value business documents or parcels, enabling standardized packaging, simplified pricing and documentation. Their technology strategy developed tracking and tracing technologies and internal information systems for monitoring system-wide performance (Forster and Regan, 2001)
The integrators can achieve economies of scale by bundling flows of cargo, but at the same time integrators are competing with a lot of different players, because they offer services in various areas (Schwarz, 2005). Asset specific investment, reduced organizational flexibility and market responsiveness are risks associated with vertical integration (Forster and Regan, 2001).

2.2 Stakeholder analysis

The stakeholder analysis is divided into the stakeholders within the company and industry with relation to the integration project and stakeholders involved in the decision to JUMP with the freight buildings to another location at Schiphol.

2.2.1 Project related stakeholders

Various stakeholders, internally and externally, have interest in the integration project. Table 1 summarizes the findings of the detailed stakeholder analysis (Appendix C).

Table 1: Summary of the project stakeholder analysis

Stakeholder	Goals related to integration project	Possible conflict
Internal stakeholders		
KLM Cargo management	- Alignment with Air France Cargo - Increase efficiency - Increase customer service level - Gain experience and knowledge for the design of the new terminal - Comply to "Arbo"-law - Ensure operational continuïty	- Internal conflict on responsibilities
Operational management	- Smooth integration between mail and EQ	- Losing responsibility - Losing believe in realization of the project
Operational workforce	- Being able to use the build-up routine in their tasks in the new situation	- Losing job
Customers		
Shippers	- Faster transport of shipment - Lower tariff for air transport	- None
Forwarder	- Lower tariff for air transport - Improve customer service - Faster transport of shipment	- Could retreat cargo when KLM tries to by-pass the forwarders in the future
Integrators (as cutomer)	- Lower tariff for air transport - Improve customer service - Faster transport of shipment	- None
Competitors		
Integrators (as competition)	- Gain market share	- Retreat cargo when KLM Cargo is aiming at their customers
Competitive airlines	- Maintain their market share of air cargo arriving and leaving Schiphol	- None
Ground handlers at Schiphol	- Maintain their market share of ground handling at Schiphol	- None
Regulatory bodies		
IATA	- Increase uniform and electronical communication of documentation	- None

Internal stakeholders

Internally the integration project, proposed by the KLM management, will have consequences for the operational management and operational workforce. Whereas the integration has the goal to reduce the total number of employees required for the same performance, people will lose their job. In first instance the number of temporary workers will be reduced, but in the end the size of the operational management and the permanent operational workforce will be reduced.

The operational management also demands a smooth transition to the integrated situation. They will have to solve the problems once the integration is realized. The growing skeptic feelings of the operational management due to the postponement of the project will not contribute to their belief in the project.

External stakeholders

The customers of KLM Cargo will benefit from the integration as long as the performance will not become worse and the continuity of the operational process is ensured. The goal of the integration project is to improve the performance and customer service.
Although the competitors will not like it when KLM improves their handling process, there is not much they could do to block the project. Important addition to this remark is the fact that the performance of the ground handling is just one of various aspects (e.g. network coverage, price) determining the choice for a carrier.
Integrators have more power to oppose to the integration, because they are in the special position of being customers as well as competitors of KLM cargo. The EQ product competes with the integrators express services. But integrators use KLM to ship cargo to smaller destinations, which they do not service themselves. Only when the volumes justify a dedicated service to a destination, an integrator will fly to the destination itself.
In the end the integrator will need other carriers to bring cargo to destinations with low volumes. For this cargo the expected improved performance is beneficial for the integrator.

2.2.2 JUMP related stakeholders

Only two actors are involved in the decision process of the JUMP at the moment (Table 2), KLM Cargo and Schiphol airport. The negotiations between Schiphol and KLM are difficult. KLM has no need to move in the near future. The required investment in a new terminal or the lease of the building will be higher than at the current location. For KLM Cargo the new terminal will be at a larger distance from the gates, which will increase the time required to handle cargo. The transportation department will have more difficulty to meet the maximum release time between touchdown and release at the terminal, whereas transportation has difficulty meeting this demand already. Schiphol would like to make room for expansion of the passenger terminal and would like to group all logistics activities at Schiphol.
Both stakeholders want to remain on good terms with each other. KLM wants to be compensated for their loss and wants to postpone the investment towards better times and Schiphol does not want to pay too much and would like a fast decision process at the same time
The different stakeholders in the JUMP have a difference in interests; nevertheless there is no unwillingness to reach a negotiated agreement. It seems to be the question "when" KLM and Schiphol will reach an agreement, not "if" they will eventually reach an agreement. Therefore it is interesting to reflect on the JUMP in this research.

Table 2: Summary of the JUMP stakeholder analysis

Stakeholder	Goals related to the JUMP	Possible conflict
	Internal stakeholders involved in the JUMP	
KLM Cargo	- Opportunity to build a best-in-class new hub - Optimal negotiation result while there is no urge to move '- Remain on good terms with Schiphol	- KLM Cargo can not collect enough capital to invest in the new terminal - Facilities of the offered alternatives are below KLM's demands
Schiphol	- Bundling all logistic activities at Schiphol '- Create room for expansion of the passenger terminal '- Remain on good terms with KLM	- No positive outcome of the negotiations because (e.g. KLM tries to squeeze out Schiphol too much)
Transportation department	- Max. 60 minute transport plane and terminal	- Set unrealistic target in new situation

2.3 Demand for Air cargo

The demand air freight and travel by air are closely related to consumer confidence and consumer spending (IATA, 2008a), this implies that the demand for air transport is very volatile. At the same time the airline industry is very capital-intensive. The combination of a volatile demand and a capital-intensive industry incorporates risks. The costs of the planes for an airline cannot be changed on the short term, because the economic lifetime of an airplane is more than a decade (Air France KLM, 2008a, p.9). At the other side the demand can change drastically. This will make it very important to forecast demand. Nevertheless, predicting demand for air transport will be very complicated due to its complexity (see Figure 49).
The forces determining demand are numerous, which makes it difficult to forecast demand. Estimates of future demand for air transport are in general based on macro economic variables like Gross Domestic Product (GDP), exports, imports, unemployment rate, inflation, private consumption and disposable personal income. Estimates of future demand can not only be based on macro economic variables only, it will also depend on several other factors, which will be different around the world: e.g. the price of air travel, population growth, demographic changes, network developments, market liberalization and deregulation (Airbus, 2007) (Boeing, 2006, p.13 & 2008)

The last decade also showed that the models used to predict the development of the demand did not incorporate certain incidents influencing demand: the terrorist attacks on the WTC in New York in 2001, the SARS epidemic and Iraq war in 2003, the financial crisis started in 2008 and (more locally) the introduction of the "Vliegtaks" in the Netherlands in 2008.

2.3.1 Long term demand expectations

Long term expectations of the market growth may cancel out the short-term effects of incidents. Therefore these seem to be most reliable as basis for a rough sketch of the future demand.

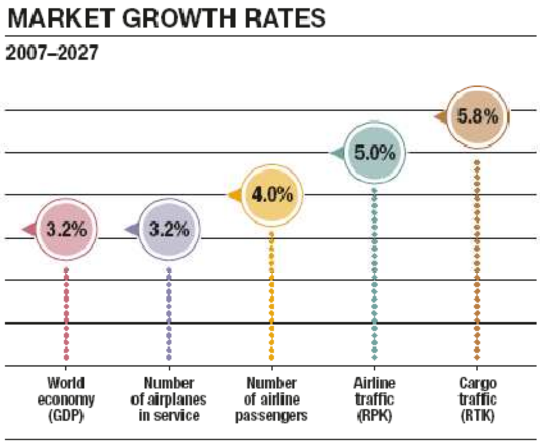


Figure 6: Summary of growth rates in the aviation industry (Boeing, 2008, p. 2)

The annual growth of passenger transport worldwide is estimated on 5%. The annual growth will differ between regions in the world (see Table 31 in appendix D.2). Freight demand is driven mainly by economic growth, globalization and trade, but freight is also facing increased competition from other modes such as shipping. Air cargo is expected to grow with 5.8% (see Figure 6) on average every year (Boeing, 2008, p. 2). The most dynamic freight markets are those associated with economies that are both fast-growing and rapidly integrating into the global economy (IATA, 2007a). Interesting aspect of cargo flows is that the flows are unbalanced (Zhang and Zhang, 2002).

Currently the financial crisis is causing a great downturn in the demand for air transportation and was not expected by the industry. It shows again that forecasting the air cargo demand is very difficult.

2.3.2 Drivers of the growth of demand

The global economy demands rapid and reliable business-to-business exchange. Air cargo transport can make such exchange possible. Manufacturers depend on air freight for efficient inventory management and to source components and assemblies from world markets, two logistic elements which have gained importance the last twenty years. The growth of air cargo has been benefiting from recent developments in logistics. Using transport by air can help to reduce inventory and will reduce the time to put product into the market. The reduction of product lifespan in many industries (clothes, computers, pharmaceutical) makes it more important to decrease transport time from manufacturer to the shop. Outsourcing of production building blocks to countries, that passes a comparative advantage in that type of productive activity, stimulates the demand for transport services, and intensifies the search for a more efficient trade regime in international air cargo services (Zhang and Zhang, 2002).

2.3.3 Expectations for airmail and EQ products

The market for international express products represented 11% of the total international air cargo in 2005. The average international express shipment size grew from 2.7 kg in 1992 to 5.4 kg in 2005, further enlarging the overall express component of international air freight traffic. As businesses continue to expand beyond domestic or close regional markets, the international express sector will continue to grow, although the growth rate will become a more sustainable, long-term rate (Boeing, 2006, p.4). The growth rate of the express products will be higher than the overall growth of air cargo of 5.8%, because the market share of express products remains growing.

The growth of the market for airmail will be below the average market growth. The growth of airmail is strongly correlated to the GDP and less dependent of other variables. The airmail sector is expected to grow with 2.5% per year to 2025 (Boeing 2006, p.16).

2.4 Sub-conclusions on KLM Cargo's commercial environment

In this chapter the commercial environment of KLM Cargo has been described. With the understanding of this commercial environment it is possible to answer the first sub-question of this research.

SQ1: What external forces have influenced KLM Cargo's decision to integrate the airmail and EQ department?

The airline industry is consolidating with different types of alliances or mergers. The cconsolidation also takes place in other part of the supply chain, integrators are gaining market share and the forwarding business is dominated by large multinational consolidated forwarders.

Air France-KLM has a strong position at this moment due to the consolidation of their operations and their extensive network. The integration project fits well in the strategy to align the operations of Air France and KLM and exchange best practises.

The expected growth of the express market is one motive for KLM Cargo to search for improvement in their handling process for EQ. KLM wants to maintain or increase their current market share. In case KLM Cargo can maintain their market share, the growth of EQ will be above the cargo the market average of 5.8%. The performance of the ground handling is an important aspect for the competitive position and therefore interesting to improve. Although the growth of the airmail volumes is lower, KLM cargo still wants to serve their customers right and remain one of the most important carriers in the airmail industry. Therefore the improvement of

mail registration and communication could be beneficial to KLM Cargo's competitive position. The growth rates for the two products estimated in this chapter will be used to perform a sensitivity analysis of the simulation model in paragraph 4.8.
The stakeholder analysis has provided no reason to abandon the integration of both departments at FB1. With respect to the JUMP it is safe to say, that KLM Cargo will make the JUMP, but it is still the question when this is going to take place.
This chapter has provided a clear description of the commercial environment of KLM Cargo and has identified the stakeholders involved in the integration of the operation of Airmail and EQ. The motives for KLM Cargo to research the integration between mail and EQ from an industry point of view are clear at this point. The findings of this chapter will help identifying the relevant performance indicators to evaluate the integration in paragraph 4.2. In the next chapter the actual handling process of airmail and EQ will be described.

3 Handling processes of airmail and EQ in FB1

The operation of KLM Cargo in FB1 will be described from top to bottom. The general purpose of the operations in FB1 is briefly explained first in paragraph 3.1. Afterwards the current operations of mail and EQ are described in paragraph 3.2. A schematic overview will display the product flows, location of processes, conveyor belt infrastructure and belly wagon locations. For both departments a time-place analysis is made and these are placed after the description as a link between the description and reality. Conceptual models of the current operations of mail and EQ are composed in paragraph 3.3. Subsequently paragraph 3.4 will emphasise the differences between the airmail and EQ product. In paragraph 3.5 important findings of this chapter are enumerated.

In this chapter the operations will be described on a low detail level. In appendix I a more detailed decomposition of all processes is made, resulting in a high detail overview. In appendix E.1 a detailed drawing of FB1 is placed.

3.1 General goal of the airmail and EQ operation

Both the airmail and EQ handling in FB1 are designed to handle three cargo flows: export, transit and import. The cargo arriving at the landside will be sorted on destination (mail) or booked flight (EQ), in order to fly the **export** shipment to the right destination. The **import** cargo will have Schiphol as final destination and **transit** cargo continues its journey by plane from Schiphol. Airmail departing Schiphol by plane will be sorted on the next destination of the mailbags. The First-in-first-out (FIFO) principle is used to process the mailbags.
EQ packages departing Schiphol by plane are sorted on booked flight number and date. At EQ, priority is given to the packages with the shortest time until departure.
The transportation of cargo from arrived planes to the KLM terminal is the responsibility of the transportation department. A belly wagon will only contain one cargo type, airmail or EQ; otherwise the product ends up in the wrong handling process. The capacity of a belly wagon will be approximately 2.7 m^3. The departing cargo, both airmail and EQ, are placed outside FB1 after sorting and brought to the plane by the transportation department.

Figure 7 is illustrating the flows of cargo through FB1. Lateral transport between FB1 and FB2 & 3 is also displayed in the figure. The existence of the flow with lateral cargo is explained on page 33.

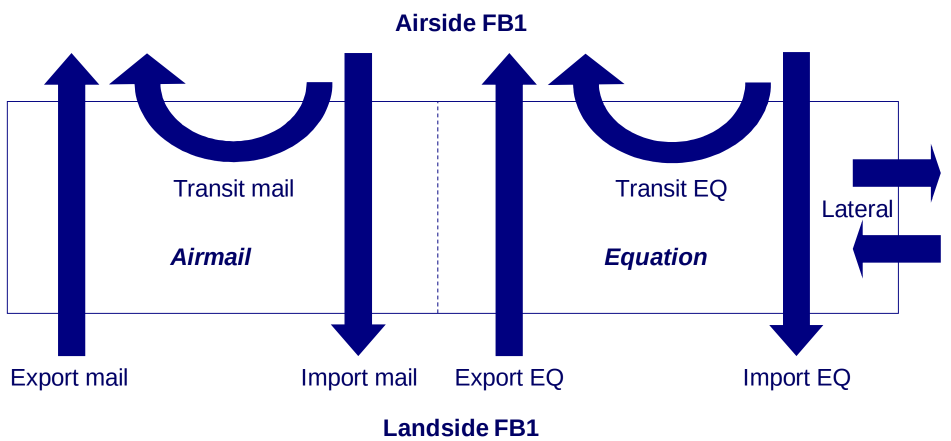


Figure 7: General cargo flows in FB 1

Table 1 shows the monthly performance of the mail and EQ department. The division into flow types reveals that transit mail represents almost 80% of total handling of airmail. Import and export mail are both representing about 10% of the bags handled in FB1. The AF/KL network is used by postal companies around the world to deliver mail and Schiphol is used as a hub in this network. KLM also provides the transport of airmail for TNT, the postal company in the Netherlands. The domestic market is responsible for a relatively small share of the cargo flow in FB1, because the terminal at Schiphol is performing a hub function for airmail from all over the world.
At the EQ department the division between the five different flows is more equal. The largest flow consists out of the import EQ and contains 37% of all processed colli.

Table 3: Production of EQ and Mail operation September 2008 (KLM Cargo, KPI report and Cargo Planning Reporting)

Production september 2008	Mail			EQ			
Flow	Bags (#)	Weight (kg)	% of total (# of bags)	Colli (#)	Weight (kg)	Volume (m^3)	% of total (# of colli)
Export	17,097	120,902	10%	17,588	862,409	6,568	14%
Import	18,769	141,162	11%	46,716	943,009	6,211	37%
Transit	136,279	1,135,940	79%	19,460	274,380	1,668	16%
Lateral incoming	-	-	0%	22,625	324,276	1,791	18%
Lateral outgfoing	-	-	0%	19,054	302,650	1,531	15%
Total	**172,145**	**1,398,004**	**100%**	**125,443**	**2,706,724**	**17,769**	**100%**

3.2 Present situation in FB 1

At this moment the airmail handling and EQ handling are strictly separated. In this paragraph the current operation of both departments will be described.

3.2.1 Airmail operations

Almost all airmail arrives at the airside of the terminal, because most of the airmail is transit mail from planes and because TNT has a mail warehouse at the Schiphol premises. The TNT warehouse (CAS) can be reached over the airport platform and therefore domestic mail will depart and arrive at FB1 from the airside as well. Arrived airmail at the airside will be stored at the transportation department in belly wagons until an airmail employee will come out and pick up a train of belly wagons.
Trucked mail is the only mail arriving at the landside of FB1. This can either be a truck between airports under a flight number or a truck from or to postal companies which retrieves import or delivers export airmail. The airmail arriving by truck is unloaded and stored inside the terminal until its turn to be unloaded on the belt at the input locations. Often this mail is stored on an ULD (Europallets, roller cages, aviation containers) otherwise it is placed in belly wagons.
Arrived airmail will be collected by an employee and brought to the input locations (Figure 8, nr 18). Here the mailbags and -boxes are unloaded and put on the conveyor belt at one of the two input locations. The barcodes, on the labels attached to the mailbags, are scanned at the same location. The labels are scanned directly after bags are put on the belt. Sometimes the barcode is missing or damaged, in this case the information is communicated with a headset to an office employee. In this way the incoming mail is registered, this activity is called RIM-ing (Register Incoming Mail) at KLM.
During their journey on the conveyor belt, the mailbags are manually divided into three flows at the switching location in the belt system (Figure 8, nr. 17). Each flow is destined for one of the three conveyor belt carousels (Figure 8, nr 16). Each carousel will cover the destinations of one of the following three geographical areas: Europe, USA and ICA representing Asia, Middle East and Africa destinations. In Table 4 the division over the three different carousels is displayed. The division is based on the airport codes of the destinations of all mailbags.

Table 4: Division of bags over the three carousels for September and October 2008 (calculated results)

Carousel	Mailbags	Volume (m^3)	% of total nr of bags
EUR Carousel	175756	11933	44%
USA Carousel	106176	7999	27%
ICA Carousel	117438	8051	29%

Around 90 belly wagons are located along the carousels. One belly wagon represents one destination. Some mailbags will reach their final destination via another destination. These via-destinations (appendix F) are known to the employees and the employees will put the via-bags in the belly wagon for the next destination after Schiphol. Employees walking along the carousels are matching the destination on the label of the bag with the destination of the belly wagon. When the destinations of the bag and belly wagon match, they put the mailbags in the right wagon.

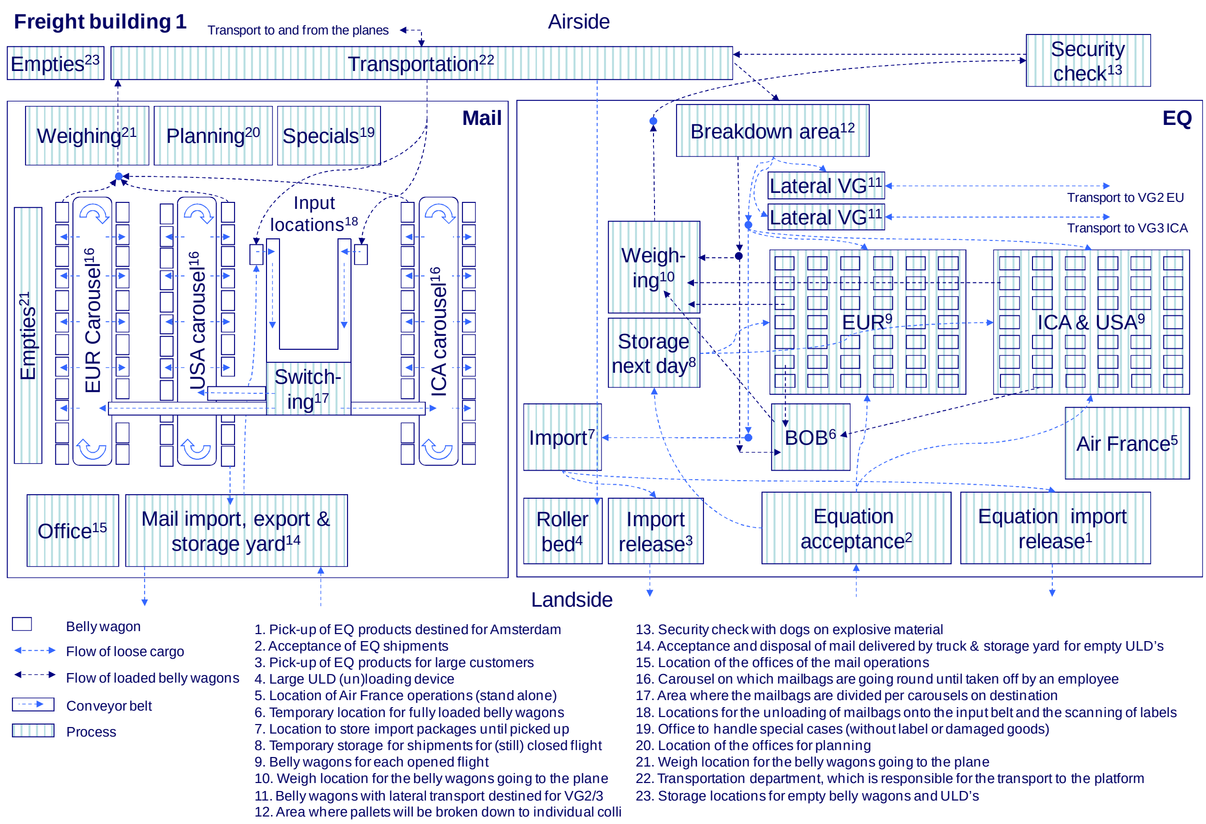


Figure 8: Schematic illustration of the current situation in FB1

An hour and fifteen minutes before the departure of a flight to a destination, the corresponding belly wagon will be collected and driven to the weighbridge (Figure 8, nr. 21). In most cases employees will collect several wagons with almost the same deadline in order to form a train. The maximum number of wagons in a train is six. At the weighbridge each wagon is weighed individually (photo: Figure 59 in appendix F). After the weighing the same employee picks up a bag with documents from the office for every flight. The bag with documents is put on one of the corresponding belly wagons.

Finally the train of weighed belly wagons is brought outside to the transportation department (Figure 8, nr 22). The transportation department is responsible for the last part of the transport to the plane.

Example of mail handling

In order to link the description in this chapter with reality, two transit mailbags are followed through FB1. The time of arrival of the bag at different processes is registered. This makes it possible to compose a timeline of the flow through FB1. The arrival times are linked to the locations of those processes in FB1 to construct a flow in time and place on the map of FB1 (Figure 9). The differences between flows are small and because the transit flow is the largest, two examples of transit flows are assumed representative for the mail operation.

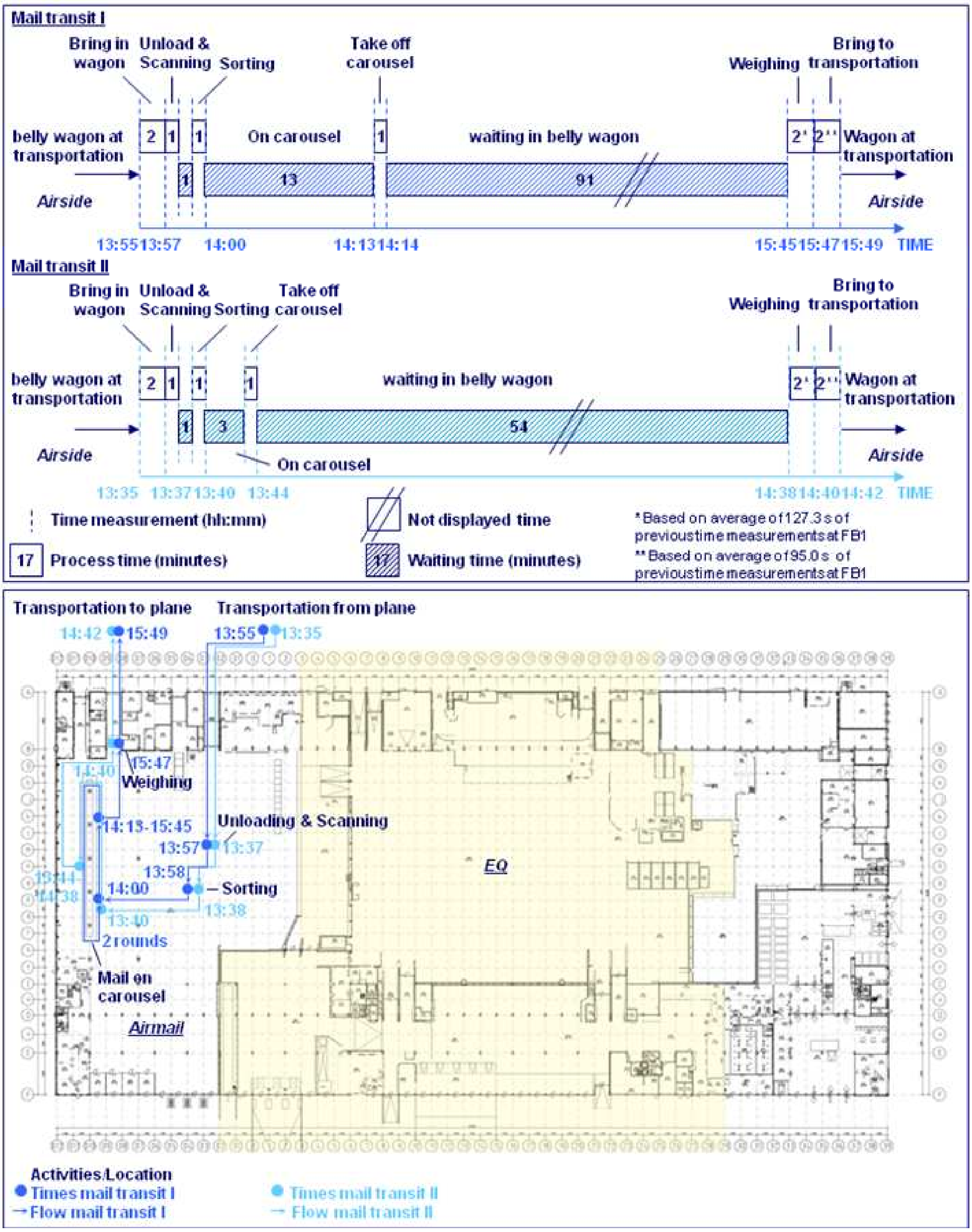


Figure 9: Time-place analysis of real example of mail transit

This example shows these bags are waiting most of the time they are in FB1. More than 80% of their stay in FB1 the bags are in the belly wagon along the carousel.

3.2.2 Equation operations

Most packages handled by the EQ department are carton boxes. The size and the weight of the boxes vary. Within FB1 most EQ shipments are placed on wooden Europallets and are transported with Forklift trucks (FLT's).
Customers will deliver their export express packages at the landside of the FB1. One label per shipment is placed a package and the shipment is transported to one of the belly wagons at the storage yard (Figure 8, nr. 9) after the ready for carriage check. Each belly wagon at the storage yard is dedicated to one flight. The export packages will be booked on a specific flight and the employee will match the flight of the wagon with the one of the booking.
Import and transit packages will arrive at FB1 from the airside. The transportation department will bring in the belly wagons or ULD's with arrived EQ packages Inside FB1 the wagons and ULDs will be waiting until the start of the break down. At the break down the different shipments are separated from each other and the cargo is placed on Europallets. The checker will count the number of packages and checks whether the shipment arrived complete. In some case it is not necessary to break down an ULD. In case an ULD contains only one large shipment for a specific customer for example.
After the check the dedicated pallets are brought to a belly wagon reserved for a specific flight, which matches the booking of the package.
Every EQ package is booked on a flight. This guarantee to the customer limits the flexibility of the EQ operation. An hour and half before flight departure the wagons for the flight are collected and weighed (Figure 8, nr. 10). The train of wagons is ready to be brought outside, to a lane at the transportation department.
On the way to the transportation department a security check with dogs is executed at the "Snuffelkuil" (Figure 8, nr. 13). The dogs specially trained can detect dangerous goods in the EQ packages on the belly wagon.

When the flight of a shipment arriving at FB1 is not opened yet, the packages of the AWB are stored in the temporary storage racks until the opening of the flight. Mind this requires a double movement to transport the AWB to the right belly wagon.

During the entire process the movement of packages to different locations is registered with the help of a real-time warehouse software program. At every move, the package barcode is scanned and the new location will be registered, in that way the location of the package is always known

Lateral transport

Sometimes other cargo products arrive on the same ULD as EQ products. When this ULD is broken down at EQ, these other products are placed in belly wagons dedicated for lateral transport (Figure 8, nr. 11). One employee is responsible for the transport of those belly wagons to FB2/3. This transport between FB1 and FB2/3 is called lateral transport.
The lateral return flow from FB2/3 exists out of general cargo of KLM, which will be transported in the belly of a plane, and EQ packages from ULDs, which are broken down at FB2/3. All the general cargo transported in the belly of the planes will be handled by the EQ department, because the EQ department is the only department which sends off bulk or loose products to the plane.

Example of EQ handling

For the EQ department a time-place analysis is constructed as well, resulting in Figure 10. This time an export and a transit shipment are followed through the process.

These examples show that EQ packages can also be waiting most of their time in FB1. More than 80% of their stay in FB1 (time between pick-up at transportation outside and the placement of the sorted EQ at transportation) the collo are in the belly wagon at the storage yard.
The real examples of mail and EQ show that there is a lot of room for certain mailbags and AWBs to add new processes without threatening the connection to the flight. It indicates that problems only arise for cargo with a relative short period between the arrival at FB1 and the (next) flight.

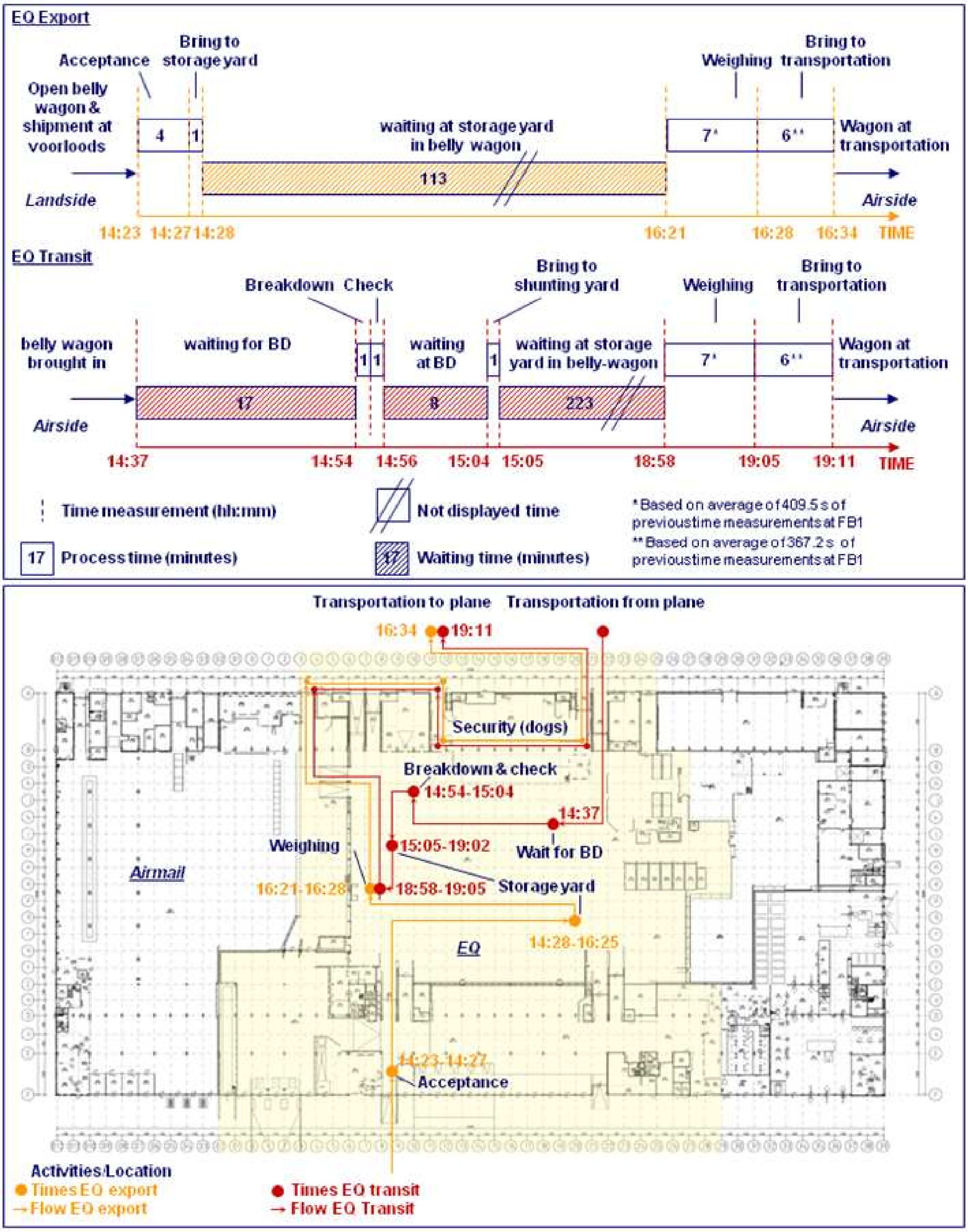


Figure 10: Time-place analysis of real examples of EQ transit (red) and EQ export (orange)

3.3 Conceptualization of the operations in FB1

The handling processes of mail and equation are analysed in detail in this chapter. In this paragraph conceptual models are constructed to order all information in a systematic way. In this paragraph the construction of the conceptual models is discussed. With the conceptual models the resources, controls, inputs and outputs of processes and the relation between the processes are indentified in structured way. The resulting models are explained in the appendix of this research, all IDEF-0 diagrams are placed in appendix I and the flowcharts are placed in appendix K.

The preliminary demarcation (paragraph 1.3) is applied for these models. The focus will be on the operational employees, movement of collo and the equipment required for these activities. Sub-processes are grouped together on the basis of employee functions as much as possible, because it is clear that the productivity of the different employees at FB1 will be of great interest for KLM Cargo.

3.3.1 Conceptualization methodology

Process-orientated analyses of the mail and equation operations are performed using IDEF-0 diagrams (Figure 11). Process-orientated models will show the relation between successive processes or activities (Verbraeck and Valentin, 2005, p.39) in the cargo handling at FB1. With IDEF-0 diagrams the resources and the controls required to perform the activities, transforming the inputs into certain outputs, can be illustrated.

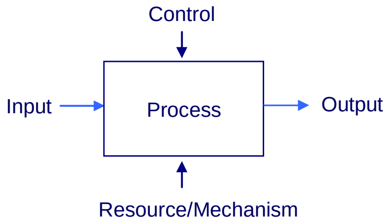


Figure 11: Basic elements of an IDEF-0 diagram (Verbraeck and Valentin, 2005, p.40)

Subsequently a time-oriented analysis is made using flow diagrams. Time-oriented models can be used to describe the dependencies between processes in the IDEF-0 diagrams. The flowcharts show the moments of choice in the operations of mail and EQ and the sequence between activities. A moment of choice is represented by a diamond and has more than one flow going out.

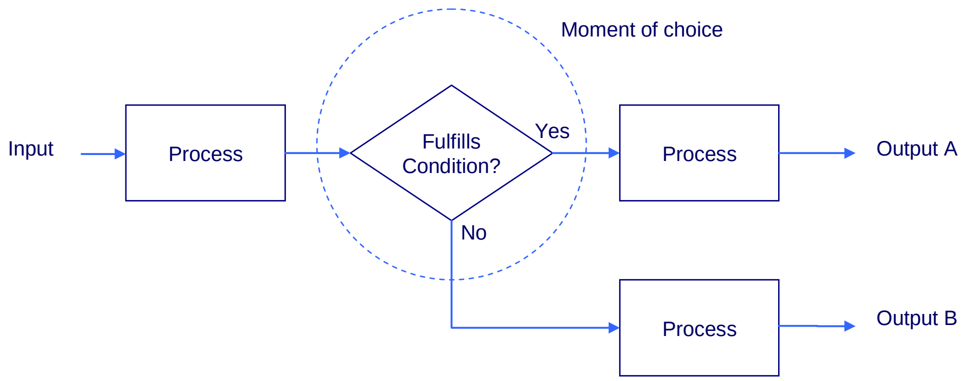


Figure 12: Basic elements of a flowchart (derived from Verbraeck and Valentin, 2005, p. 48)

With respect to the simulation of the processes in FB1, the process-oriented IDEF-0 diagram is constructed primarily to identify the relevant processes, information and the required resources. The flowchart is primarily made because the structure of the flowchart will be the basis for the structure of the simulation. The transformation from the conceptual models to the simulation model is explained in more detail in the paragraph 4.4.2.

3.3.2 Process-oriented description with IDEF-0 diagrams

The first level IDEF-0 diagrams of the operations of the airmail department (Figure 61) and EQ department (Figure 70) are displayed in appendix I and display the basic division in processes and the flow of belly wagons and cargo through the whole operation. Per process the different sub-processes, transformations of input to output, required resources and controls will receive attention in the detailed description in appendix I.
Not all activities in the IDEF diagrams are relevant for all mail or EQ flows. Some activities will be specific for one of the flows. This sub-paragraph will discuss what processes in the IDEF diagrams are applicable for the different flows at the mail and EQ department.

Process-oriented description of the current mail handling process

Figure 13 shows which activities of the first decomposition of in the IDEF-0 diagrams (Figure 61) are applicable for each mail flow. The more detailed IDEF diagrams are placed in appendix I.1. At the mail operations the differences between flows are small, because all flows are sorted via the conveyor belt system. Only the truck unload process (A2) is unique for export mail.

Mail

Export mail	A2 Unload truck & Bring in load	A3 offloading	A4 Scanning	A5 Sorting	A6 Offloading carousel	A7 Weighing & transport
Transit mail	A1 Bring in wagon	A3 offloading	A4 Scanning	A5 Sorting	A6 Offloading carousel	A7 Weighing & transport
Import mail	A1 Bring in wagon	A3 offloading	A4 Scanning	A5 Sorting	A6 Offloading carousel	A7 Weighing & transport*

*excluding checking of the allotment

Figure 13: Relevant processes for each airmail flow through FB1

Process-oriented description current EQ handling process

Figure 14 shows the relevant processes of the first decomposition of the IDEF-0 of the EQ handling process (Figure 70) for the different cargo flows at EQ. The handling of the different flows of EQ shows less overlap than mail. The detailed description of the handling process is placed in the appendix I.2

Equation

Export EQ	A1 Open belly wagons	A2 Export shipment Acceptance			A6 Reposition empty wagons	A7 Collect & weigh string	A9 Bring to transportation & bring in empties
Transit EQ	A1 Open belly wagons	A3 Breakdown & cargo check	A4 Bring away sorted shipments		A6 Reposition empty wagons	A7 Collect & weigh string	A9 Bring to transportation & bring in empties
Transit EQ in combination with lateral transport	A1 Open belly wagons	A3 Breakdown & cargo check	A4 Bring away sorted shipments	A5 Lateral transport	A6 Reposition empty wagons	A7 Collect & weigh string	A9 Bring to transportation & bring in empties
Import EQ		A3 Breakdown & cargo check	A4 Bring away sorted shipments		A6 Reposition empty wagons	A8 Distribution to customer	

Figure 14: Relevant processes for each EQ flow through FB1

The handling of lateral transport (A5) is a special process because specific employees are responsible to retrieve the lateral cargo, sort out the incoming lateral cargo and bring away the lateral cargo to the belly wagons at the storage yard.

3.3.3 Time-oriented description with flowcharts

The flowcharts are used to display the moments of choice in the handling of the products. In appendix K.1 the flowchart of the current mail department is placed. In appendix K the flowchart of the current EQ department is placed. Both flowcharts identify important choices during the handling of mail and EQ.

3.3.4 Validation of the IDEF-0 models and flow diagrams

The meetings of the IT-team to validate their process models were used to validate the constructed IDEF-0 diagrams and flow diagrams as well. The models made by the IT-team were primarily focused on the software packages which had to accompany every process in the operations. Nevertheless the IT-team also had to identify the processes and put these in the right sequence in order to make their diagrams, this made the diagrams comparable.
A special meeting with a business analyst was organized to compare the process-oriented models of this research with the process models of the IT-team. The difference between the diagrams were investigated and adjusted when required. Remaining differences between the two types of diagrams are the attention for the software and documentation in the diagrams of the IT-team, which will both be outside the scope of this research. In the IDEF-0 diagrams of this report more attention is paid to the different functions of the employee and the equipment that is required for the operation.
The flowcharts were validated in the meetings as well. Often the moments of choice and their arguments were the subject of discussion in the meeting.

3.4 Differences between airmail and equation

Currently the division of handling processes of cargo in FB1 is based on product types. Airmail and EQ are different products and each type is divided into different products itself as well. The characteristics of the products will have implications on the requirements for the future operation. The general differences are grouped on five aspects: product, commercial, physical, documentation and IT related differences.

Product differences

Airmail and EQ are different products, sold by different departments. In general the airmail is sold against lower prices and requires a lower service level than EQ. Differentiation is present within both product groups as well. This differentiation within and between products makes it possible to sell the different products for a different price and costs and to match a wide variety of demands of customers.
In Table 5 all types of airmail is listed from high priority (top) towards low priority. When a plane reaches capacity and not all airmail in FB1 can be put on a flight the cargo with a lowest priority will be taken off the plane first.

Table 5: Product differentiation of airmail and EQ

Product differentiation differences	Mail	Equation
	1st class	M21 & M25
	EMS	General cargo
	DIP	-
	S.A.L. (2nd class letters)	-

At equation only M21 shipments are accepted from and distributed to customers at the landside of FB1. Nevertheless some general cargo will be processed at the equation department, due to the lateral cargo flow.
At the other freight buildings the equation **heavy** product (M25) of KLM will be handled. This cargo will be transported at a high service level just like the M21 product, but the shipment is

very large or heavy. The required process for this type of cargo resembles the handling in FB 2 & 3, therefore the M25 products are handled in FB 2 & 3.

Commercial differences

A customer expects a certain service level when he buys a KLM Cargo product. KLM Cargo has determined the possible service level for airmail and equation products, in Table 6 the transport conditions are listed for mail and EQ.
The customer can deliver a shipment until a certain minimum time before the departure of a flight, the last acceptance of cargo. The KLM has set a maximum period required to handle transit cargo for both products. KLM promises customers that it is possible to make the connection between flights when the period between arrival and departure is longer than the offered transit time for a product. Similarly to the last acceptance KLM has set a target for the period between the touchdown of a plane and the moment import cargo is available for pick-up by the customer.

Table 6: Commercial differences between airmail and EQ

Commercial differences	Mail	Equation
Last acceptance	v - 60 min	v - 90 min
Transit time	v - 140 min	v - 180 min
Time available after flight	a - 60 min	a - 90 min
Planning	First in first out (FiFo)	Booking

EQ shipments are booked on a specific flight, this can be the first flight leaving for a destination, but this does not have to be. Normally airmail is processed according to the FIFO principle. Only when a flight is constrained (capacity is not sufficient to transport all mail to a destination), airmail with a lower priority can be pushed off a flight.
The mail will be sorted based on destination instead of a specific flight. EQ shipments are booked and will be sorted on flight number. EQ has a higher priority than airmail. Therefore EQ will always be put on the flight, mail could be taken off when the capacity is constraint.

Physical differences

The physical characteristics of both products have influenced the design of both processes. Airmail is normally shipped in mailbags or small mailboxes, equation product are primarily cardboard boxes of all sizes (see Figure 15).

Figure 15: Regular mailbags (left) and regular EQ packages (KLM Cargo)

Both types are moved manually over very small distances by the employees of KLM Cargo. Nevertheless for the larger movements a conveyor belt system is used at the mail department and forklift trucks (FLT's) are used at the EQ department. The use of FLT's is possible because EQ

shipments are placed on pallets. Using load devices at the mail department is not favourable, because steady stacking of mail bags is not possible.
A higher maximum weight of a package is allowed at the EQ department, because heavy boxes can be lifted by FLT's. The employees at the break down area can lift a package together when necessary. The number of scheduled employees is always more than two at the break down area. KLM Cargo applies a norm of 300 kilogram as the maximum weight for an EQ shipment, no maximum exists at the mail department.
The sorting of mail is performed at a switching table (photo: Figure 56 in appendix F) in the conveyor belt system. The mail is pushed onto the table by the conveyor belt and an employee can relatively easy push the mailbag to the right slide because the surface of the sorting table is equipped with a large number of turning balls. The sorting performed at the break down area of the EQ department is done manually by the break down workers.

Table 7: Physical differences between airmail and EQ

Physical differences	Mail	Equation
Handling method	By hand	By hand
Movement method	Conveyor belt	Forklift trucks
Max weight per piece	31,5 kg	70 kg
Max weight per shipment	None	300 kg
Packing	Bags & mailboxes	Cardboard boxes
Load devices used for internal operation	None	Pallets
Sorting method	Semi-mechanized	Manual

Administrative differences

Each shipment has a unique number, for mail this is called a dispatch number, for EQ this is called an Air Waybill number. An air waybill number is the common cargo registration, airmail is the only air cargo product with an own registration type.
Within each mail shipment a distinction between different mailbags can be made based on receptacle number, every bag has an own receptacle number. The individual packages within an EQ shipment does not have an unique number per collo at this moment/
The labels used for mailbags are UPU-labels (see Figure 16, left side). These differ from the labels used for other cargo products at KLM, the INCA-2 label.
In the future KLM wants to use the IATA 606(B) label (see Figure 16). The IATA6060(B) and the UPU label both contain a barcode, which can be scanned to register the AWB (EQ) or dispatch number (mail).
Some postal companies (often from less developed countries) use old labels, which cannot be scanned and in some cases a barcode cannot be scanned because it is double folded, fallen off or damaged.

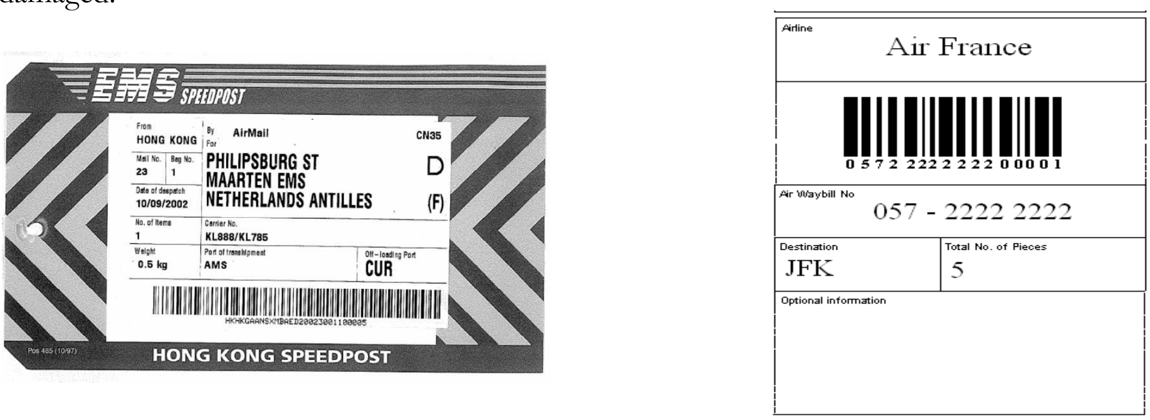


Figure 16: Different label types, UPU label (left) & IATA 606(B) (KLM Cargo)

The IATA 606(B) label has a barcode, which contains the airway bill number, a serial number within the airway bill, destination code and total number of pieces of the airway bill. Besides these standard items, it is possible to customize your label and display other information, e.g. flight number. With the IATA606(B) label it is possible to track the collo within a shipment, because a serial number is added to the label.

The documents accompanying the cargo in the plane are CN-documents for mail products and air waybills for EQ products. The CN-documents for mail are put on the belly wagons after the load is weighed. The CN-documents are transported in the belly of the plane together with the mailbags. At the destination the documents are again put on a belly wagon just like the mailbags, in this way it is prevented that the mail documents end up at the cargo handling instead of at the mail handling. The Air waybills are transported in the cockpit of the aircraft. In this way all information of the cargo in the aircraft is always available, which is part of the safety regulation for the airline industry. The documents are driven to the aircraft before departure by a special courier of KLM Cargo.

Table 8: Administrative differences between airmail and EQ

Documentation differences	Mail	Equation
Identification	Dépêche/dispatch number	Air Waybill number
Label	UPU	IATA 606 (B)
Document	CN-document	Air Waybill (AWB)

IT related differences

In the fall of 2008 KLM Cargo has just implemented "Hermes" at EQ as real-time warehouse system. This system did not live up to the expectations and was removed again after a couple of weeks. At this moment the operation is working with "Chain" to coordinate the EQ cargo through the process. This program is used by the other KLM Cargo departments as well. In general the software system of EQ should be able to register and provide information on the location or destination of the cargo in the operation.
The gathered information of the cargo departing Schiphol by plane is communicated with Cargoal. This program collects all information from the different departments for all flights. Cargoal is used to produce the required documentation for a specific flight. The cargo that will take a specific flight is put on the manifest of that flight. The manifest will have to entail the exact information on the cargo going to the plane.
Planners will use the information in Cargoal to see whether shipments are already sorted and waiting for the flight. Afterwards the information in Cargoal can be used to see which shipments have missed their flight and had to be rebooked on another flight.
The mail department is working with a different software packages, especially developed for the airmail industry, Trips. At this moment KLM Cargo only scans mailbags when the bags are put on the conveyor belt at the input location. In this way the arrival of the bag at KLM is registered. No other registration takes place for mail in FB1. KLM Cargo assumes a mailbag which entered the belt system, will reach the belly wagon along the carousel for a specific destination within approximately a quarter of an hour.

Table 9: IT related difference between airmail and EQ

IT differences	Mail	Equation
Software package	Trips	Hermes
Track & trace	Only one scan at input location of the belt system	Location based warehouse system

3.5 Sub-conclusion handling processes of airmail and EQ in FB1

The general goal of both operations is very similar, but the aspects discussed in this chapter also indicate important differences.
The transit flow is most important (almost 80%) for the mail department. The mail process is designed to support this flow. The division between the flows is more balanced between all flows

at the EQ department and the variation in flows is larger due to the incoming and outgoing lateral cargo.
The handling of mailbags is performed by employees without equipment, this constraints the weight and size of a collo. At EQ heavy lifts are performed with FLT's.
The differences between EQ and mail, discussed in paragraph 3.4, will have implications for the integration. The track and trace facilities for EQ should also be available at the mail department after the integration. Furthermore the registration of mail and EQ data is strictly separated at this moment and different software packages are used. The priority of EQ shipments is higher than most mail products. The new process should support prioritizing of products as well. The time between collection and flight departure differs between mail and EQ. The extra time between collection and departure is used to perform a security check with dogs at EQ.
The conceptual models constructed in paragraph 3.3 will be used as basis for the simulation model of FB1 in the next chapter. The IDEF diagrams identified the relevant processes, information and the required resources. The flowcharts identified most important moments of choice in the operation.
The description of the current processes and products in FB1 show overlap between the goals of both operations. Nevertheless important differences between processes and product aspects exist, which have to be taken into account when integrating the two departments. The differences between the products will partially cause the uncertainty related to the integration, which is discussed in paragraph 6.5.

4 Simulation model description

This chapter describes the trajectory from the understanding of the activities in FB1 (chapter 3) towards a simulation model in Arena. This trajectory starts with stating the goal of the simulation model in paragraph 4.1; subsequently the performance indicators to evaluate the integration proposal will be discussed in paragraph 4.2. After the selection of performance indicators it is possible to determine the required output of the simulation model in paragraph 4.3.
At this stage it is possible to determine what simplifications can be made in the constructed conceptual models, without reducing the possibilities to determine the scores on the selected performance indicators with simulation.
Paragraph 4.5 sums up the required input for the simulation, which can be divided into four subjects: production, flight schedules, process time distribution and resources.
In paragraph 4.6 the structure of the model is discussed, with attention for the ULD transitions and the coordination in the model. The model description is completed in the first six paragraphs. In paragraph 4.7 the simulation model is verified and validated. Subsequently the results of a sensitivity analysis will be discussed in paragraph 4.8 and finally the sub-conclusions of this chapter will be enumerated in paragraph 4.9.

4.1 Goal of simulation model

Goal of this research is to use an integral approach to determine the effects of the proposed integration. The reasons to use discrete simulation to research the integration are already explained in paragraph 1.6.2. The software package used to simulate the operation in FB1 is Arena of Rockwell Software. The constructed simulation model should be able to calculate the effects of the changes required for the integration. In this way it will be possible to answer to the research questions.

4.2 Basis for the evaluation of the integration

In the previous chapters and in the research questions the general term "operational performance" was used to represent a large variety of performance indicators. In this paragraph the general term will be subdivided in performance indicators which represent most relevant areas of the operational performance. These performance indicators are used to evaluate the difference between the current situation and the integrated situation.
Not all performance indicators can be derived with a simulation model. A discrete simulation will only be applicable for quantitative performance indicators; qualitative performance indicators cannot be evaluated by means of simulation.

Qualitative performance indicators which cannot be evaluated with discrete simulation

Product safety, employee safety and accuracy are performance indicators which will be influenced by the new design, but cannot be calculated with simulation. It is expected that these performance indicators will not be significantly influenced by the integration, for the following reasons:

- The sorting process will closely resemble the current sorting and will remain dependent on the manual sorting of employees at the sorting station and along the carousels, therefore the accuracy is not expected to be influenced.
- Product safety for fragile goods will remain the same, because fragile goods will not be transported via the sorter belt. For the other goods the product safety is of less concern.
- It is hard to predict the effect on employee safety. Less FLT movements at EQ could increase safety, but this might be counterbalanced by the increased length or the increased

number of collected trains at the current mail department. Predicting safety will be difficult independent on the method used, an ex post evaluation will reveal the effects.

Performance indicators used in the simulation study

The performance indicators used to evaluate the performance in comparable air cargo simulation studies, are often related to handling times, employee utilization, equipment utilization, turnaround times or queue lengths (DeLorme et al, 1992) (Nsakanda, A.L. and Turcotte, M., 2004) (Ou, Zhou and Li, 2007). Performance indicators used in the different studies show great resemblance, but are often unique for the specific operation under investigation.
In this study the performance indicators are specially developed as well and are corresponding with the expected benefits of the integration (as discussed in chapter 1).Quantitative performance indicators which can be derived with discrete simulation are selected for four of the five objectives. The objective to gain experience with the integration of airmail and EQ before the JUMP is not quantifiable by simulation. This results in the following quantitative performance indicators to evaluate the integration:

Resource utilization

The scheduled utilization of the employees in FB1 will be determined. The scheduled utilization is calculated by dividing the average number of employees per function by the average number of employees scheduled to work. This will

- Utilization rates of employees working in the mail or EQ operation.

Handling times

The time intervals between the arrivals at specified locations or stages in the handling process are used as representation of the handling times in the operation of KLM Cargo. The following intervals will be used to discuss the simulation results.

- Time between export acceptance of cargo from the EQ customers to the moment the cargo is sorted and placed in a belly wagon
- Time between the arrival of cargo on the airside of FB1 and the moment the cargo is sorted and placed in a belly wagon
- Time between the collection of the belly wagons with cargo and the positioning of the wagon at a lane at transportation
- Turnaround time in F1, which is the time between the arrival at FB1 and the moment the cargo is ready at the transportation department again.
- Turnaround time, which is the time between arrival of transit cargo and the moment the cargo is ready for departure under the plane again after the handling process

Number of re-bookings

The number of re-bookings is considered for mail and EQ, although mail is not booked on a specific flight in reality. The term "re-booking" indicates the mailbag will fly on another flight in the simulation than it did in reality. For EQ it will imply that the shipment flies on another flight than the shipment was booked on. The re-bookings are divided into four different groups.

- Number of EQ packages that will fly on an earlier flight than the flight they are booked on, due to implementation of the FIFO-principle
- Number of EQ packages that will miss their booked flight
- Number of mailbags that will fly on an earlier flight than they will in the base case
- Number of mailbags that will fly on a later flight in the integrated situation.

Space requirements
At EQ at least one wagon will be positioned at the storage yard for one flight, but the number of belly wagons for one flight at the storage yard will be dependent on the amount of cargo waiting for the specific flight.
At the mail department the maximum number of destination locations required along the carousel will be the indicator of the demand for space. For some destinations more than one belly wagon will be located along the carousel, however this number of wagons with the same destination is constant, therefore the following performance indicators are determined:

- Maximum number of belly wagon locations required at EQ storage yard
- Maximum number of belly wagons locations required along the carousel

The simulation model should be able to calculate the performance of the operation in FB1 on these performance indicators. Aspects of the operation which does not affect these performance indicators could be left out of the model.

4.3 Required output of the simulation model

The required output of the model is divided into data on the processed cargo and flight details.

The output of the simulation model with regard to cargo can be divided in six aspects:

- To check if the original input is processed correctly, all characteristics of the input file are also written to the output file.
- The scheduled utilization of all different employees at the mail and EQ department should be registered.
- For every entity the time of entering a new process will be registered. With this information all relevant handling times can be calculated.
- For the registration of the cargo that missed its booking three characteristics are registered, the location where is noticed the cargo is late, the time of noticing that the cargo missed its flight and the attribute indicating that the cargo did miss the flight.
- When cargo will fly on another flight than it was booked on (EQ) or did fly on in reality (mail) the original and the new flight index is registered. In combination with the time of collection it is possible to determine whether cargo flew on an earlier flight than their original flight.
- For EQ the attributes which indicates the cargo is grouped on an ULD will be registered.
- For mail (and small EQ in the future) the attributes indication the number of rounds the entity made on the carousel is registered.

The output of the simulation model with regard to the flight details can be divided in two aspects:

- Time variables are registered to check whether the activities coordinated by the flight entities will occur at the right moment, e.g. the moment of opening and closing of flights at the EQ department.
- Furthermore, variables are registering the data on the cargo carried by specific flights. This data contains information on the volume, weight and the number of pieces of the load. This information will be used to determine the maximum volume per new destination location along the carousel in sub-paragraph 7.7.2.

The tables displaying the format of the five output files are placed in appendix H.1. This output data can be processed in such a way that the values on the selected performance indicators can be calculated.

4.4 Transformation of the conceptual models to the simulation model

The conceptual models describing the operation of airmail and EQ are very detailed (see appendix I & K). It is not necessary to simulate all elements of the conceptual models to retrieve the required output. To reduce the complexity of the simulation, reductions are made during the transformation of the conceptual models to the simulation models. The possible simplifications are discussed in the next sub-paragraph. Subsequently the transformation of the conceptual model to the simulation model is described in the second sub-paragraph. The last sub-paragraph discusses the required level of detail of the simulation model.

4.4.1 Simplification of the conceptual models for simulation

It is hard to find processes which can be left out of the simulation, because almost all processes and employee functions are influenced to some extend by the integration. And besides, the goal of the research is to use an integral approach to determine the effects of the integration, which limits the possibilities for simplifications. Nevertheless it is possible to simplify the following elements of the constructed process-oriented models.

Simplifications in processes

Specialities at mail department
At the airmail department the specialty department is not taken into account in the simulation model. The employees working with specialities are not involved in other processes and the number of bags that will have to be investigated is small and will proceed in the normal process after a new labelled is applied. This implies exclusion of processes A43, A44 and A45 in the IDEF diagram in Figure 65 appendix I.1.

Repositioning of employees
Around each carousel employees are walking along the belt, the repositioning of these employees is not modelled. Instead of the repositioning of the employees each mailbag will be applied with an initial time required to move to the right wagon along the carousel taken from a uniform distribution because:

- It is possible that the mailbag is destined for the first wagon along the belt after the drop-off point. But it is also possible that it should be taken off at the last wagon it encounters on his first whole round.
- The number of employees along the belt does not influence the average time to reach the right wagon along the carousel.
- One whole round on the carousel will take the cargo 240 seconds.
- When no difference is made between the number of pieces destined for certain wagons, the time from drop-off point to the wagon can be represented by a uniform distribution with a minimum of 0 seconds and a maximum of 240 seconds.

Once the cargo is arrived at the right wagon, the model will check whether all employees along the specific carousel are busy. When all employees are busy the bag remains on the carousel. When one employee is idle, he will check the label of the bags and take off the bag. In the new situation he makes the exit scan as well.
The only disadvantage of this construction is the fact that only the activities for which the employee is processing the bag physically are included in the calculation of the utilization of resources in the model. This will result in a lower utilization rate of the employees along the belt than they will have in reality. Walking along the belt is part of their tasks, but does not count as

an activity in the simulation model. This effect should be taken into account when evaluating the model outcomes.
For other functions, employees will be working at the same location all the time or time required to move somewhere else is modelled as a process in the simulation (e.g. walking in to office in included in the process to upload the data from the scanners).

Truck process at the mail department
Mail arriving and departing with a truck is not modelled as a separate process. The mail arriving by truck is assumed to come in on belly wagons just like import and transit mail. The employee responsible for the export mail arriving by truck is left out the simulation as well. This implies exclusion of the process A21 in the IDEF-0 diagram in Figure 63 appendix I.1.

Routes used to model movements
In Arena there are possibilities to model transporters, in this model it is chosen to model the movement of goods in a simplified way with route modules. Before the cargo starts a route it will claim the responsible employee, the process time for this movement is inserted as the route time. Upon arrival at the destination the employee is released again from this responsibility. This will limit the possibilities to animate the employees accompanying the cargo, only the cargo movement will be animated.

Transportation department
The arrival and departure times of the flights at Schiphol are registered in Trips and Cargoal. Therefore it is known at what time cargo arrived at Schiphol. In order to determine the arrival rate of the cargo at FB1, the transport time required to move the cargo between the plane and FB1 has to be estimated. Although this department is outside the scope of this research the transport time is required to make the cargo arrive at FB1 in a realistic way. This will be modelled as a route with a route time taken from a triangular distribution (further explained in sub-paragraph 4.5.3).

Export airmail
In most cases the export mail is brought to the planes by TNT directly over the airport platform. This mail is not coming in FB1 and will therefore be left outside the simulation.

Simplifications of inputs

Empty ULD
The empty ULDs brought back or released by KLM are not taken into account. This is partially because there is no information available on the number of empty ULDs released and brought back. The ULDs leaving FB1 with cargo could be brought back loaded with cargo or empty. And partially because the handling of these empty ULDs will have a lower priority than the handling of cargo anyhow, which will prevent the handling of empty ULDs hurting the performance of the cargo handling.

Rush shipments
Rush shipments, shipment which will receive special attention in order to make the first flight to a destination, are not simulated. Rush cargo will not increasing the workload at EQ, but sometimes will receive priority and make other packages wait. The rush shipments will only be handled in advance of shipments that does not run the risk of missing a flight. Rush shipments are not more profitable, therefore it makes no sense to give priority first to a shipment which will cause another shipment to miss the flight.

Often rush shipments consist only a couple of boxes. A forwarder would rather bring in an important shipment or ULD more in advance of flight departure than running a larger risk of late arrival, independent of the guaranteed given by the KLM. The courier, driving the documentation to the plane with a car (outside the scope of this thesis), is often taking rush shipments to the plane together with the documents. In this case the workload for the employees of interest will even decrease.
Because there is no information on which AWBs are handled as rush shipment it is not possible to distinct the rush shipment for the simulation. The effect of the existence of rush shipments should never have a negative impact, it is meant as notification for employees that they should act faster when possible, but it should not push off other cargo. Therefore it is expected that leaving rush shipments out of the simulation is not overestimating the performance in FB1.

Simplifications of resources

Transportation between FB1 and the planes
The security check and the transportation to and from the planes are modelled as route times. No resources are linked to these activities because those processes are not part of the scope and are not studied in detail.

Security check
When the dogs are alarming the employees at the security check, the specific train of wagons is moved to a special location for further investigation. The alarming by the dog will not disturb the handling of the other cargo which has to go through the security check, because the suspicious cargo is moved away from the security check. Therefore the security check is not simulated as a limited resource.

Simplifications of controls

Plane capacities
The flight schedule, the allotment (for both mail and equation) and the aircraft types are varying often. The allotment on flights and the planning process are very dynamic. The allotments will depend on the cabin luggage of the passengers, fuel requirements etc. This will imply that the allotment on a flight for a certain destination is not the same every time it departs. This study analysis the effects of the integration independent of changes in the flight schedule and therefore the capacity constraint of flights are left out of the simulation.

Data communication and documentation
Data communication is outside the scope of this thesis, only when a process is performed to register data this will be modeled.

The transformation of the conceptual models to the simulation can be made in the next sub-paragraph, after the identification of the possible simplifications.

4.4.2 Transformation of the conceptual models to the simulation

In appendix L the transformation of the conceptual models to the simulation model is described in detail with the help of an example from Arena. Similarities between the conceptual models and the visual interface of Arena simplify the transformation of the conceptual models to the simulation model. The example shows it is possible to link specific resources and process times to specific processes. In this way the identified processes and resources from the IDEF-0 diagrams can be translated to the Arena model. The flowcharts are primarily used to map the flows of cargo and the sequence of processes.

4.4.3 Detail level

The required level of detail for mail and EQ will be the collo level, because the number of collo will determine the use of the employees for certain processes. For example the mailbags will be taken off the carousel one by one and the EQ packages will be broken off one by one at the break down process.
Besides the fact that the number of collo is a driver for the time required for a process, the location of an individual collo can also be very important. When a total shipment has to be collected and one package of this shipment is not taken off the carousel yet, it will delay the other packages of the same shipment. Therefore it should be possible to simulate the processes on collo level. The observation that information will be required on collo level will have consequences for the required data for the simulation model (see paragraph 4.5).

4.5 Required input

At this stage the required output, the possible reductions, the logic of Arena and the detail level are known. With this information it is possible to determine the required input for the simulation model.
The required input can subdivided into four groups: the production data on collo level of mail and EQ, the flight schedules of flights with EQ and flights with mail, the process time of the relevant processes and the resources and their responsibilities. This building blocks show resemblance with comparable studies of air cargo operations (Nsakanda, A.L. and Turcotte, M. 2004, p. 1794) (DeLorme et al, 1992, p. 1327) (Ou, Zhou and Li, Z. 2007). The next four sub-paragraphs will each discuss one of these groups.

4.5.1 Production data

Production data of September and October 2008 was collected. This production data contains the information individual mailbags and EQ AWBs require to travel from origin to destination.
The objective was set to use as much real data as possible and lot of effort was put into retrieving detailed data from reality. Several advantages of the use of real data motivated this objective:

- The data to validate the simulation model is expected to be limited. The loss of information was minimized by the use of real data instead of making assumptions or using averages.
- Detailed information will make detailed modelling possible. The high detail of the information will force the model builder to take all available aspects into consideration. (e.g. the availability of the ULD characteristics resulted in the collecting of all cargo in an ULD, which would be grouped together)

Information on AWB level is the lowest detail level for the EQ production. Therefore it was required for EQ to use the number of pieces in an AWB (which is known), to transform the AWB to collo level at places where the number of collo is the driver for processes in the simulation. For the mail department the production data is available on collo level already.

Relevant characteristics Cargo

At the generation block the entities will receive all the data which makes an AWB or mailbag unique. With these characteristics per entity the flow of the cargo through the simulation can be completed in the right way. In appendix M.2 the relevant characteristics for both airmail and EQ are placed in two tables.
In general the main characteristics of the cargo are: unique identity numbers per AWB or receptacle, cargo flow, weight, volume, number of pieces, origin, destination, incoming flight data, outgoing flight data, incoming ULD data (EQ), outgoing ULD data (EQ), unique flight id, which carousel and the number of export packages that should be grouped together on a incoming ULD.

Transforming

Arena can only read numbers and cannot read text. In order to insert all required data in the simulation, text had to be transformed to numbers. In order to do so coding schemes for the different aspects, registered as text, were made. Examples of the use coding schemes are placed in appendix M.1.

Assumptions production data

Some assumptions had to be made in order to have a value for all attributes, because not all information was available for all entities. Below two important assumptions are discussed in detail, the other less influential assumptions are discussed in appendix M.2.

Exceptions within small shipments

Due to the lack of information on the individual weights, individual sizes, fragility or danger it is not possible to determine if a **small** shipment contained exceptional packages. Exceptional packages cannot be transported via the conveyor belt and should be handled as a **large** shipment via the current EQ department. The average weight per collo will be used to divide small and large shipment in the model.
Other exceptions, e.g. dangerous, odd sized or fragile packages are not taken into account, because it is not possible to indentify these exceptions. This assumption could overestimate the share of "small" shipments, which can be transported with the belt system. Depending on the effects of the integration this could under or overestimate the advantages of the integration. With a sensitivity analysis the sensitivity of the model for the percentage of exceptions will be studied in sub-paragraph 4.7.2. In this way the influence of the existence of exceptions can be evaluated.

Arrival of export EQ

The time of arrival of export EQ at FB1 is not registered in the Cargoal. Data from another sources STEPS was used to retrieve the arrival time.
An analysis of the raw data from STEPS was made in order to determine the time between RCS and flight departure for each export AWB. A histogram can be made which displays the probability of occurrence for different time intervals (Figure 17). The histogram indicates that a large share of EQ shipments is brought in a couple of hours before departure. It might be possible to transport these export AWBs with an earlier flight to the same destination, when the FIFO principle is applied. The flight schedule will influence to what extend this is possible, the simulation will quantify the potential number of re-bookings.

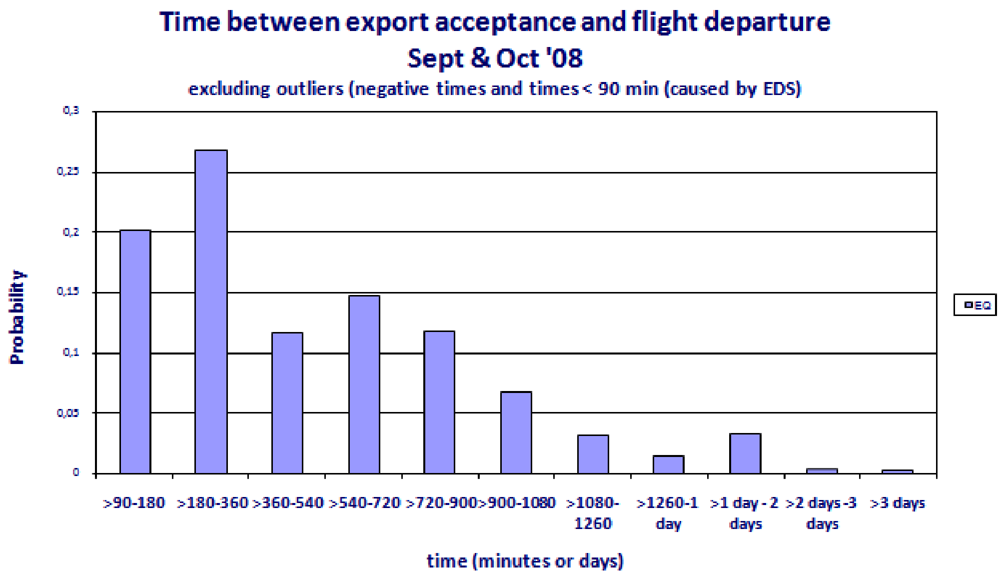


Figure 17: Histogram of time between export acceptance and flight departure of EQ

Resulting Arrival and departure pattern of airmail and EQ

The resulting arrival patterns for each flow through FB1 are placed in appendix M. In appendix M.3 the arrival pattern of the mailbags is found and in appendix M.4 the arrival of the EQ AWBs. This is not the same as the arrival pattern at FB1, because the transportation from the plane to FB1 takes place before the arrival at FB1.

4.5.2 Flight schedules

The characteristics of arriving flights will differ from the characteristics of the departing flights and the characteristics of mail flights will differ from the characteristics of EQ flights in the simulation. In this paragraph the flight characteristics will be described and the two differences will be discussed.

Flight arrival and flight departure times

The input of the EQ flight differs from the input of the mail flight due to a difference in the available data. For the mail department only the **scheduled** arrival and departure times are present in the available data, for the EQ department the **actual** as well as the **scheduled** arrival and departure times are known.
The scheduled departure time (STD) of flights is the basis for the deadlines of the collection for weighing of the departing mail and EQ and the opening of the flights at EQ in the current situation. The actual time of departure (ATD) is used to link the cargo when ready at the gate to a flight in order to determine if the cargo made the flight after the weighing and transportation process. The scheduled pattern will be often be disrupted and the difference between actual and scheduled times can be substantial (Rosenberg et al, 2002). The scheduled times are used as the basis for deadlines in the operation in FB1, because in the operation no real-time information on disruptions is used in the planning process. The actual times are used to link the cargo to the incoming and outgoing flights, because this represents the reality, including the disruptions in the scheduled pattern.

Estimation of ATD for airmail based on STD of EQ

The available databases for airmail do not include the ATD and ATA per collo. Therefore the ATD and ATA are estimated by correcting the STA and STD with a distribution representing the difference between actual times and schedules times. In appendix N.2 the derivation of the distribution is described.

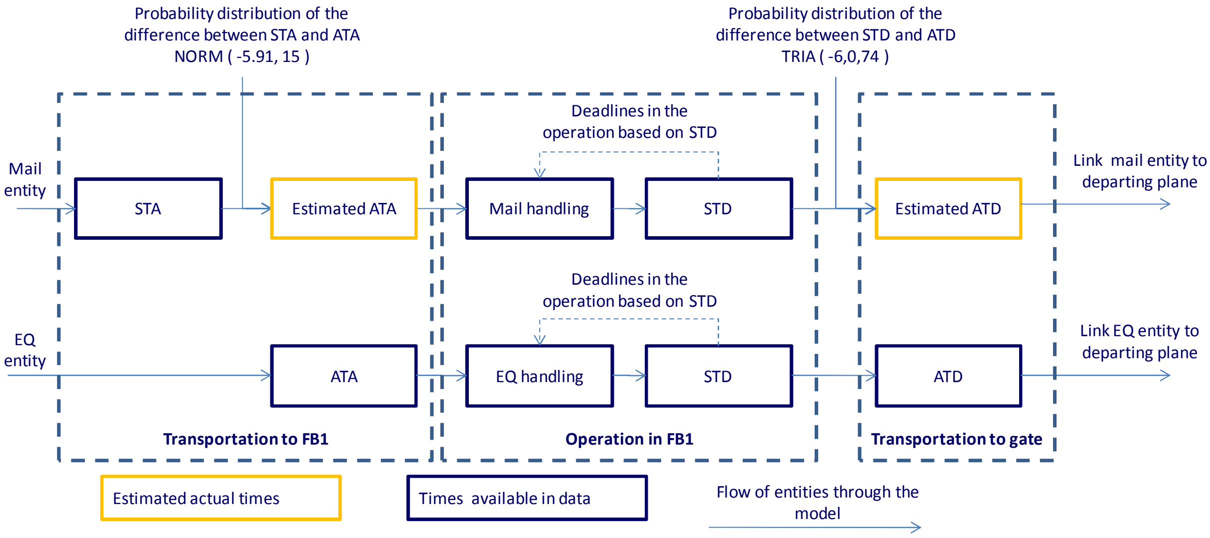


Figure 18: Overview of the actual and scheduled times used in the simulation model

The correction is normally distributed for arriving flights and triangular distributed for departing flights. Figure 18 displays the coordination within FB1 based on the scheduled flight times and the arrival and departure by plane of entities based on the actual or the estimated actual times (mail).

Flight destinations

For arriving cargo the origin of the flight is not important in the simulation. In order to coordinate the arrival of cargo in the model only the date, time and flight number are used. Together the date and the flight number will be an unique combination, which is used to link the cargo and the plane at arrival.
The departing flights can have several destinations, when the plane is destined for more than one destination under one flight number. All three possible destinations per flight are added as attributes and are used to collect cargo ready for departure when applying the FIFO-principle.

Flight index

A special flight index is added as attribute to departing flight. The index is used to register the allocation of cargo on a specific flight. A comparison between the final flight allocation and the initial flight allocation after the simulation can be used to determine the number of re-bookings.
For the integration all outgoing flights are put in one input file and overlapping identical mail and EQ flights are taken out of the file. Each flight will receive a new flight index.

Resulting flight characteristics

In appendix N the input format of flight details is displayed. The resulting characteristics give due weight to the difference between the scheduled and actual time of departure and arrival for EQ and reflect the unavailability of actual times for mail flights.

Resulting arrival and departure pattern of flights with airmail and EQ

KLM is using a seven-wave pattern at Schiphol (www.corporate.klm.com, 20-3-2009). Due to the fact that only flights carrying cargo are taken into account, the resulting arrival patterns for flights with airmail (Appendix N.4) and EQ (Appendix M.4) do not exactly resembles a seven-wave pattern. The graphs are based on the **scheduled** arrival and departure times.

4.5.3 Process times distributions

The distribution of process times of all relevant processes in the mail and EQ operations are derived from time measurements at the FB1 in the September 2008. The time measurements per process are placed in appendix 0.
The time measurements are an important input for the simulation. In this sub-paragraph the estimation of the process times is described.

Estimation of the distribution of process times

The time measurements are used to estimate a probability distribution for all process times. These distributions of process times can be inserted in the process-modules of Arena and reflect the stochastic character of the activities. Service times are rarely represented by a normal distribution (McGuire, 1994), but which distribution can be used to display the behaviour in reality properly.
The processes times of the different processes at KLM Cargo will all fall in a finite range. All processes will require a certain minimum time to perform the activity and after a certain maximum time the activity will always be completed. Most processes have a high frequency and the level of routine of the employees performing the job is high. Because employees are skilled at their job the process time will in most cases be closer to the minimum (McGuire, 1994), which will make the distribution asymmetrical. Nevertheless every time between the minimum and

maximum process time can occur. Statistical distributions with a finite range are the beta, triangular and uniform distribution.
In this research process times are expressed in three different ways: as a formula derived with linear regression, as a triangular distribution and as a constant. The process times were estimated by linear regression analysis for processes which were expected to be correlated with the value of an independent driver. Process times are fitted in a triangular distribution when more than five measurements are available. The processes, for which only a couple measurements were obtained, are assumed to be constant. The average of this limited number of measurements will be used as constant.

Linear regression analysis
Linear regression analysis is applied for the processes which were expected to dependent on the value for a certain independent variable. In Microsoft Excel the correlation was tested, resulting in three processes expressed by a linear formula. The minimum value of the R-square values of the three linear process times is 0.67. An example of a linear process time distribution is displayed in Figure 101 in appendix 0.

Triangular distribution
The triangular distribution is chosen for the following reasons:

- The triangular distribution can be used to represent high frequent human processes as explained previously. It can be composed out of a minimum, maximum and the mode of the time measurements.
- The triangular distribution is a simple distribution, which reflects the limited amount of time measurements better than a more sophisticated distribution.
- The triangular distribution is relatively easy to understand and to communicate. This is advantageous in the communication with KLM employees. When validating the estimated distributions a minimum, maximum and most likely process time can be asked to an operational employee.

Two equations of the triangular distribution are used to determine the parameters of the triangular distributions. The first equation (Dorp and Kotz, 2002) is used to calculate the most likely process time, the mode. The minimal, the average and the maximum process times are derived from the time measurements for each process. With these three variables known it is possible to calculate the mode.

$$E\ (T) = \frac{Tmin + Tmode + Tmax}{3} = Taverage$$

The mode resulting from this calculation is used in the second formula to determine the probability of the mode occurring. This is necessary to compose the graphs of the triangular distribution for all processes. Figure 100 in appendix 0 shows a graphical example of an estimated triangular probability function.

$$\int_{Tmin}^{Tmax} P\ (T)\ dT = \frac{1}{2} * (Tmax - Tmin) * P(Tmode) = 1$$

Additional information on measurements, the analysis and the estimating of the process time distributions is placed in appendix O.

Results of the process time distribution estimation

A close look was taken at the number of time measurements per process, but at this time it is all information on process times which can be worked with. When bottlenecks come to light during the interpretation of the results (chapter 5 & 7), it can be decided to perform more time measurements in order to exclude the fact that unreliable time measurements are the cause of the bottleneck.

Mail department

Applying the previous described techniques results in the overview in Table 10 of estimated process time distributions for the relevant processes at the mail operation.

Table 10: Process time distributions for the airmail department with corresponding drivers

Airmail	Activities per function	Time (s)	Driver
1	**Hr_mail_unload**		
1.1	Pick-up bellywagon	NONE	is included in activity 2.5
1.2	Unload (& scan)	TRIA (2.3/6.4/9.2)	# of bags
1.3	Move string during unloading	TRIA (10/10/45)	# of moves
1.4	Bring away wagon	CONST (87.7)	# of trips
2	**Hr_mail_scanning**		
2.1	RIM bags	CONST (17.3)	# of bags
2.2	Read scanner in office	CONST (116.7)	# of flights
3	**Hr_mail_switching**		
3.1	Sort mailbags	TRIA (1.9/3.6/6.1)	# of bags
4	**Hr_mail_carousel (EUR, USA & ICA)**		
4.1	Match bag with wagon	TRIA (1/1.9/5)	# of bags
4.2	Unload belt	TRIA (3/4.7/12)	# of bags
5	**Weighing**		
5.1	Collecting string	LINEAR; 20 * # of wagons +45	# of wagons to collect
5.2	Weighing wagons (incl. canvas)	LINEAR; 48.6 * # of wagons +23.2	# of wagons
5.3	Retrieve documents	CONST (121.7)	# of stings
5.4	Bring to transportation lane	TRIA (48/77/160)	# of trips
5.5	Replace wagons at the belt	TRIA (44.0/70.6/180.0)	# of wagons

EQ department

For the EQ department this result in the process time distributions displayed in Table 11.

Table 11: Process time distributions for the airmail department with corresponding drivers

EQ	Activities per function	Time (s)	Driver
1	**Hr_eq_checker**		
1.1	Print stickers/prepare breakdown	TRIA (75/116/327)	# of flights brought in
1.2	Count and check AWB's	TRIA (1.7/3.5/5.7)	# colli
2	**Hr_eq_bring_away**		
2.1	Bring away load devices (Import)	TRIA (96/155.6/181)	# load devices (Europallets)
2.1	Bring away load devices (Lateral)	TRIA (29/54/58)	# load devices (Europallets)
2.1	Bring away load devices (Storage)	TRIA (49/66.8/104)	# load devices (Europallets)
2.1	Bring away load devices (Wagon)	TRIA (54,58.4,310)	# load devices (Europallets)
3	**Hr_eq_break_down**		
3.1	Break down wagon/pallet	LINEAR; 21.16 * # of colli on wagon + 88.87	# number of wagons to break down
4	**Hr_eq_lateral driver**		
4.1	Retrieve cargo from FB 2/3	TRIA (145/247.75/287.5)	# of trips
4.2	Bring cargo to FB 2/3	TRIA (145/247.75/287.5)	# of trips
5	**Hr_eq_lateral bring away**		
5.1	Sort cargo from FB 2/3	Assumed to be equal to activity 2.1	# load devices (Europallets)
5.2	Sort cargo from temporary storage	Assumed to be equal to activity 2.1	# of trips
6	**Hr_eq_weighbridge**		
6.1	Collecting string	TRIA (20, 185, 390)	# of trips
6.2	Weighing belly wagons	TRIA (28, 225, 510)	# of trips
6.3	Security check with dogs	Is included in measurement 5.4	# of trips
6.4	Bring to transportation lane	TRIA (170/301.6/630)	# of trips
6.5	Place new wagons (from break down)	CONST(13.3)	# of wagons
6.6	Place new wagons (from outside)	CONST(44.2)	# of wagons
7	**Hr_eq_weigh_opening**		
7.1	Open wagon in Hermes	CONST (24.4)	# of wagons
7.2	Place envelops	CONST (61.7)	# of wagons
8	**Hr_eq_export_acceptance**		
8.1	Unloading/Loading & check of export/import	TRIA (28/132.4/310)	# of shipments/AWB's
8.2	Bring away export cargo	TRIA (170/224.1/556)	# of pallets
8.3	Retrieve import products for customers	TRIA (75/123.8/240)	# of pallets
8.4	Check departing cargo and release to customer	TIRA (30/42.5/60)	# of shipments/AWB's
8.5	Retrieve dolly's for export	CONST (94.5)	# dollies
8.6	Load dollies for export	CONST (118.5)	# of ULD's
8.7	Transport TULDs between Voorloods and airside	CONST (260)	# of ULD's
8.8	(Un)loading truck with TULD	TRIA (89.3/124/234)	# of ULD's

For the simulation package Arena the only required input are just the minimum value, mode and maximum value and the corresponding unit of time.

Transportation department

During the analysis of transportation times between the planes and FB1, a division was made between intercontinental flight and European flights. Intercontinental flights (for cargo on the ICA and USA carousel) are primarily using the E and F gates, which are at a considerable larger distance of FB1 than gates B, C and D, which are used for the smaller aircraft types flying primarily to European destinations. This resulted in the following triangular distributions:

Table 12: Table with the parameters of the triangular distribution per carousel

Transport times	n	5%-percentile	Minimum	Maximum	Average	Mode
Carousel 1	40	2.00	18	50	32	30
Carousel 2 & 3	19	0.95	17	73	47	53

Appendix V.1 shows the position of FB1 in relation to the passenger terminal, appendix V.2 shows the gates at Schiphol. The measurements and the graphs of the triangular distributions for the transportation department can be found in appendix O.3.

The drivers are searched on their way to the gate. In order to model this process an extra delay on the transportation time of 1 minute is inserted for trains going to the plane.

The correction for the difference between STA and ATA and for the difference between STD and ATD for some flights will be added to the route time representing the transportation between FB1 and the plane. This correction in explained in appendix N.

Transportation times with the conveyor belt

The new conveyor belt system will have consequences for the travel time of the cargo from the input locations to the carousel. The travel times for mail in the current layout were measured in the FB1. With these measurements and the length of the belts the average speed of the belt is determined. The speed of the belt system will not be changed by the integration. With the new distances from the future conveyor layout and the average speed of the belt, the time required for the transport with the belt for different trajectories can be determined (Table 13).

Table 13: Transportation times on the conveyor belt in the current and future situation

Route	Time (s)		
Route elements	Slope	Horizontal	**Total**
Far input - Switch	30	22	**52**
Close input -Switch	30	2	**32**
Switch - ICA carousel	7	42	**49**
Switch - USA carousel	10	16	**26**
Switch - EUR carousel	5	50	**55**

New routes	Time (s)		
Route elements	Slope	Horizontal	**Total**
Export acceptance EQ	-	250	**250**
New input location 1	-	184	**184**
New input location 2	-	200	**200**
Input at breakdown	-	267	**267**
Switch - ICA carousel	7	42	**49**
Switch - USA carousel	10	16	**26**
Switch - EUR carousel	5	50	**55**

4.5.4 Resources

The employees in the FB are modelled as resources which can be claimed for certain processes. The resources can work according to a certain schedule. The simulation program will register what time of the scheduled working time the resources are utilized. This will result in the utilization per function. The same can be done for the weighbridges. The different employee functions and the equipment modelled in the simulation are listed in appendix P.1.

Employees

Basis for the work schedules in the simulation were the new standard minimum work schedule at both departments (KLM Cargo). Only the functions of employees that are involved in the physical handling of airmail and EQ were taken into account. This results in the schedules in appendix P.

Equipment

The employees are using equipment for almost all processes in FB1. The equipment varies from FLTs to scanners. In most cases the availability of the equipment is not a limitation, because every employee has the required equipment dedicated to him during his shift. There are even spare ones in FB1 and in FB2 & 3, so there is redundancy in the required equipment.

4.6 Simulation model description

The data from the previous paragraph is used to construct a simulation model, which is partially *trace-driven* and partially *self-driven*. The input sequences of the cargo are derived from trace data obtained through measurement of the real system, but the process times are taken from the probability distributions (Balci, 1990, p. 27).
In this paragraph an overview of the different building blocks of the model will be constructed in the first sub-paragraph. Subsequently the structure which has been modelled to map the transition between the different ULD types at the EQ department. Finally the coordination used in the model is discussed.

4.6.1 Model structure

In a discrete simulation the entities running through the model will have to be created first. The creation of entities will take place in the "generation" building blocks of the model. The entities representing EQ packages, mailbags and flights will be the most important entities running through the model. These entities will contain the relevant information of the specific flight, AWB or mailbag to guide them through the model, representing the operation of KLM Cargo (see paragraph 4.5).
After generation, the entities enter the model. From this moment the building blocks of the model will closely correspond with the process blocks of the IDEF diagrams. During each different processes or step in the operation new or updated information can be attached to the entities. In this way the entities will be able to carry the information on the performance to the end of the process. At the end of the process the data is taken over from the entities and registered in order to make analyzing possible.
All the building blocks in the model and the flow of the different entities can be illustrated by the model structure (Figure 19).

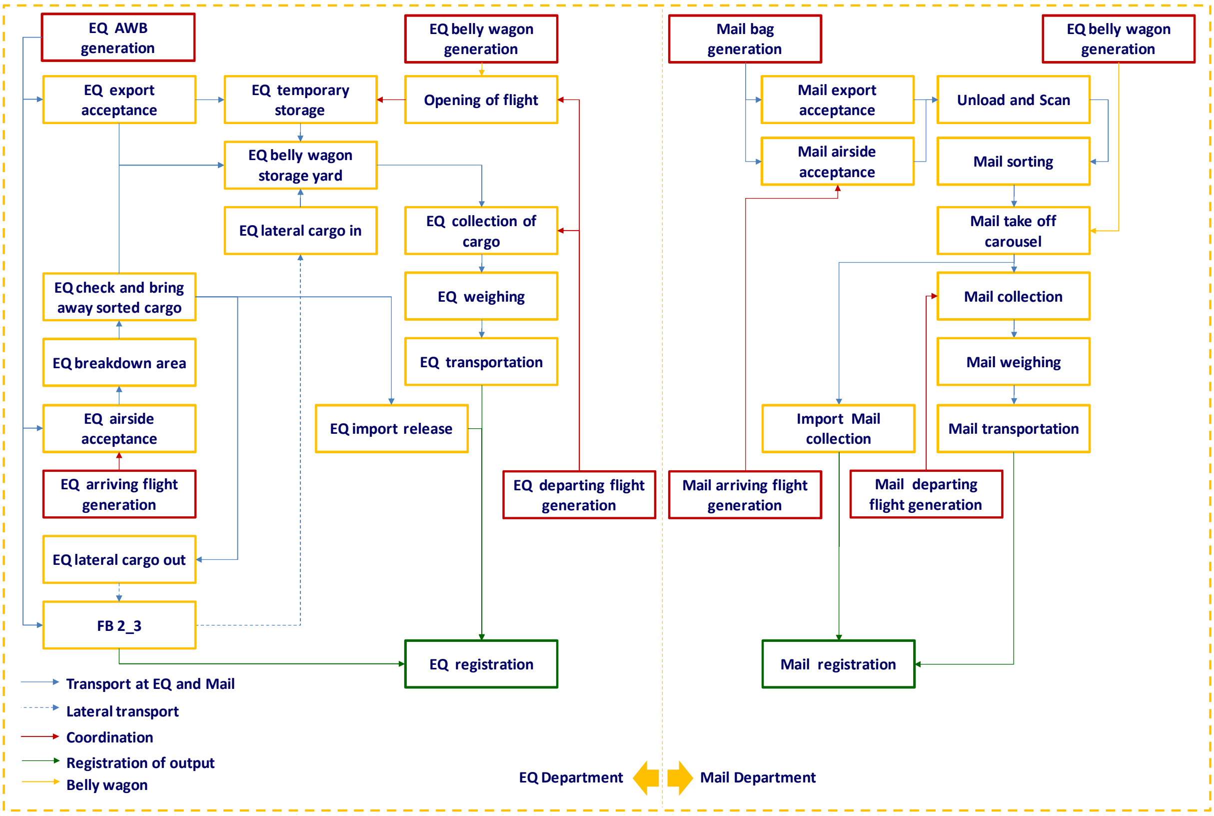


Figure 19: Structure of the simulation model

4.6.2 ULD transition structure

The load unit used to transport the cargo is crucial in the process. This is already emphasized in the sub-paragraph on the level of detail (4.4.3). The load unit is especially important at the EQ department. The packages at EQ are placed on pallets, taken off again, broken down one by one from an ULD or a belly wagon etc. To put it short a lot of changes are made in the load unit used. The complexity of the required structure justifies the construction of an overview of the ULD transitions. The overview of the structure can be found in appendix Q.1. The transitions between AWBs, ULDs, Europallets, and colli at the different building blocks are displayed.

4.6.3 Coordination based on flight arrivals and departures

The operation of mail and EQ contains several deadlines (see appendix Q.2). Often these operational deadlines are set in relation to the departure of a flight. In this sub-paragraph the coordination between cargo and the flights is explained, because it is seen as the most important coordination in the model.

The entities representing the cargo will flow through the processes in the model until they will end up in an "infinite hold" module. This infinite hold module is a queue for cargo and will be used in the simulation everywhere the cargo is waiting on the next incentive. These incentives in the model correspond to the existing deadlines in the operation.

The waiting queue can be searched on special characteristics with a "search" module. For example, all cargo waiting in the belly wagons along the carousel can be searched on the airport code "JFK". When found this cargo can be taken out the queue and send to the next processes. In this case the next process is the weighing process after all cargo to JFK is collected.

When the flight entities will initiate the search of the queues only the flight entities have to enter the search modules on the right time. Because the flight entities do not undergo any further processes, they can be used easily to accurately coordinate the flow of cargo. This search principle is applied to link cargo to arriving and departing flights.

In the future EQ AWBs and flights will be linked together on the basis of the destination according to the FIFO-principle, instead of a link based on specific flight number, as is currently the case. This change is visualized in appendix Q.3

4.7 Verification & Validation

In order to use information obtained from the results of the simulation model, the model should resemble reality in a satisfactory way. Possible concerns regarding the accuracy of the model are addressed in the verification and validation process.
Verification of an simulation model is often defined as "ensuring that the computer program of the computerized model and its implementation are correct" (Sargent, 2005, p. 130) Model validation is often defined as "substantiation that a computerized model within its domain of applicability possesses a satisfactory range of accuracy consistent with the intended application of the model" (Sargent, 2005, p. 130). In short, verification deals with building the model *right*, validation deals with building the *right* model (Banks, 1998, p. 336).

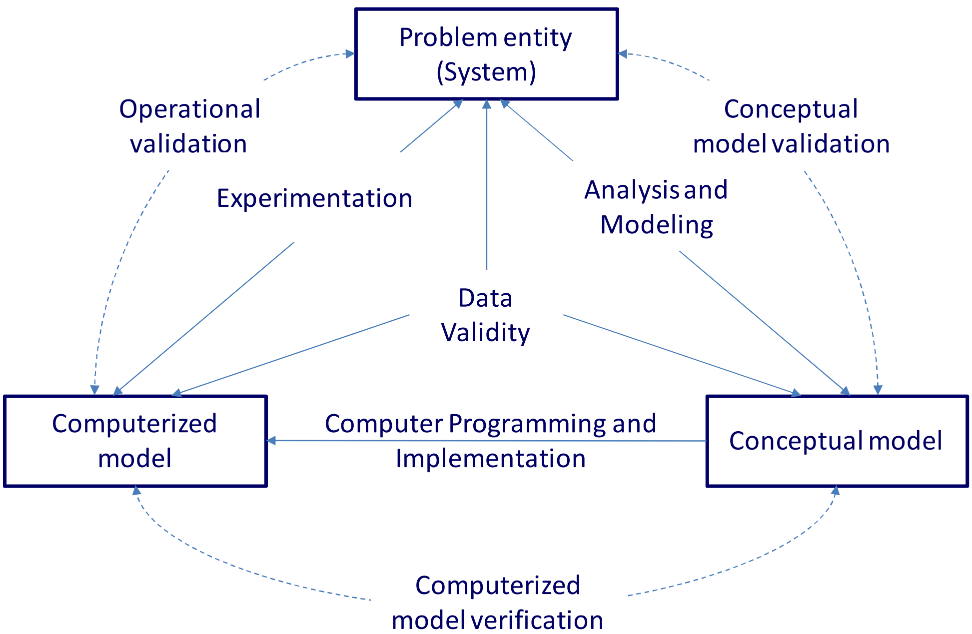


Figure 20: Simplified version of the modelling process (Sargent, 2005, p. 132)

Figure 20 displays the modelling process in a simplified way. The *problem entity* is the system to be modeled, in this case the operation of mail and EQ in FB1. The *conceptual models* are a logical representation of the system developed for a particular study. In this study the IDEF-0 diagrams and the flowcharts are the conceptual representation of the system. Inferences about the system are obtained by conducting computer experiments on the *computerized model* in the experimentation phase (Sargent, 2005).
The conceptual models of the operation in FB1 were validated in the meetings with the IT-team and in a special arranged meeting with a business analyst (3.3.4). The *computerized model verification* is to a large extend executed simultaneous with the construction of the model. The *operational validity* of the final model was tested after the construction of the model. The verification and validation of the simulation model will be discussed in the following two paragraphs. Afterwards the resulting limitations of the model are discussed in sub-paragraph 4.7.3.

4.7.1 Computerized model verification

A large number of techniques are available to verify a computerized simulation model (Balci, 1990, p. 31) (Sargent, 2005, p. 134) (Robinson, 1997). Tracing is used to verify the working of the final model after the building phase, nevertheless important verification activities are performed simultaneously with the construction of the model and these techniques will be described first.

Verification during the construction of the simulation model

During the construction of the simulation model several techniques were applied to reduce possible mistakes:

- The model was expanded step by step. This incremental approach ensured the model would work correct at every stage.
- Displaying the values of counters, variables and queue length as much as possible. When unexpected values were displayed, this indicated an error in the model.
- When a building block was finished the in- and output were checked with the help of counters on all flows. Often this indicated errors in an early stage.
- At "decide"-modules in Arena there is always an outgoing connector for entities which did not meet any of the conditions. Conditions, which covered all expected entity characteristics at that location in the model, were inserted. In this way entities with unexpected characteristics would be sent to the exit for the left over entities. After these exits infinite holds were placed, in this way an unexpected event in the simulation will come to light in an early stage.

These techniques made sure errors in the model or in the input files were identified in an early stage. These errors in the simulation model are solved along the way. Each model iteration has been tested in order to end up with a working model.
At the end of the construction process a structure walkthrough was performed to check if the process times were inserted correctly and if the employees were allocated to the right processes.

Tracing

For both departments some entities of the input files are selected, which reflect the possible variation of cargo passing through FB1. The following entity characteristics were varied for EQ shipments in this test: cargo flows, loaded on ULD or not, multiple piece AWBs. To see whether the model did register the missed bookings in the right way two transit entities with a very short time between flights (115 minutes) were send into the model as well. For mail the variation of entity characteristics was smaller and only included: cargo flows and carousels.
The first tracing tests revealed some errors in the registration of the operation in the model and an error at the grouping of the cargo for a flight. These malfunctions of the model were solved and an extra test showed the predicted results (appendix Q.4).
From the time registration at the entrance of all building blocks in the model the flow of the entities through the model could be verified. With this small number of entities it was possible to check if all cargo entities were correctly allocated to the different flights and whether or not the volumes, weight and pieces were added up in the right way. As expected the EQ AWBs with a very short transit time are registered as missed bookings before they are flown to the same destination on one of the next flights.

4.7.2 Operational validation of the simulation model

Operational validation of the simulation model is very difficult for the operations at FB1, due to the lack of data from the real world and due to the fact that the performance indicators used by KLM Cargo does not isolate the operation in FB1 in the same way as the simulation does. A brief comparison between the outcome of the model and the performance indicators of KLM Cargo in appendix Q.5 explains why the performance indicators are not comparable.
As a result comparable real data on the performance of the operation in FB1 is limited. This was expected and therefore the model works with as much real world data as possible. A technique to

validate a simulation model without the availability of real data is face validation, which uses the experience of experts to validate the model.
Another technique to test the model is a sensitivity analysis. In sub-paragraph 4.8 the results of the sensitivity analysis are discussed.

Face validation

The model is considered to have *face validity* if the results are consistent with how they perceive the system should operate. The simulation analyst should review the simulation results for reasonableness (Balci, 1990). During face value validation individuals knowledgeable about the system are asked whether the model and/or its behavior are reasonable (Sargent, 2005, p. 134).

The results of the simulation study are discussed in two meetings with the operational management[2]. In the first meeting, the 16th of March the basic elements in the Arena model were explained and the structure of the model was discussed. The second meeting was the final presentation on the 15th of May. In this sub-paragraph the comments of the management on the model outcomes and indirect the model validity will be discussed for the four performance indicator areas: resources utilization, handling times, number of re-bookings and the space requirements.

Resource utilization
The operational management recognized the workload pattern (Figure 35 & Figure 36) over the different functions at both departments. The shift in workload from the EQ department towards the mail department, due to the integration, is reflected in the model outcomes and is consistent for all functions.

Handling times
The question was raised why the handling time from the input location at mail to the right belly wagon along the carousel was longer than the handling time from the breakdown at EQ to the right wagon along the carousel (Table 59). Further analysis of the simulation results revealed the larger number of mailbags brought in at the same time for unloading extended the average handling time for mailbags on average.

Number of re-bookings
The number of mailbags missing their flight between the arrival at the transportation department and the departure of the flight are not up to date anymore with the current performance according to N. Aipassa.
This can be explained by the fact that the process time measurements which are the basis for the model were made six months ago and in at that time the merger of the transportation departments of the airmail and the EQ department was not yet working optimally. In the meanwhile the performance is improved and this implies that the performance of the transportation department will be better in reality than in the model. This has to be taken into account when discussing the results (Chapter 5 & 7).
The number of mailbags flying on earlier flights is considered high. This can be explained by the fact that the model will not take capacity constraints of the outgoing flights into account. Even when this number is overestimated in the simulation, it is possible to use the base case as benchmark to evaluate the influence of the integration, because the possible overestimation is the same for all models.

[2] I. Bocken (EQ), N. Aipassa (Airmail) and G. Bergkamp (integration implementation manager)

Space requirements
The maximum number of belly wagons positioned at the storage yard of the EQ department in the simulation model is larger than the actual capacity of 144 wagons. In reality some wagons will be located at the transportation department outside prior to the collection deadline. This difference between reality and the model is not expected to be influencing other performance indicators other than the maximum required belly wagons at the EQ storage yard. Therefore the difference is acceptable and the maximum number of wagons at the storage yard in the base case should be used with some caution.
At the mail department the maximum number of wagons along the carousel corresponds to the real variation of destination locations along the carousel.

4.7.3 Limitation of the simulation model

It remained difficult to validate the quantitative values of the performance indicators. Nevertheless it is possible to see if the score on one performance indicator is reasonable in relation to the score on other performance indicators. Additionally it is possible to judge whether or not the direction of a change in the value of a performance indicator due to the change in the simulation is explainable. In general the operational management recognized the relative scores on the performance indicators and all changes in the operational performance can be explained.

The face validation of the model proves the model can be used to predict interrelations in the operation of FB1. However quantitative outcomes of the model should be approached with some reserve, because it is not possible to validate the model outcomes with high accuracy. The validation revealed the limitations of the simulation model. Therefore the model results should not be communicated as the exact truth. Nevertheless the face validation also shows the model results are a good indication of the performance and the behaviour of the operations in FB1.

4.8 Sensitivity analysis of the base model

A sensitivity analysis is performed by systematically changing the values of the model input variables and parameter over some range of interest an observing the effect upon model behavior (Balci, 1990, p. 31). Unexpected effects may reveal invalidity.

To test the simulation model two types of input variables are varied for the model of the current situation. The transportation time is extended with 15% in the first analysis. The processed cargo quantities of small cargo and mailbags are increased by respectively 25 and 12.5% in the second analysis. In appendix X the results of the sensitivity analyses of the base model are displayed. Here only most remarkable effects are enumerated.

Growth of the processed cargo quantities

The growth rates are chosen based on the expected market developments identified in subparagraph 2.3.3. The expected yearly growth would result in an index value of 127 for EQ and 113 for airmail after five years from now. This is rounded down towards 25% and 12.5%.
During the sensitivity analysis the following remarkable effects were observed for the increase in workload at FB1:

- The utilization rate of the employees which will move the cargo on collo level will increase proportional to the increase in mail and EQ.
- The utilization of the weighing employees is increasing, but much less than the increase in mail and EQ. The driver for the utilization of these employees is the number of flights, more than the length of the trains with wagons.

- The time required for mailbags to reach the right belly wagon from the input locations will increase disproportional. This indicates that the workload of the employees involved reach the maximum and queues are formed because of their high occupation.
- The time required for EQ to reach the right belly wagon from the input locations will increase disproportional. This indicates that the workload of the employees involved reach the maximum and queues are formed because of their high occupation.
- The number of mailbags that will miss their flight will increase by 22,5%
- The number of EQ AWBs that will miss their booking will increase, which is expected due to the increase in the quantity of AWBs. Nevertheless the increase is less than proportional.

Extension of the transportation times to and from the plane by +15%

The extension of the transportation time is chosen to test the model behavior with respect to the number of re-bookings and because it is interesting with respect to the JUMP. The movement of KLM Cargo is expected to increase the transportation time, with this sensitivity analysis it is possible to estimate the effect on the selected performance indicators.
During the sensitivity analysis the following interesting effects were observed for the increase in transportation time:

- The increase will not influence the scheduled utilization of any employee
- The time between the arrival at the input location and the arrival at the belly wagon is decreasing for export mailbags. This could be the result of the postponement of the arrival of large numbers of mailbags by planes. In this way the export cargo arriving in the morning could be processed faster.
- The turnaround time in FB1 is shorter, but at the same time the total turnaround time from arrival with the plane to departure with the plane is unchanged. This implies that less time is spend at FB1, because the transportation time is a larger share of the total time between arrival and departure.
- Due to the increased transportation time the number of mailbags flying on an earlier flight will decrease with 5%. The number of export bags making an early flight will slightly increase; this is related to the second observation.
- The number of mailbags which will not arrive at the plane on time will increase by 90%. Although only 13% more bags will be late for the collection of their flight. This implies that that the time between collection and flight departure is tight at the mail department.
- The number of missed EQ AWBs will also increase, even thought the time between collection and the flight departure is longer than at the mail department.

Results sensitivity analysis

The results from the sensitivity analysis have pointed out possible bottlenecks in the mail and EQ operations. The observations from the sensitivity analysis are used to explain the effects of the integration in the first paragraphs of chapter 7 and help to refine the alternatives of the integration proposal in paragraph 7.9.
The disproportional increase in handling time between different locations and the belly wagon is observed at both departments. The extra pressure on employees will increase the handling times, this can be compensated by increase the number of scheduled employees.
The number of mailbags missing their flight between collection and transportation to the planes will be much larger when the transportation time is extended. This implies that that the time between collection and flight departure is tight at the mail department and might need evaluation.
In general the model behaves as expected in the sensitivity analysis.

4.9 Sub-conclusions on the model description and experimental plan

This chapter started off with the goal of the simulation, which resulted in the identification of the performance areas used for the evaluation of the integration: resource utilization, handling times, number of re-bookings and required space. The scores on these performance indicators can be calculated with the simulation output.

The required output have pointed out the essential elements in the process which has to be incorporate in the model, other elements from the conceptual models can be left out of the simulation. The reduced conceptual models have been transformed towards a simulation model of FB1 in Arena. This model requires input in four areas: production data, flight schedules, process time distributions and resources.

The possibilities to validate the simulation model are limited, because all available data are used to compose the model and no other quantitative data on the performance of the operations are available at KLM Cargo to compare the simulation results with. The face validation of the model however showed the model results are a good indication of the scores on the performance indicators.

The sensitivity analysis showed that the performance in FB1 at the mail department is very sensitive for the extension of the transport time to the plane. This sensitivity to the transportation times is interesting with respect to the JUMP, because the new terminal will be further away from the gates. The growth of both flows in the model showed that the current number of employees scheduled will not be able to process these larger volumes at the same quality level. Nevertheless the capacity of both operations can easily be increased at all stages by enlarging the number of scheduled employees.

With the constructed and validated simulation model it is possible to experiment and determine the performance of the current operations in FB1. The simulation results of these experiments will be discussed in the next chapter.

5 Simulation results current situation

In this chapter the simulation results of modelling of the current operation are discussed. An experimental design for the experiments has to be determined first in paragraph 5.1. Afterwards the simulation results will be discussed in separate paragraphs for all four performance areas as discussed in sub-paragraph 4.7.2: resource utilization, handling times, number of re-bookings and space requirements. Table 59 in appendix Y.2 gives an overview of all simulation results. The results for the simulation of the current situation are displayed in column "BM" of this table, BM stands for base model. The results of BM are used as benchmarks for the results of the simulation of the integration in chapter 6. Paragraph 5.6 summarizes the findings of this chapter.

5.1 Experimental design

The experimental design of a simulation study contains: the defined warm-up period, the replication length and the number of independent model replications (Law, 2003, p. 69).

Warm-up period

The collected data files contained data on the production at the mail and EQ department arriving in August and leaving FB1 in September 2008. Simulating the processing of this cargo in the last week of August as warm-up ensures that cargo and belly wagons are present in FB1 when the real replication starts. This is a good representation of the real situation, because there is always cargo in the FB1 at the beginning of a workday. The handling in FB1 can be seen as a continuous operation, never will all cargo be process first before new cargo is accepted.
In order to simulate the last week of August as well, it is necessary to model 8 days (24-31 August) as warm-up period, in this way the flights leaving on the 25th of August can be opened 24 hours prior to departure.

A steady-state of the number of belly wagons and the amount of cargo in FB1 is obtained before the end of August. In Figure 21 the scheduled utilization rate[3] of the weighing employees at mail and EQ are displayed. The weighing employees are selected because the weighing and collection process is the last process in the flow of cargo to the plane. They should be the last to reach a steady state. The graphs show that the utilization rate will vary around the final rate from 1 September 2008. The variation is far bigger at the beginning of the replication length, this lies within the character of the scheduled utilization rate, which is based on two averages. The utilization rates of both employees are increasing slightly after 1 September; this reflects the increase in workload at the end of the week at FB1.

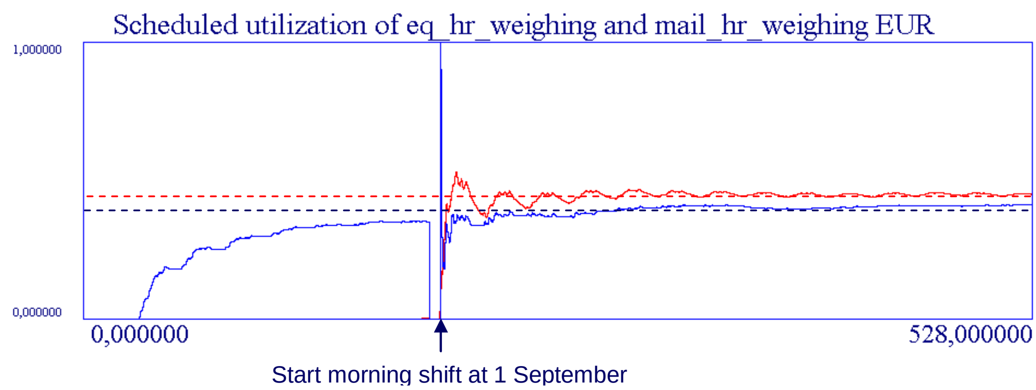


Figure 21: Graph of the scheduled utilization rate of the weighing employees at mail (blue) and EQ (red)

[3] Scheduled utilization rate = Average number of employees busy / Average number of employees scheduled

Replication length and corresponding simulated period

The replication length will be 14 days. In this way every pattern used in the simulation model is at least modeled twice. The throughput of the operations in two weeks will approximately be 113,850 mailbags and 8,130 AWBs. This number of mailbags and packages will secure a large enough sample sizes to determine the performance of both departments.
A longer replication length is not desirable, because this will make the time required to run several replications of all alternatives very large. Running one replication will take about 21 minutes. The computational power is a constraint is this way, mainly because of the immense number of mailbags passing the FB1 in a short period.

Number of independent model replications

The results of each simulation model experiment will be derived initially from 8 replications. Due to limitations with respect to computational time and the limited amount of rows in the Excel file used to register the output of the model, it will be feasible to run eight successive replications in acceptable period of time. The construction of a confidence interval is advised when processing the simulation results (Law, 2003, p. 69). The number of replications can be enlarged afterwards, in case the results are not satisfactory with regard to the reliability. Figure 22 is a schematic overview of the experimental design used in this simulation study.

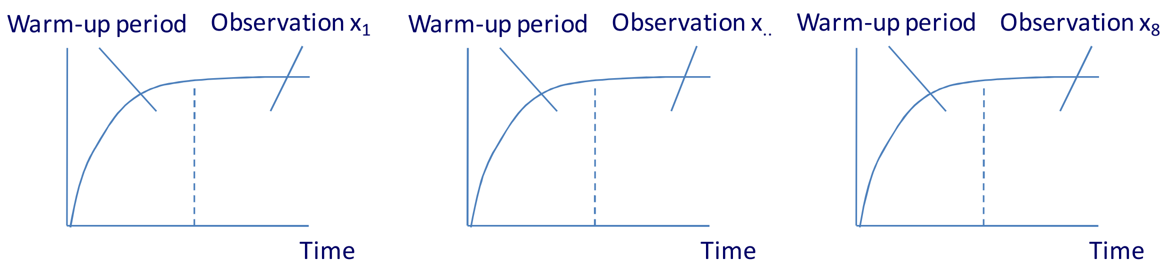


Figure 22: Multiple simulation runs including warm-up period, all runs result in a single observation (Verbraeck and Valentin, 2005, p.91)

5.2 Resource utilization

The resource utilization at the mail and EQ department is displayed in Table 14. Below these results of the simulation are discussed for the mail and EQ department separately.

Table 14: Resource utilization at the mail (left) and EQ department in the current situation

Mail resources	utlization rate
hr_mail_unload	0.71
hr_mail_scanning	0.70
hr_mail_switching	0.29
hr_mail_carousel_EUR	0.19
hr_mail_carousel_ICA	0.21
hr_mail_carousel_USA	0.16
hr_mail_weighing_EUR	0.41
hr_mail_weighing_intercontinental	0.49
equipment_mail_weighbridge	0.19

EQ resources	utlization rate
hr_eq_checker	0.27
hr_eq_bring_away	0.38
hr_eq_break_down	0.33
hr_eq_weigh_opening	0.31
hr_eq_weighbridge	0.51
hr_eq_export_acceptance	0.48
hr_eq_lateral_sorter	0.36
hr_eq_lateral_driver	0.27
equipment_eq_weighbridge	0.19

5.2.1 Resource utilization at the current mail department

In the base situation the utilization rate is the highest for employees at the input locations. These employees are unloading and scanning the incoming mailbags, both utilization rates are above 70%. These high utilization rates will not leave room for an increase in their workload.
The two switchers at the mail department are not intensively occupied, they are busy only 30% of their scheduled time. Switchers are crucial for the continuous flow over the conveyor belt and should be able to handle the peak in the workload. Therefore a reduction in the scheduled number of switchers is undesirable.

The employees along the carousels seem to be least busy of the mail employees; the utilization rate at all carousels is around 20%. Nevertheless their workload is underestimated in the simulation model, because their repositioning is a valuable activity which is not modelled, as is explained in paragraph 4.4.1.
The employee responsible for the weighing of departing belly wagons at the EUR carousel is less busy, 41% of the scheduled time, than the employee responsible for the ICA and USA carousel, 49% of the scheduled time. The collection of mail and the positioning at the transportation department are crucial task in order to make the deadlines of mail. An increase in the workload for the weighing employees due to the integration could therefore result in more mailbags missing their flight. This should be monitored when discussing the results of the integrated models.
The two weighbridges are clearly sufficient when only two employees are weighing, every weigh employee can use one of the weighbridges exclusively.

5.2.2 Resource utilization at the current EQ department

The results of the simulation of the base case are used as benchmarks for the results of the simulation of the integration. Due to the scheduled nightshift for some crucial functions (see appendix P.4) the scheduled utilization is underestimated at EQ. The workload at night will be much lower than during the day. Although the minimum number of employees to ensure continuous throughput is scheduled at night, the average utilization rate will be pulled downwards by the night shift. Nevertheless it is possible to compare the results of the different models because this underestimation is structural for all models.

The weighing employees are the most intensively used employees at the EQ department, 51% of the scheduled time. Followed by the export acceptance employees, 48% of the scheduled time.
For the other functions the utilization lies around the 30%. These remaining functions are very dependent on the arrival of flights, which bring in new workload. In FB1 it is observed that these employees are sometimes waiting for flights to arrive, but at peak times they are working longer periods successively.

5.2.3 Combination of the utilization rate

The total number of required hours necessary to process all mailbags and EQ AWBs of two weeks is calculated for the current situation. This number will be compared to the required number of hours after the integration. The difference will indicate the change in efficiency due to the integration.
The total required hours is calculated by summing up the products of scheduled hours and the utilization rate per function. The processing of the mailbags in the current operation requires 478 hours, the processing of the EQ AWBs requires 700 hours in the current operation. The total required number of hours in two weeks of production is 1,178.

5.3 Handling times

The handling times at the mail and EQ department are displayed in Table 15. Below these results of the simulation are discussed for the mail and EQ department separately.

Table 15: Handling times at the mail (left) and EQ department in the current situation

Handling times mail	hours
Arrival input location - ready in belly wagon	0.4
Collection - ready at transport	0.2
Ready in belly wagon - collection	7.3
Average turnaround time mail; arrival FB1 -ready at transport	8.0
Average turnaround time mail STA-ATD plane	10.0

Handling times EQ	hours
Export acceptance EQ - ready in belly wagon at EQ	0.4
Arrival breakdown - ready in belly wagon at EQ (excl. temp)	0.6
Arrival breakdown - ready at import EQ	0.5
Collection - ready at transport	0.3
Ready in belly wagon - collection	8.6
Average turnaround time eq FB1	14.4
Average turnaround time eq FB1 ATA-ATD plane	16.6

5.3.1 Handling times airmail

In the current mail operation the mailbags spend most of their time in FB1, about 8 hours, waiting for collection in the wagon along the carousel, more than 7 hours. The remaining time in FB1 exists out of: the time required for processes taking the mailbag to the right belly wagon along the carousel, around 0.4 hour, and the time required to bring the wagon from the carousel to the transportation department, 0.2 hour. The difference between the turnaround times in FB1 and the turnaround times from arriving to departing by plane is 2 hours. This time is required for the transportation between FB1 and the arriving and departing planes.

5.3.2 Handling times EQ

In the model small and large EQ shipments are considered as one product group, just as is currently done in the operation itself.
The time required to bring an EQ shipment to the right belly wagon at the storage yard from the arrival at the export acceptance or from the arrival at the break down area will both be around half an hour on average. From the arrival at the breakdown area it will take half an hour on average before an import AWB is ready for pick-up by the customer as well.
The differences between the pure process times of the required activities and the handling times are large. The handling times will incorporate the breaks taken by employees in the operation and the formation of small queues when packages arrive at the same time and all employees for these function are already executing a task. When shipments are moved around on more than one pallet the time is registered only when all pallets of one shipment have arrived at the next stage in the operation.
The time required to bring the belly wagons to the transportation department requires 0.3 hours at the EQ department. This handling time at EQ is longer than the one at the mail department, because of the security check is executed on the way to the transportation department.
The average turnaround times at EQ are larger than the ones at the mail department, approximately 6 hours. This is not because the processes will take that much longer, but because EQ shipments will not leave FB1 as soon as possible. Instead the shipments have to wait until the booked flight is collected.
It is not possible to find the connection between the turnaround times and other time intervals for EQ, because some AWBs are stored in FB1 temporarily. The time some AWBs spend in the temporary storage increases the average turnaround times in FB1 for all EQ shipments.

5.4 Number of re-bookings

In this paragraph the number of re-bookings in the current situation for both departments are discussed.

5.4.1 Mailbags on different flight in current mail operation

In the simulated weeks the mail department processes approximately 113,850 mailbags. Some mailbags are able to fly on an earlier flight in the model than they did fly on in reality and some mailbags will miss their flight at FB1.

Mailbags that will fly on earlier flight

To compose a base case, the number of mailbags catching an earlier flight than they did in reality had to be determined. As discussed during the validation of the model (sub-paragraph 4.7.2), the number of mailbags which are able to take an earlier flight is overestimated by the fact that no capacity constraints for the departing flights are modeled.
The model shows that without any capacity constraint around 17,000 mailbags can make an earlier flight in only two weeks.

Mailbags that will miss their initial flight

The simulation indicates approximately 5,300 mailbags are missing their initial flight in the current situation. The bags can miss their flight at the moment of collection, which implies the bags are still on the carousel or did not even arrive at the carousel yet at the time their initial flight is collected for transport. The bags can also miss their flight on their way to the plane from FB1. The model shows only 1,400 bags are missing their flight at collection and 3,900 bags are missing the flight on the way to the plane.
The model calculates a number of bags missing their flight during transportation, which is fairly high compared to actual performance at this time in FB1 as explained during the face validation (paragraph 4.7.2).

5.4.2 Number of AWBs on different flight in current EQ operation

The EQ department processes around 8,130 AWBs in the simulated September weeks. Some of this AWBs will not fly according to their booking but on another flight. What percentage of these AWBs, will fly earlier or later than the booking will be discussed in this sub-paragraph.

AWBs that will fly on earlier flight

In the current operation no AWBs will be transported with an earlier flight than their booking. All shipments will wait at the storage yard with belly wagons until this flight is collected.

AWBs that will miss their booked flight

Approximately 140 AWBs will miss their booking in the simulation model. Around 90 of these bags will miss their flight because the flight is already closed and the wagon is brought to the weighbridge already. The remaining 50 will miss the flight during transportation to the plane.

5.5 Space requirements

In the current situation the storage yard at EQ has a capacity of 144 belly wagons and 90 belly wagons are located along the carousel.
The simulated results indicate a higher maximum at the EQ storage yard (as discussed in paragraph 4.7.2) than 144 belly wagons. In reality some wagons will be opened later or will be brought outside earlier in order to prevent an overload at the storage yard.
The maximum number of wagons calculated with the simulation model for the current situation along the carousel is reflecting the reality. Maximally 81 different destination locations are required. However for some destinations multiple wagons are located along the carousel in reality. The doubles, 9 wagons, will have to be added to the simulation results in order to determine the wagons along the carousel. This implies that on average 90 wagons are located along the belt, which corresponds to the actual 90 belly wagon locations along the belt.

5.6 Summary of the simulation results of the current situation

The simulation model has resulted in the determination of the performance of the current operations in FB1. These results of the base model “BM” will be summarized below for all four performance areas.

Resource utilization

The processing of the mailbags in the current operation requires 478 working hours, the processing of the EQ AWBs requires 700 hours in the current operation. The total required number of hours in the simulated two weeks is 1178. Efficiency improvement due to the integration would be revealed by the reduction in the required number of hours at both departments.

Handling times
Due to the existence of the booking principle at the EQ department the average turnaround times are much longer for AWBs than for mailbags. The difference could indicate potential benefits of the introduction of the FIFO-principle at the EQ department.

Number of re-bookings
At the mail department a little less than 5% of all mailbags leaving by plane will miss their flight. At the same time three times as much mailbags can leave by plane earlier than they did in reality. The lack of a capacity constraint on departing flights in the simulation is causing this large number of bags taking an early flight in the simulation. In reality this constraints is very important.
At the EQ department around 140 of all 8,130 AWBs are missing their flight currently, which is less than 2% of the total.

Space requirements
The simulation results with respect to the space requirements are representing reality exactly at the mail department. The space requirement at the EQ department shows the full capacity of 144 wagons at the storage yard will be used to its full extend currently.

Furthermore the scores in the base case on all performance indicators are calculated in this chapter. These results from this chapter will be compared to the results of the simulation models of the integrated situation in FB1 in chapter 7. In this way the results discussed in this chapter are the benchmark for the evaluation of the integration results in chapter 7.

6 Integration of the handling processes in FB 1

In this chapter the integration of the airmail and EQ department will be described in detail. Paragraph 6.1 enumerates the objectives, constraints and requirements of KM Cargo with respect to the integration. The observations of the visit to Sodexi are described in paragraph 6.2. The combined operation of airmail and EQ at Sodexi at Charles de Gaulle airport is seen as an example for KLM Cargo. Sodexi is an interesting benchmark because KLM and Air France want to align their operations and at the Sodexi warehouse mail and EQ are already combined. The design requirements and the experience of Sodexi have resulted in an integration proposal for the joint operation in FB1 by the integration project team. This integration proposal will be described in 6.3. From this proposal the required changes to the processes, to the infrastructure and in the equipment can be derived, which is discussed in paragraph 6.4. From here it is a small step to the uncertainties related to the integration, which have already been mentioned in paragraph 1.1. In paragraph 6.5 these will be discussed in detail. A quantitative data analysis of the integrated situation is performed in the last paragraph of this chapter.

6.1 Design requirements

The alignment with the Air France operations and the continuous search for improvement of the operations were the immediate causes to start studying the integration of mail and EQ. As explained in chapter 1 KLM Cargo started the business case study for the integration for five potential benefits. These benefits can be translated to KLM Cargo's objectives for the integration project. These objectives will be enumerated in the next sub-paragraph. This paragraph will be followed by a sub-paragraph listing the relevant constraints set by KLM Cargo for the integration. In sub-paragraph 6.1.3 some other requirement of KLM Cargo with respect to the integration are enumerated.

6.1.1 Project objectives

The five objectives of KLM Cargo can be summarized as follows:

- Increase the efficiency of the handling of airmail and EQ, in order to reduce the required number of FTEs for the same performance.
- Improve the customer service level due to improvement of the track and tracing of airmail bags and shorter transport times for EQ because some shipments can fly on an earlier flight.
- Increase the load factor by advancing the transport of available EQ cargo on earlier flights when possible. This will release capacity on the later flights, which could attract new cargo that would be rejected otherwise.
- Gain experience with the integrated situation in the current FB1 for the movement of KLM Cargo to another location at Schiphol.
- Reduce the total required space for the operation of both departments.

These objectives have a large overlap with the key issues that the industry should address in the near future according to literature: service reliability, cargo visibility, tracking and tracing, accurate documentation, cargo consolidation and logistic services (Ramachandran and Tiwari, 2001, p. 81) (Lobo and Zairi, 1999 p. 168).

6.1.2 Project constraints

The constraints for the integration of the both departments can be enumerated. These constraints are derived from the business case (KLM Cargo and M3 Consultancy, 2006) and some constraints derived from literature and interviews are added.

Employee safety

The Dutch "Arbeidsomstandighedenwet" or Arbo-law limits the design space with regard to the human capabilities and limitations. Ergonomic principle embraces physical as well as mental task. Equipment should avoid repetitive and strenuous manual labour (Groover, 2001, p. 289).

The limitations and requirements from the Arbo-law which are especially relevant for KLM are:

- Maximum weight to be lifted by employees, which should be 23 kilograms according to arbo-law (www.arboportaal.nl, 10-3-2009). KLM uses a maximum weight for one colli of 35 kg, because it is possible that employees work together (exceptional for the mail department) or use a FLT (at EQ department)
- Employees should not work bended over, currently the scanner is working bend over. The input locations are designed in the past to make it easy to transfer a mailbag from the belly wagon onto the conveyor belt; therefore the conveyor belt height matches the height of the bottom of the belly wagons.
- Making dedicated walking paths in the FB is currently required and this will be required for the new design as well.
- The direction of traffic flow should be one-way at all lanes to improve the safety of employees in the FB. At the mail department it is required to position the belly wagons parallel to the carousel in the best case or under a maximum angle of 45° as is allowed now in the worse case.
- The parallel placement of the wagons will require more of the carousels length than the situation that all wagons are set square with the carousels. This is not allowed, because when wagons are set square the risk exists that employees will get crushed between the carousel and the belly wagon, in case someone else will bump into the belly wagon from the other side (Interview H. Deben, appendix R.3).
  Besides the risk of crushing employees square positioning will also make it heavier to put mailbags in belly wagons, because the bags will have to be lifted over the side of the wagon.

Product safety

The mail product is a very robust product and therefore it is possible to drop the mailbags relatively rough onto the carousels. This makes it possible to use very steep slides form the higher placed transportation belt onto the lower placed carousels. The EQ products are often more valuable and also more fragile than mailbags. This will require changes to the slides after the integration otherwise the product safety level will become worse.
Even after the changes to the slides some products will be excluded from transportation (dangerous goods and fragile goods) with conveyor belt. In this way the same or improved product safety can be ensured.

Conveyor belt restrictions

The supplier of the conveyor belt system has given indications of the capacity of the conveyor belt. The capacity of an input location is estimated on 450 colli per hour, the capacity of the transportation belt is estimated to be 1000 colli per hour. (Statement S. Troost, Consultant Decision Support KLM). The speed of the belt is 24 meters per minute.

Building

The design of FB1 itself will limit the possibilities for the integration. Obviously the sizes of the building and the immoveable facilities in FB1 will form a restriction, for example be a weight-bearing wall.

6.1.3 Project requirements

Besides the constraints, KLM Cargo's management has also determined the requirements for the integration project. These requirements will be described below.

Earn-back period

The investment in the integration, which cannot be used at the new location, should be earned back in the operational period until the JUMP of KLM Cargo. In order words the capital expenditure (Capex) to make the integration possible should be earned back by a lower operational expenditure (Opex) in the period till the JUMP. This implies that the operation should be more efficient in any case when the investment will have to be earned back by reducing the labour costs. The date of the JUMP is still unclear; therefore the write-off period used in previous studies is used as an indication. These studies used a write-off period of 2.5 years for infrastructure investments. A longer write-off period is allowed for process and IT investments with the idea that these investments can be moved to the new FB easily (KLM Cargo and M3 Consultancy, 2006).

Operational performance

The operational performance of the operation should remain the same or improve by the integration. Besides the minimum level of operational performance on the long term, KLM cargo's (operational) management also demands continuity of the operations in the transition period. KLM is seen as a very reliable airline. Therefore it is important that the implementation of the integration project will not cause a discontinuity in the operations. The communication with the customers will also create understanding for some shipments with a bad performance, as will be learned from the integration at Sodexi (paragraph 6.2)

The performance of the mail handling at Schiphol will be expressed by the on time performance (OTP). This performance can be split up in the OTP for transit, import, export and transport. The performance of EQ is displayed by departed (DEP) and notified (NFD) scores. DEP is expressed by the share of shipments and documents which have departed on a booked flight or truck and by the share of shipments departing within 60 minutes of the planned time. NFD is the percentage of customers which are informed that the shipment and documents are ready for pick-up (KLM Cargo and M3 Consultancy, 2006).

Uniformity

KLM Cargo's management want to apply one inventory principle. At this time the EQ department applies the booking system and mail applies the FIFO-principle already. At the mail only exceptions are made when a flight is constraint. In this situation the mail with the lowest priority will stay at Schiphol.

Reliability

KLM Cargo's management has decided to keep a shipment together at all time. This will imply that all colli of a shipment are treated as large shipments even if only one shipment is heavier than the maximum weight of one collo for the belt. In this way sending off incomplete shipments is prevented.

Security

The mail department traditionally is a highly secured department. The whole department is screened off from the other departments. Only authorized persons are allowed to walk in and out. The security measures at EQ are less severe at the landside. Often the doors are open to receive the export cargo from the customers. Only employees are allowed to walk into the freight building of course, but there is not a continuous physical barrier.

For the security of the airplane all EQ shipments should be checked on dangerous goods by specially trained dogs. This will imply that when EQ and mail are combined in the handling process, all wagons with mail have to be checked by the dogs as well, in order to maintain the same security level.

6.2 Sodexi operation at Charles de Gaulle airport, Paris

Often Airmail and EQ are transported in the belly of planes, loaded as bulk cargo. In the belly airmail and EQ are often mixed together during the loading of the plane. Various ground handlers and airlines are accepting mixed loads, with airmail and EQ together on the same belly wagon or ULD. Beside the expected benefits for the operations in FB1, the integration will also reduce the sorting activities of the bulk load under the plane and it will reduce the number of wagons transported between the gates and the freight buildings. These advantages explain why other parties in the industry have combined the handling of airmail and EQ products.
A visit to Sodexi at Charles de Gaulle airport was made to compare the proposed integration with a real example. A summary of the observations of this visit and some photo's can be found in appendix S. Here a brief summary of the most relevant observations is placed.

General flow of cargo

At Sodexi (Figure 23) all cargo from the airside is directly brought to the double input location. At the input location the cargo is broken down, scanned and put on an automated sorter belt. Afterwards the package is scanned again to determine the location of the bag on the automated sorter belt; the scanning however is performed manually. Once the sorter system knows the location of the collo on the belt and the destination from the label, it will send the bag to one of the ten shoot of the belt system automatically. Around each shoot there is room for approximately 10 ULDs, each of those locations is linked to a destination. At the end of the conveyor belt there is a shoot for all small destinations. At this shoot roller cages are used to store the cargo per destination (Appendix S.2)
At each shoot, employees will proceed the process manually. They will place the bags and packages in the ULDs or roller cages for the right destination. At the same time as they place the collo in the ULD they make a scan of the barcode on the label. This information is used by the planners and is the input for electronic data exchange with receiving parties.

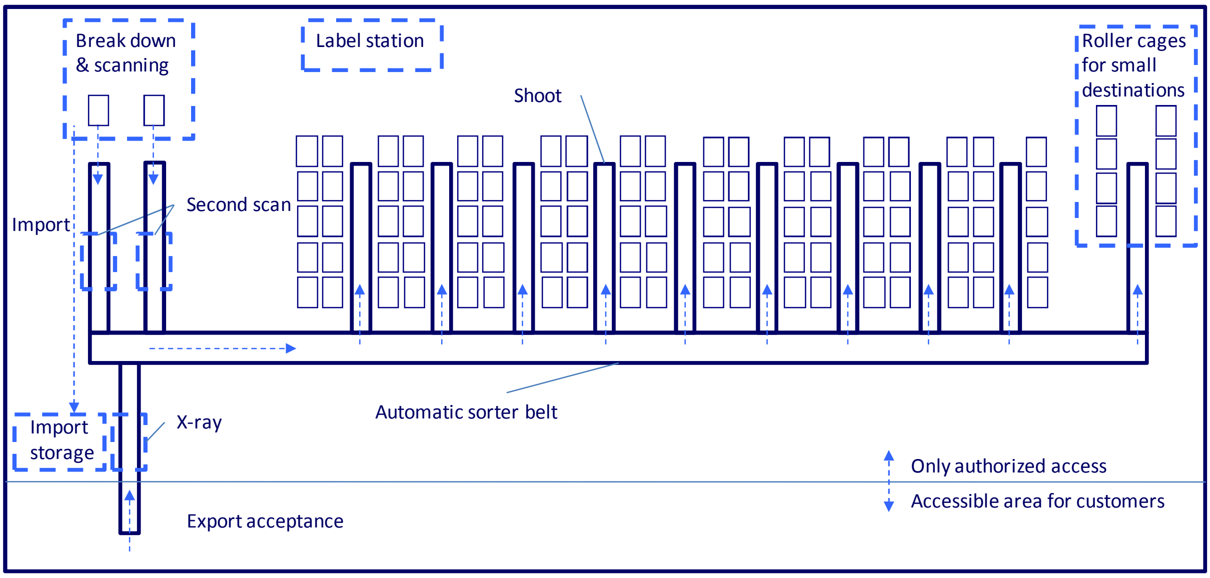


Figure 23: Schematic layout of the integrated operation at Sodexi

Observations during the visit

The Sodexi warehouse is located at a large distance from the gates at Charles de Gaulle airport. A lot a time is required for transportation of cargo between the warehouse and the gates. The long transportation times are increasing the minimum connection times. Sodexi is planning to build a depot near the gates at Charles de Gaulle to reduce the transportation time. This depot will primarily be used for transit cargo and can be used to bundle flows between the planes and the warehouse at the current location of Sodexi.
All colli are labelled when they are arriving without a label. This is done at a special labelling station. For mailbags only a label with the destination is attached, for EQ an IATA606(B) label is attached. Every station that sends packages without a label is contacted and the desired change is communicated. This has resulted in a relatively fast adoption of the IATA606(B) label.
Odd size and heavy shipment are brought to the wagons or ULDs directly. No separate location to process heavy or odd sized shipments exists.
The acceptance of export cargo is performed by the customer itself. The customer picks up the label and labels the shipment. The shipment can be placed on an input belt and the package disappears in the system. This input belt is equipped with a x-ray machine to check the package on dangerous goods. Import cargo is brought to storage racks directly from the input locations
At Sodexi EQ a larger percentage of all cargo consists out of EQ. Most cargo will be loaded in small ULD types instead of belly wagons. Some locations for ULDs are integrated with a weighbridge, in this way the actual weight of the ULDs is known, which is very useful in case the capacity is constraint for that destination.
Sodexi communicated intensively with their customers during the transition period. Good communication increases the understanding for delays. Sodexi tried to involve their customers by explaining the benefits of the integration. Convincing the customers of the advantages made them more cooperative. Labelling their packages in advance with the right labels could be one of the results of this cooperation.

Effects of integration at Sodexi

The integration of airmail and EQ at Sodexi resulted in a better tracking and tracing of cargo and increased the load factor by mixed loading in ULDs. Mistakes made in the process are noticed earlier and can be dealt with more adequately.
The integration was accompanied by the optimization of the planning of the transportation to the plane with a new software application, called Gioppi. This optimization did pay off very fast because of the large distances at Charles de Gaulle airport.

6.3 Integration proposal

The proposed integration of both departments in FB1 will be described in detail in this paragraph. The first sub-paragraph states the chosen starting point of the integration design. The next sub-paragraph describes the design of the integrated process including the required changes to the process, infrastructure and equipment in FB1. Subsequently by the enumeration of the uncertainty related to the integration in the fourth sub-paragraph. Finally the integrated situation was subjected to a quantitative data analysis.

6.3.1 Starting point for integration design

KLM Cargo started the design stage with the current processes of airmail and EQ, including the existing conveyor belt system. This starting point was mainly chosen because of the short earn-back period (until the JUMP) and restrictions on the maximum capital expenditure.
The integration is focused on the incremental improvement of the current operation and not the thorough reengineering of the business processes. Business process reengineering (BPR) strives to break away from the old rules of organization and conducting a business, in order to find new ways to accomplish the work with the hope to achieve quantum improvement in performance

(Rotab Khan, 1999). BPR would require an extensive analysis. A thorough analysis of the operation was performed by M3 consultants, but they were not commissioned to design a new process from scratch, but were asked to test the first ideas of KLM Cargo during the business case study.
This study resulted in a proposal for the integrated design, which is based on the current lay-out of the conveyor belt system. In appendix E.2 a map of the proposed situation in FB1 is displayed, including the extension of the conveyor belt system.

6.3.2 Design of the integrated process

In order to make the combination of operations possible, the infrastructure in FB1 will be changed. New conveyor belts (Figure 24, yellow) will connect the present EQ hall with existing belt system for mailbags. The USA carousel will be extended (Figure 24, extension of USA carousel included in orange ellipse) to make room for a larger number of belly wagons positions along the carousels.

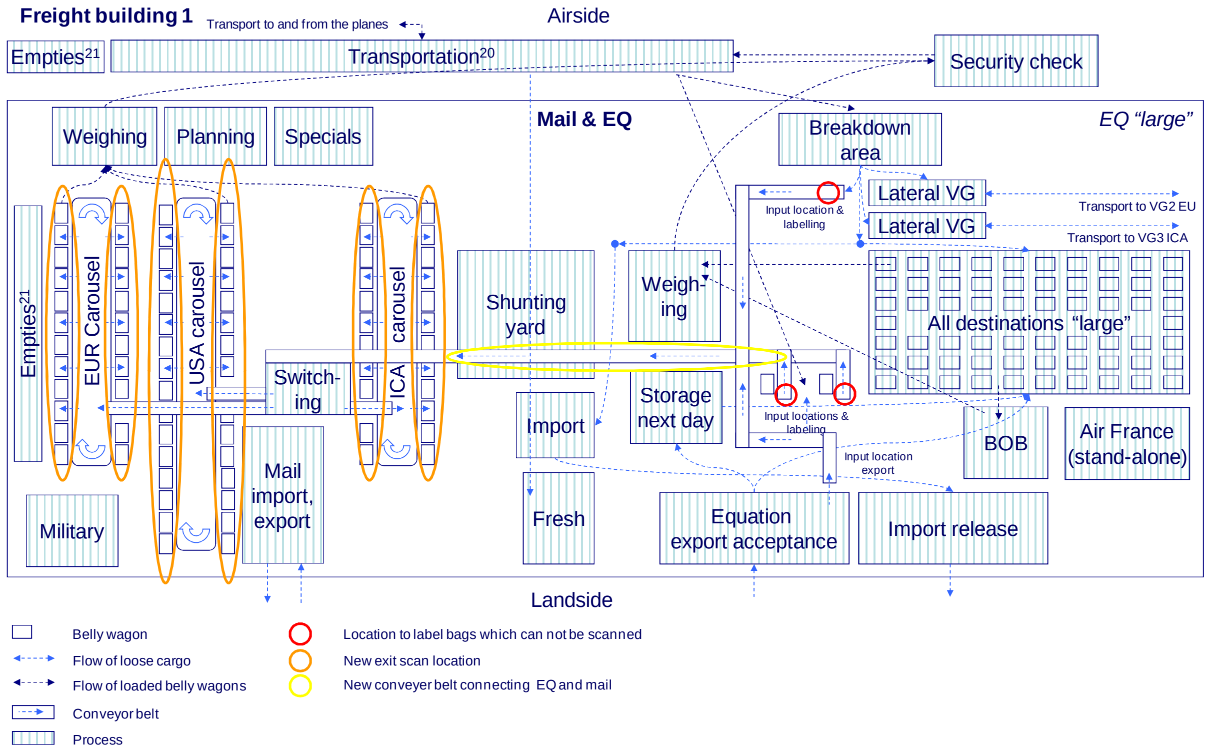


Figure 24: Schematic representation of future situation FB1

In the future situation the **small** export and transit EQ shipments are loaded on the conveyor belt system at the new input locations (Figure 24, red circles) at the EQ department. Input locations are created at the export acceptance and at the breakdown area. The colli that will not be applied with an IATA606(B) label will all have to be labelled at these input locations.
Via the new conveyor belt (Figure 24, yellow circle) the packages will reach the switching table in the existing mail conveyor. From there the process will be the same as the mail handling from the sorting table, with the exception that an exit scan (Figure 24, orange circles) will be performed when collo are taken off the carousel.
The input locations at the current mail department will be removed. In this way all cargo, airmail and EQ, will enter the conveyor system from the present EQ department. This implies the mail and EQ belly wagons can be brought in simultaneously and both products could be mixed in the belly wagons in the future. This mixed loading will be applicable for arriving and departing cargo. It is expected that this will decrease the number of wagons going to and from the planes, which

could result in less trips to the planes for the transportation department. The transportation to and from the plane is outside the scope of this research however.
For **large** EQ shipments and fragile or dangerous goods the **flow** of goods process will not change. The conveyor belt is not suited to transport this cargo. The only change in the handling process for large cargo is the introduction of the FIFO-principle, nothing more.
The handling of import EQ will not change either, because the goods cannot be brought to the storage of import cargo faster via the sorter system than is done at this moment using FLTs.

Enumeration of required changes in the process at the mail department

In the mail process the following changes will be made for the integration:

- The mail bags without a UPU-label with barcode that can be scanned will have to be labelled (Figure 25, A) before it is put on the conveyor belt.
- An exit scan will be performed when taking mailbags and EQ collo off the carousel (Figure 25, C).
- On the way out to the planes the mail (often mixed with EQ on one wagon) will have to pass the security check, just as EQ has to do now (Figure 25, D).
- The input locations will be moved further away from the sorting location in the belt system. This will extend the travel time on the belt for the mailbags (Figure 25, E).
- The time between the collection of cargo and the flight departure will be increased to 90 minutes at the mail department, to synchronize the time of collection for mail and EQ at both locations and to create room for the future security check for mail.
- All flights currently used to transport mail or EQ from Schiphol are made accessible for both products

Enumeration of required changes in the process at the EQ department

The process for small EQ will be the same as the process for airmail after the packages are put on the conveyor belt at an input location. Before EQ reaches this point the following changes are made to the EQ operation:

- The packages of **small** export shipments are loaded on a conveyor belt, which will transport them to the sorting station.
- All **small** transit and export cargo (includes small lateral incoming EQ) will have to be labelled with an IATA 606(B) label before it is loaded onto the conveyor belt to be transported to the sorting station. (Figure 25, including B). When loaded on the conveyor the labels are all scanned as entry scan.
- The FIFO-principle will be applied for all EQ shipments.
- All flights currently used to transport mail or EQ from Schiphol are made accessible for both products

From the placement of the EQ cargo on the conveyor belt, the handling of **small** EQ will be completely different than the current situation and will exactly resemble the future mail process from there (Figure 25, including C & D). Figure 25 is based on the previously used time-place analysis in Figure 9 and Figure 10.

Enumeration of changes to the infrastructure and changes in used equipment

Changes to the infrastructure in FB1 are proposed to make the integration possible:

- Making an opening in the load bearing wall for the conveyor belt connecting the new input locations at the current EQ department with the existing conveyor system.
- Removing the fence between airmail and EQ
- Moving ICA carousel in the direction of the sorting station, in order to create more space for the storage of empty belly wagon and dollies with empty ULDs.

- Decreasing the slope of the slides onto the carousel. At some point the mailbags are dropped down very hard. This is not a problem for mailbags, but it might damage the EQ packages. The wear of the conveyor belt will also be reduced by the flatter slope, because corners of large boxes which are dropped on the belt can damage the belt. When the current conveyor belt system was designed mail was primarily being transported in mailbags, which would be less damaging when dropped on the carousel.

The changes to the equipment will include: the introduction of the scanners to perform the exit scan along the carousels, new wireless scanners at the mail input locations and the movement of the weighbridge currently used by EQ. The entry scan resembles an existing scan, but is performed by other employees.

- The scanners should be able to read the barcode on the UPU labels and on the IATA606(B) labels and the scanner should be "live". This will provide the planners with real time information and it will not be necessary to walk to the office to upload the data from the scanner every couple of flights.
- The weighbridge currently used at the EQ department will be moved to one of the exit to the airside at FB1. This will replace the weighbridge at the current location, which will have to move to make room for the new input locations.
- KLM Cargo will require printing equipment at the input locations and the export acceptance to print IATA606(B) and UPU labels for the cargo without a label with barcode.

Example of integrated handling of airmail and EQ

It is not possible to construct a time-place analysis for the future situation with same detail level as is done for the current situation in paragraph 3.2, nevertheless it is possible to display the flow of cargo on the map of FB1 and it is possible to point out at what stages the handling processes is changed in the timeline. The resulting time-place analysis is displayed in Figure 25.

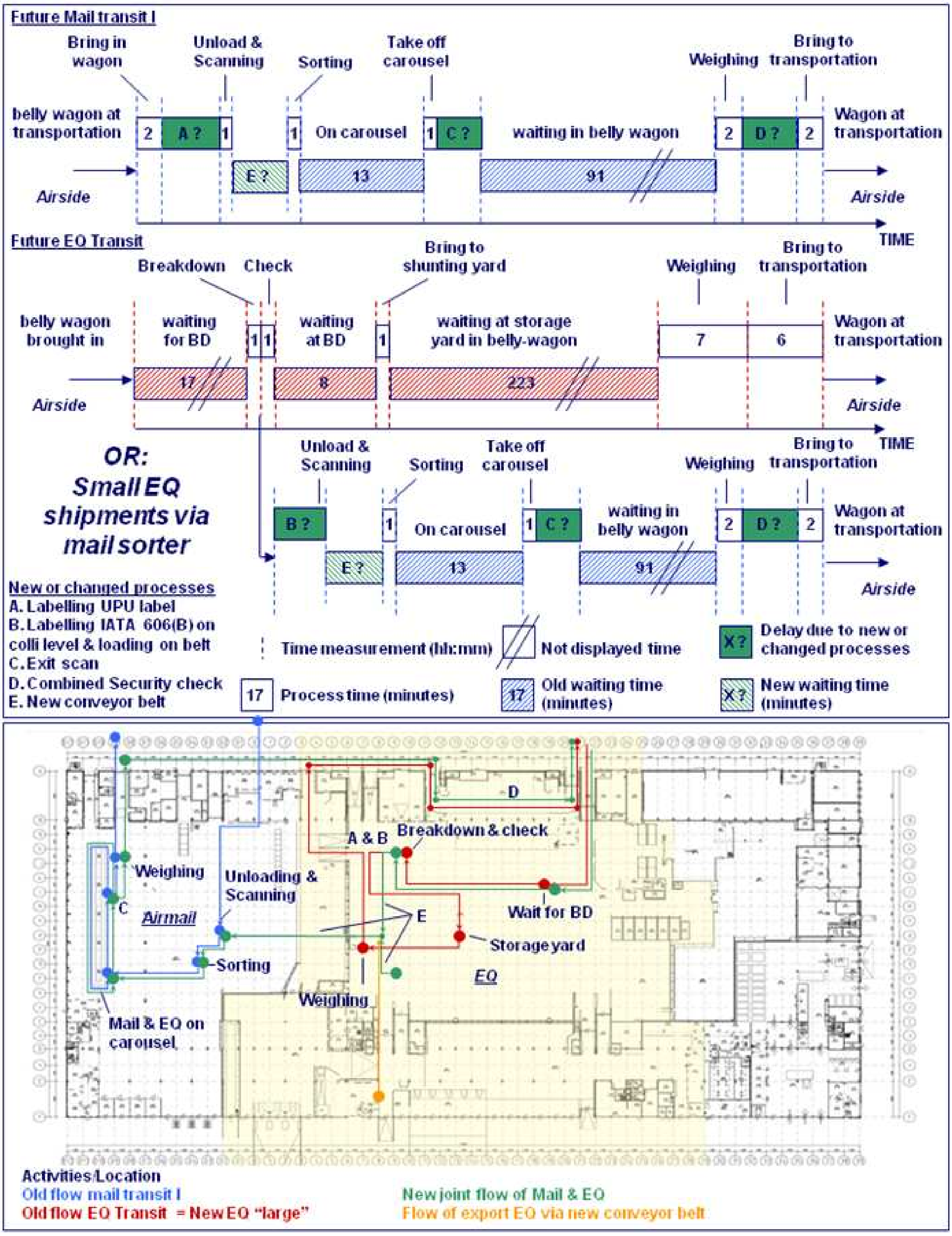


Figure 25: Expected changes on the time-place analysis due to the integration

The integration of the two product flows is described in a simplified way in this integration proposal. More details will have to be worked out before the integration can be successful. Some mayor challenges related to the integrations will be described in the next sub-paragraph.

6.3.3 Limitation of the solution space by the design requirements

The design requirements, discussed in paragraph 6.1 of this chapter, limit the freedom during the design of the integrated process. In this paragraph the effects of the limitations on the final integration proposal are discussed. Not all limitations at the current location are applicable at the new location after the JUMP. Therefore the effect of the limitations on the final design is even more interesting, because it could indicate possibilities to improve the process at the new location.

Due to the limited earn-back period the total initial investment in infrastructural works cannot be very large in case these items cannot be used at the new location after the JUMP. Without this limitation KLM Cargo could invest in a more sophisticated sorter system, which will reduce the required labour for the same performance. At the new location more KLM Cargo has a longer period to earn back the initial investment.
The current infrastructure and the layout of FB1 limit the options to fully integrate both departments as well. Without these restrictions it would be easier to combine the export acceptance, import release and the planning activities of both departments. No uncertainty would exist whether enough destination locations can be created along the carousels either.
In general, the current design requirements are limiting the options for KLM Cargo to start over and design totally new process. Process reengineering on the current location is not possible.

6.4 Conceptualization of the integration at FB1

The characteristics of the processes from the current situation will not be changed by the integration. The integration adds a small number of processes and changes the flow of a part of the EQ shipments, but the processes itself will not be changed.
The flowcharts of the current mail and EQ points are combined to construct the flowchart for the future situation (Figure 82 in appendix K.3). The additional processes and choices following from the integration proposal are highlighted (red squares and diamonds) and the cargo flow of mail and EQ together is emphasised (the orange arrows). The combined operation is only modelled in a flowchart and not in the IDEF-0 diagrams because the sub-processes itself will not change radically; the flow of certain cargo through the building will change in particular.

6.5 Causes of uncertainty

It is unknown what effects the integration will have on existing processes and what effects the introduction of new processes and a new operational setup will have on the performance of the integrated operation. Finally it is not clear yet what software adjustments have to be made to support the integrated operation. The first three causes of uncertainty are within the scope of this research and will be further explained in the next three sub-paragraphs.

6.5.1 Effects on existing processes

The integration will change the existing operation in three ways (Figure 26). These three elements will be described below.

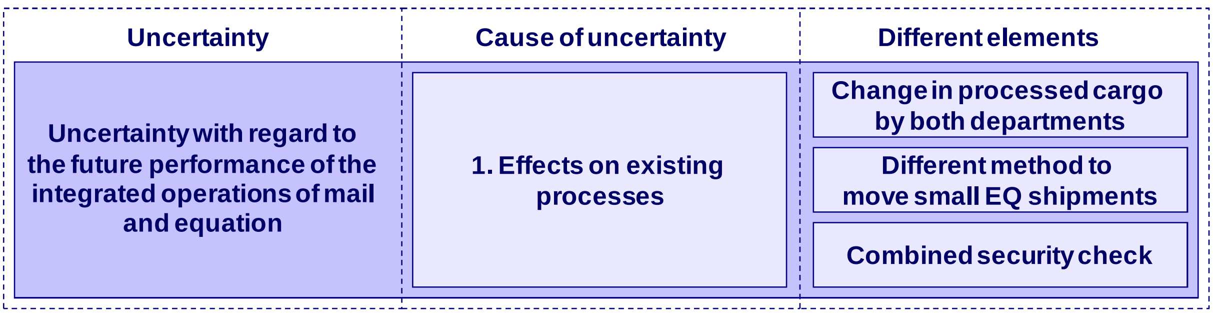


Figure 26: Zooming in on the effects on existing processes of the integration

The shift of a part of the EQ cargo to the mail department will change the quantity of processed cargo at both departments. KLM Cargo expects that it will require less FTEs in total to process

the same quantities in the new situation. The changes in workload for all different operational functions are still uncertain and will be quantified in this report.
Airmail and small EQ shipments will be transported to the switching table by the new conveyor belt connecting the current mail and EQ departments (Figure 24, page 74, yellow ellipse). The labour demand is expected to reduce because the conveyor belt is performing a task which is currently performed by FLT drivers.
KLM Cargo has chosen to security check all outgoing belly wagons with EQ. Dogs are inspecting the wagons on their way out to transportation. In the future situation EQ and airmail might be mixed on wagons and therefore all wagons have to be checked on dangerous goods.

6.5.2 New processes in the combined operations

New activities will be implemented in the operation for the integration at two locations: all products without a proper label for scanning will have to be labelled and all barcodes are scanned before the cargo is placed on the conveyor belt and an exit scan is performed for all individual pieces taken off the carousel. With these two scans valuable data is captured, which forms the basis for capacity allocation, documentation, tracking and tracing, coordination and planning by office employees. The new scans are expected to delay the throughput times of the packages and mailbags. The most important purposes of both scans are:

- The entry scan is primarily used as check whether cargo has actually arrived at KLM Cargo (Figure 24, three red circles).
- The documents for departing cargo will be based on the information collected by the exit scan (Figure 24, six orange ellipses).

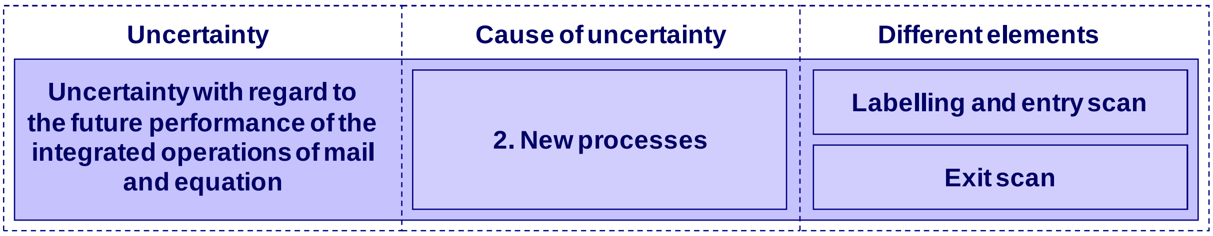


Figure 27: Zooming in on the effects of new processes for the integration

With the data from the exit scan, KLM Cargo knows exactly what cargo is ready to be sent to a plane for all belly wagons along the carousel. This real time information of the scan will improve the quality of the documentation sent to the receiving party considerably, especially for mail documentation.
At the moment KLM Cargo assumes a bag will be taken off again within approximately a quarter of an hour after it is put onto the belt. An employee will make a quick scan for mail with a specific destination on the carousel just before collection of a flight. Furthermore the weight for a destination at the weighbridge is compared to the weight of the scanned bags for the destination at the input, a small difference is accepted. In this way there is a small change that a bag, which is stated on the documents, is not on the flight. However this procedure will not be accepted when handling EQ packages over the carousel for two reasons. First, the EQ product is booked on a flight and the customer is paying for this guarantee. Secondly, a difference between the documents and the actual load on the plane is not accepted for safety reasons for EQ. The captain of the plane can even refuse to take off when the documents are not correct.

6.5.3 New operational setup

In paragraph 1.1 is explained the operational setup after the integration situation will influence the performance of the operation to a large extend. The two main aspects for the operational setup of the operations involve:

- The decision criteria to determine if a shipment has to be considered a "large" EQ shipment
- The allocation, replacement and collection of belly wagons along the carousels and at storage yard for large shipments

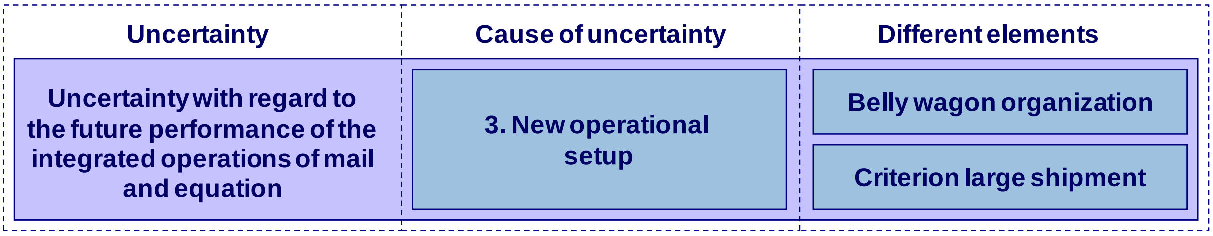


Figure 28: Zooming in on the effects of the new operational setup after integration

In case an EQ shipment consist out of a large number of packages or when the packages will be too large or too heavy to transport with a conveyor belt, the packages will be transported with forklifts to the belly wagons at the storage yard at the current EQ operations (figure 3, nr. 9). For large shipments it will be more efficient to keep the whole shipment together on a pallet and put them in the right belly wagon all at once. The decision criterion to determine whether a shipment has to be considered "large" has to be decided upon.
The new configuration will create new challenges for the allocation, replacement and collection of belly wagons along the conveyor belt carousel (Figure 24, within orange ellipses) and at the storage yard with belly wagons for the "large" shipments (photo: Figure 54 in appendix F). In the future combined operation, the wagons along the carousel will be filled up faster due to the extra EQ packages using the conveyor belt. The variation of destination locations along the belt has to become larger as well, because EQ has different destinations than mail. At the same time the extension of one of the carousels will create 15 extra locations along the carousel (see sub-paragraph 6.6.1). It is still unclear if this extension creates enough space for the integration.
Some solutions for these challenges are thought of by KLM Cargo in previous analyses. It might be possible to place roller cages along the carousels instead of a belly wagons or to build a storage rack along the carousel for low volume destinations. (Interview H. Deben, appendix R.3).
In the next paragraph a quantitative data analysis is executed with a focus on the described uncertainties.

6.6 Quantitative data analysis of the integration design

In this paragraph some important aspects of the integration will be analysed from real production data from Cargoal and Trips. The aspects involved are: estimation of the required number of destination locations along the carousel, the share of large shipments for each flow in the future and the share of mailbags and EQ packages that have to be labelled in the combined operation.

6.6.1 Required number of destination locations along the carousel

The total variation in destinations along the carousel will be determined first, in order to calculate the required number of destination locations along the carousel in the combined situation. To determine the destination locations along the carousel a tree diagram is made starting with the total variety of destinations determined previously.

Total number of destinations using the conveyor belt system

The variation in destinations for cargo sorted via the carousel will increase substantially in the new situation. The small EQ cargo, destined for other destinations than the mail destinations, will add to the variation of the destination locations required along the carousel. Figure 29 displays the overlap of the variation of destinations for both departments. A total number of 142 destinations served from the operations in FB1.

The variation of destinations is based on real data of the mail and EQ operation from September and October 2008. It is expected that the variety in this period resembles the general variation.

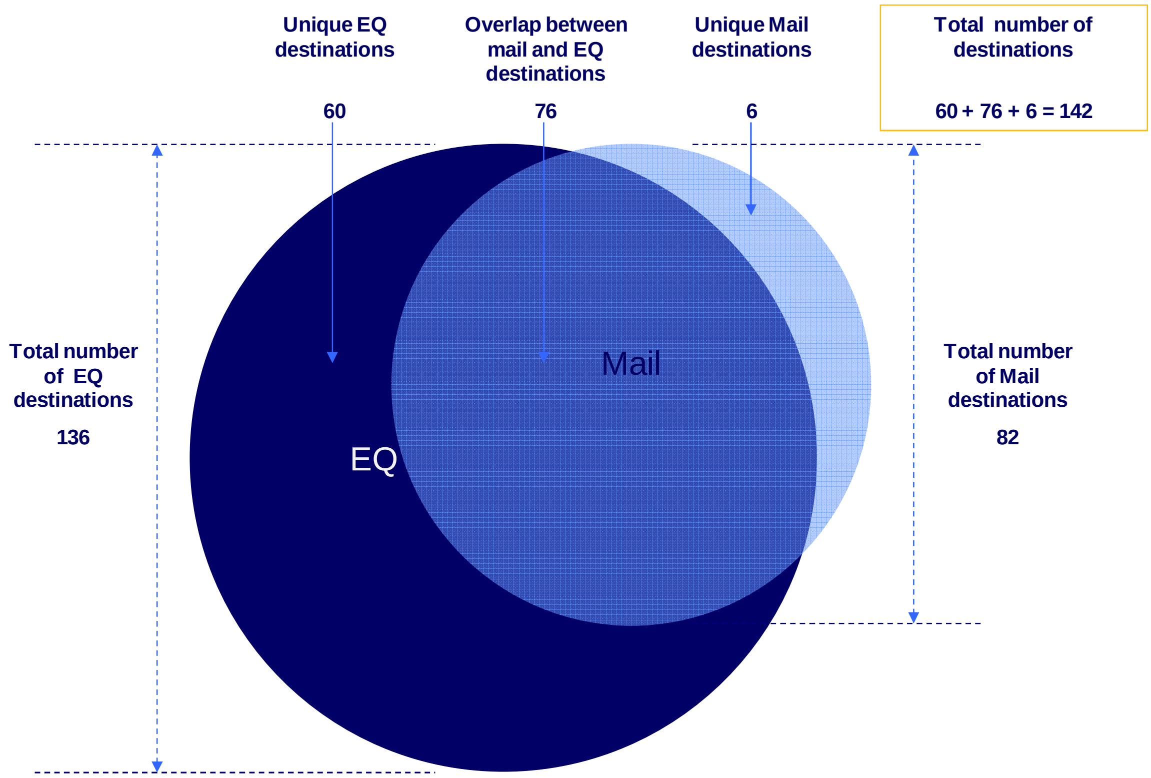


Figure 29: Variation in the total number of destination served from the different departments in FB1

Required number of destination locations along the carousel

Currently 82 different destination locations are in use along the carousel. At each location a belly wagon is placed along the carousel. The total number of locations for belly wagons along the carousel is approximately 90. For some destinations more than one belly wagon is positioned along the carousel at this moment. The large quantity of bags for one destination (e.g. AMS) or the possibility to separate 1st and 2nd class mail is often the reason to separate mail to two locations.

In the new situation the variation of destinations will grow, which implies the number of destination locations along the carousel has to increase. An overlap between destinations at both departments exists. Therefore it might be possible to place only one wagon along the carousel for both mail and EQ cargo with the same destination. In this case the wagon is loaded mixed as well and this will reduce the total number of wagons send to the planes, because the wagons are loaded more efficiently. Nevertheless two reasons prevent the mixed loading of overlapping destinations one the same belly wagon or ULD along the carousel

- Sometimes the cargo coming off the carousel is loaded into an ULD instead of a belly wagon. In this case capacity is reserved for mail or EQ on the plane in a lower deck container. To load mail and EQ into the same ULD, it is necessary that the receiving handler has combined the handling process of mail and EQ. Otherwise mixed ULDs will not be accepted by the receiving party. This implies that, in case the handling of mail and EQ at the receiving airport after Schiphol is separated and the capacity reserved in the plane consists an ULD, the destination will not accept mixed loaded ULDs and two locations along the carousel are required, one for mail and one for EQ.
- Another reason why mail cannot be mixed loaded with EQ is the fact that the capacity of the flights to certain destinations is often fully used. Flights with a constant high load factor are

called constraint flights. For these flights the cargo with the highest revenue has priority. In this constraint cases the EQ packages will still be put onto a flight, because KLM guarantees a certain service level for this product type. For mail the available capacity will be very limited and the mail with the lower priority will be pushed off. For these constraint destinations it is required to separate mail and EQ along the carousel, because in this way EQ can get priority without having to separate EQ and mail at the last moment.

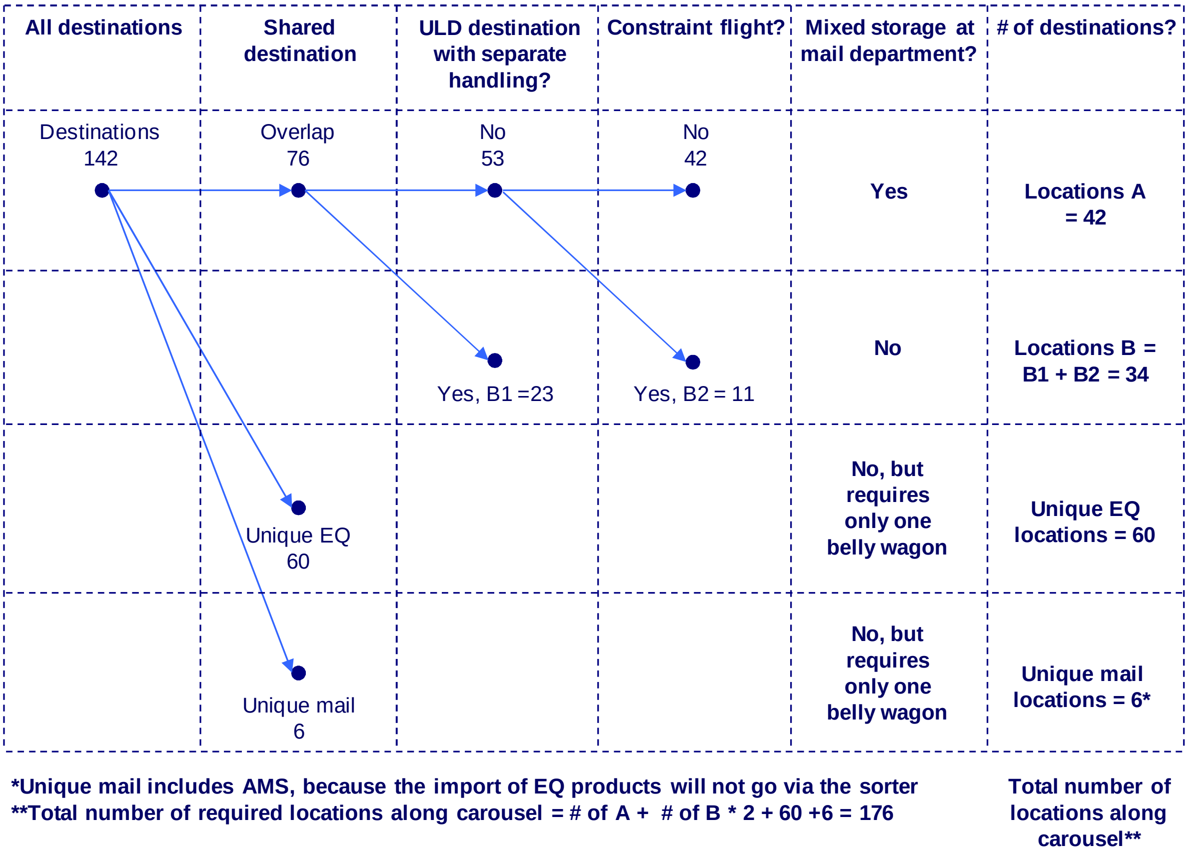


Figure 30: Tree diagram of the required number of locations along the carousel

With the data on ULD capacity reservations, joint handling of mail and EQ at other airports and constraint destinations it is possible to determine whether it is possible to collect mail and EQ mixed along the carousel for all destinations. When mixed loading is not possible it is required to have two locations along the belt for one destination. A tree diagram (Figure 30) was used to display the results and the diagram shows a total number of required locations along the carousel of 176.

The number of required locations is substantially higher than the currently available number of locations for belly wagons along the belt. When only the overlapping destinations and unique mail destinations are considered the required number of destination locations will already become 116[4].

In case one carousel is extended by half its length, the extension is estimated to result in 15 new belly wagon locations. This is an increase of 1/6 of the current total of 90 wagons, which is proportional with the increase in length of the carousel of 1/6.

The use of roller cages for less important destinations along the carousels could increase the number of possible destination locations for the same length of the carousel. The ratio of three roller cages for one belly wagon was used by KLM Cargo in previous analyses. On the other hand

[4] Required number of destination locations = (42 + (2 * 34) +6) = 116

the use of roller cages increases the workload at the mail department. Roller cages cannot be used for the transportation to the plane and therefore an extra transhipment would be required, which would be undesirable. The extra transhipment is also required in case storage racks are positioned along the carousel. Because the required volume for most mail destinations is larger than the capacity of one roller cage, the use of roller cages seems undesirable as well. Replacing the roller cage more than once for one destination, before the departure of the next flight, would justify the use of a belly wagon for this destination.

The possibility that only large shipments are sent to a EQ destination is not taken into account when determining the total number of destinations using the carousel in the future at this stage. With the simulation the maximum required capacity along the carousel (also taking the criterion for "large" shipments into account) can be determined for each new destination along the carousel. This will result in the required volume per destination location for the unique EQ destinations using the carousel after the integration. These data is required to come up with possible solution for the space shortage.

6.6.2 Share of Large shipments

The commercial criterion for large shipments will be the starting point for the division in shipment sizes in the combined operation. An analysis is performed with the available data from Cargoal to determine the share of shipments that will be using the conveyor belt system to sort the cargo. In this sub-paragraph the criteria for a shipment to be handled as a large shipment will be explained first. Pie charts, which display the division in large and small shipments for each flow through FB1, will be displayed subsequently.

Shipments which contain more than 20 colli and/or have a total weight higher than 300 kg are considered large. Furthermore shipments containing individual packages of heavier than 35 kg will be considered large.

Beside the size of the shipment, the characteristics of the products can be a constraint for the use of the conveyor belt as well. Fragile goods, dangerous goods, damaged cargo etc., will never be transported with the conveyor belt. The transport with the belt system will be too rough for these products, mainly because of the drop from one belt to another in the current belt configuration. No data is available on these characteristics; therefore this could not be included in this analysis. It implies that the analysis shows a maximum percentage of small EQ shipments and will become lower when the fragile cargo will be taken out as well.

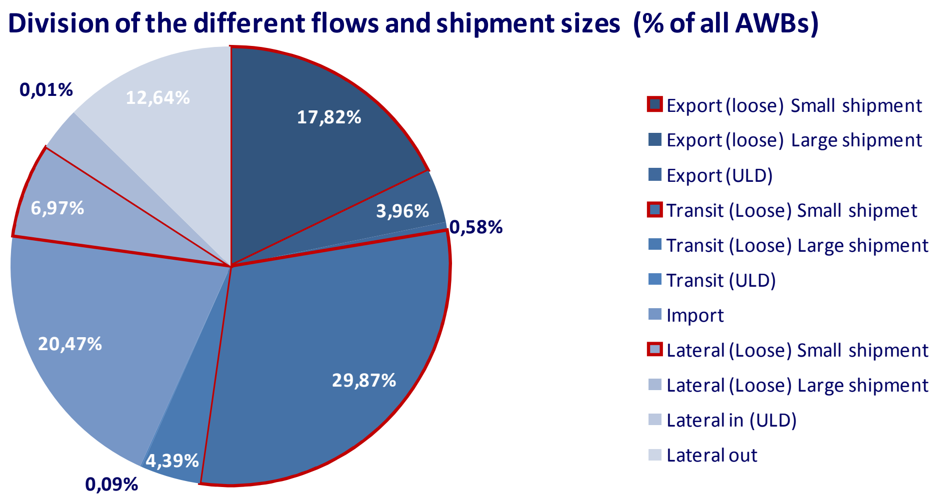


Figure 31: Division of all AWBs between the different flows and shipment sizes

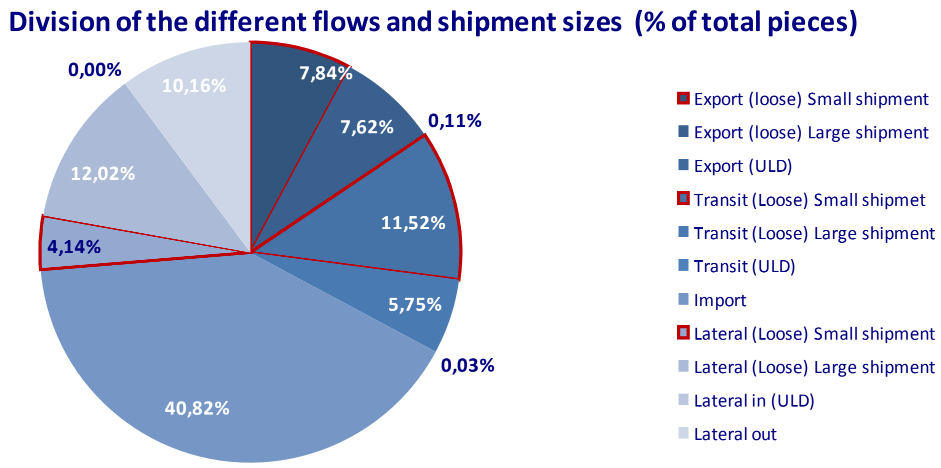


Figure 32: Division of all EQ colli between the different flows and shipment sizes

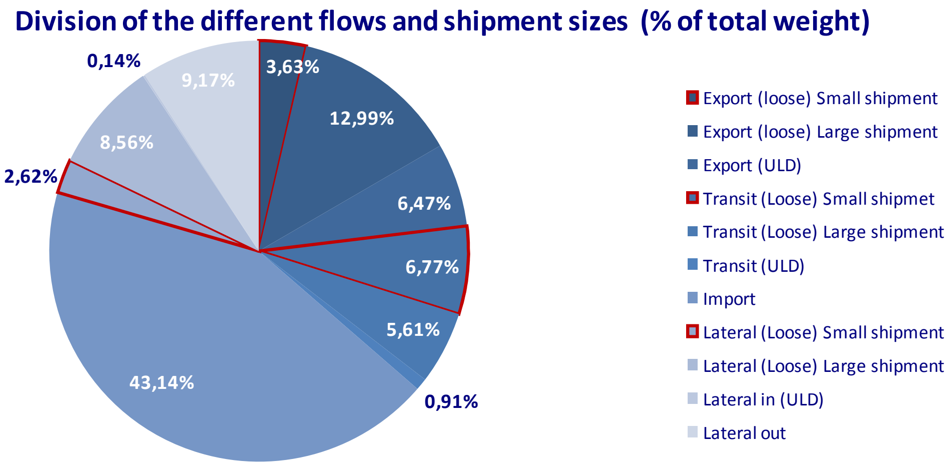


Figure 33: Division of the total weight of EQ between the different flows and shipment sizes

The different pie charts display the differences in the share of small shipment compared on the total weight, pieces and AWBs handled at EQ.

Table 16 summarizes the different percentages. In appendix U.1 a table containing the data used to make the pie charts can be found.
The number of pieces is interesting because this will be the unit which will be moved around by employees in the FB. The division into weight is interesting because the weight will be the most important aspect in the calculation of the fare for the transport by plane.

Table 16: Summary small shipment share (calculated results)

Share of total:	Export	Transit	Lateral	% small shipments
AWBs	18%	30%	7%	**55%**
Pieces	8%	12%	4%	**23%**
Weight	4%	7%	3%	**13%**

It is possible to argue that only the AWBs representing 13% of the turnover of EQ will use the extension of the conveyor belt system after the integration.

6.6.3 Attaching IATA 606(B) labels

In the combined situation all cargo using the conveyor belt should have a label with barcode for the entry and the exit scan. In this sub-paragraph the share of mail and the share of EQ which require labelling by KLM Cargo in the new situation are calculated.

Scan versus manual Registering Incoming Mail

The mailbags which are scanned currently will not have to be labelled in the future, because their label already contains the appropriate information. All transit and import mailbags which are manually inserted in Trips will have to be labelled in the future. This will imply that 8.7%[5] of the total number of bags using the conveyor belt is manually inserted in the system and has to be labelled with a barcode.

Table 17: Division between RIM-ing and scanning at mail for Sept & Oct '08 (calculated results)

	Scanned		Manual	
Flow	**Pieces**	**%**	**Pieces**	**%**
Export	2835	71%	1147	29%
Transit	317668	92%	28184	8%
Import	42824	86%	6712	14%
Total	**363327**	-	**36043**	-

Export mail is all labelled, in Table 17 it looks like 29% of all export cargo is RIM-ed, but this can be assigned to the fact that TNT transfer the data of the mailbags send directly to the plane to KLM and these mailbags will also get the "manual" characteristic. In the simulation no labelling will be required for export mail.

EQ department

For import cargo there is no need to apply a new label on collo level upon arrival at FB1. Import cargo will be brought to the import storage in the same way as is currently done. A single INCA-2 label will be sufficient, because no entry or exit scan is performed.
Large shipments can also work with the current labels, only the EQ cargo using the conveyor belt will have to be labelled with an IATA606(B) label on collo level. This implies that small export, small transit and small incoming lateral shipments will have to be labelled on collo level. With a small survey the percentages of AWBs that will not have a label is determined.

Table 18: Share of AWBs with an IATA606(B) label arriving at of EQ (calculated results)

Break down	Import		Transit		Export	
Sticker	**Number of AWBs**	**%**	**Number of AWBs**	**%**	**Number of AWBs**	**%**
no	15	31%	41	25%	4	7%
yes	34	69%	123	75%	51	93%
Total	**49**	**100%**	**164**	**100%**	**55**	**100%**

6.7 Sub-conclusions on the integration of handling processes

KLM Cargo's project objectives, constraints and requirements have been taken into account for the design of the integrated operation at FB1. The design resembles the operation at Sodexi, which is seen as an important example. A description of the integration proposal and the enumerations of changes to the infrastructure, processes and equipment have resulted in a good understanding of the required changes to the current situation. The design gives due weight to the identified differences between mail and EQ in paragraph 3.4.
Uncertainty related to the effects of the integration remains present in three different areas: the effects on the existing processes, the effects of the addition of the new processes and a new operational setup.
The quantitative data analysis in paragraph 6.6 focused on these three areas. The analysis of the required number of destination locations along the carousel shows that the proposed extension of the carousel will not create enough destination locations along the carousel to place for all

[5] (28184 + 6712)/(363327+ 36043) * 100% = 8.7%

possible destinations. The extension could create just enough room to support the handling of all mail destinations together with EQ to those existing mail destinations.
The analysis of the total weight of the small shipments using the conveyor is only 13% of the total weight processed at EQ. Often the revenue is linked to the weight of AWBs; this indicates that the investment is made to move a flow which is approximately responsible for 13% of the revenue. The calculated shares of unlabelled cargo are used in the simulation model in of the integrated situation.
Now the design of the integrated situation is determined, it is possible to transform the simulation model of the current operation to the integrated one step-by-step. In the next chapter the sequence of experiments will be described and the results of the simulation of the integrated situation are discussed.

7 Simulation results integrated situation

In this chapter the results of the simulation experiments of the integrated situation are discussed. The chapter will start off with a description of the sequence of experiments with the different simulation models in paragraph 7.1. In paragraph 7.2 a sensitivity analysis is executed for a model of the integrated situation. The tests used to determine whether the changes in the results of the different models are significant are explained in 7.3. From there the next four paragraphs discuss the results of the simulation runs for each of the four different performance areas: resource utilization, handling times, number of re-bookings and space requirements. The description of the results will follow the outline of chapter 5 as much as possible. Subsequently, the previous described results are summarized in paragraph 7.8. These results are used to find possible improvements for the operational setup of the operations. The refined alternatives and the results of the simulation after these improvements are discussed in paragraph 7.9. The chapter ends with a short summary of this chapter in paragraph 7.10.

7.1 Sequence of Experiments

This paragraph discusses the sequence of the different simulations used to determine the effect of the integration. Based on the sub-questions (as described in sub-paragraph 1.4.2) a sequence with four different experiments is composed (Figure 34). Each step will answer one of the sub-questions of this research. From here the abbreviations corresponding to the model names (BM, IMEX, IMIN and RM) are used to indicate specific models in the text (Figure 34).

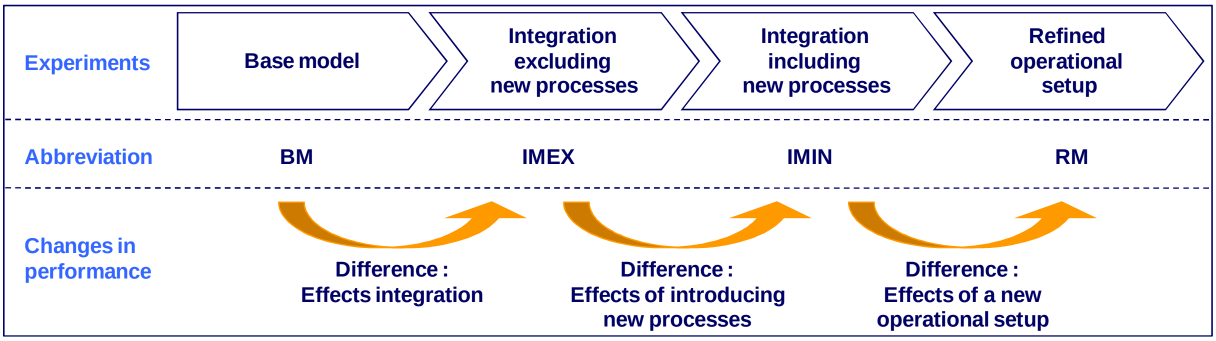


Figure 34: Sequence of simulation experiments

The first experiment is the simulation of the current operational processes in FB1 with the base model or BM. The results of this first experiment are discussed in chapter 5 will be used as base case in this chapter.
The next step, modelling the integration excluding new processes ("IMEX"), will consist of the simulation of the integration with only the minimal required changes. The differences in the score on the performance indicators between the simulation results of BM and IMEX answer the second sub-question of this research.

SQ 2: What is the effect of the integration on the performance of the existing processes at the airmail and EQ department?

The labelling process, entry scan and the exit scan are added as new processes required for the integration in IMIN. This will delay the operation and increase the workload for the employees again. The simulation results of IMIN are compared to the results of IMEX to answer the third sub-question of this research.

SQ3: What is the effect of the addition of new processes on the integrated performance?

In the RM results from the previous experiments (e.g. maximum volumes and weights per destination) are used to improve the operational setup in FB1. This experiment is discussed in paragraph 7.9 and answers SQ4.

Specification of the differences between the four simulation models
The specific differences between the four simulation models are discussed in appendix T. These differences in the simulation models are based on the changes identified in the design proposal in sub-paragraph 6.3.2 and the refinements of the model towards RM, which will be discussed in paragraph 7.9.

Experimental design
The same experimental design is used for the simulation of the integrated situation as was used for the simulation of the base case (see paragraph 5.1). This ensures the results of the simulation of different models are comparable.

7.2 Sensitivity analysis integrated model

The sensitivity of the integrated situation including new processes (IMIN) to the existence of exceptions is tested in this paragraph. In this analysis 10% of the small shipments is exceptional and cannot be transported with the belt. As explained in paragraph 4.5.1 the share of small shipments might be overestimated for two reasons:

- The average weight per package is used as criterion to divide the different sized shipments.
- No information is available on the share of exceptions in the small shipments which cannot be transported with the belt.

By varying the share of exceptions in the integration model, it is possible to test the sensitivity of the model for this potential overestimation.

All results of the sensitivity analysis with IMIN are displayed in appendix X.2. Most remarkable effects are summarized below:

- The utilization rate of the employees for which the number of flights is the driver for the workload will increase disproportional at EQ. This effect is dedicated to the increased variation in destination for which wagons have to be weighed and opened for the exceptional shipmetns.
- A shift from the number of early flown small EQ shipments at the mail department to the EQ department occurs. The small number of EQ shipments that will make an early flight will decrease with about 5% in total.
- The maximum number of destination locations will increase by 22% at the EQ storage yard for belly wagons, due to the larger required variation in the flight destinations.

Results of the sensitivity analysis of the integrated model (IMIN)

The sensitivity of the integrated model, to a change in the share of exceptions in the small EQ flow, is large. The exceptions will undo a part of the integration, because certain EQ shipments remain at the current EQ department. The existence of these exceptions will increase the number of wagons required at the storage yard and the workload of the weigh employees disproportionally.

7.3 Analysis of differences between simulation results

The results of the simulation of the different models will be compared to each other in order to determine the effects of the changes made in the operation.

The Kolmogorov-Smirnovtest is used to test whether the averages are normally distributed. In case the Kolmogorov-Smirnovtest test indicates the averages are normally distributed, a paired-wise Student t-test is used to determine whether the differences between the models are significant. In the other case a Wilcoxon test is used (Verbraeck and Valentin, 2006, p. 52).
The results of the Kolmogorov-Smirnovtest are displayed in appendix Y.3 for all performance indicators of the base model and show that in most case a paired-wise Student t-test is used to prove a significant difference.
The used random numbers, flight schedules and entity characteristics remain the same for each replication and for all different models in Arena. In this way the average scores on performance indicators of the same replication number can be paired to each other for the different experiments. In appendix Y.4 the results of the executed t-tests are displayed for all compared variables.
In the model output certain selections of entities had to be made during the determination of the scores on the performance indicators. The used selection of entities in the simulation model output is displayed in Table 58 in appendix Y.1.

7.4 Resource utilization

In this paragraph the scheduled utilization rates of the integration models will be compared to the model of the current situation, BM. Dividing the average number of busy employees by the average number of scheduled employees results in the scheduled utilization. Arena will calculate the scheduled utilization of all different resources in the simulation model.
In reality some increases in the workload could induce resistance of employees in the operation. In this description of the results an increase in workload is not accepted in case queues are emerging, which implies the employee cannot keep up. In this case the schedule of KLM should be adjusted, because the capacity is dependent on scheduled workers. Increasing the scheduled hours however will cost money.

7.4.1 Resource utilization rates at the mail department

Figure 35 displays the utilization rates per function at the mail department. Only the relevant changes in utilization rate are discussed.

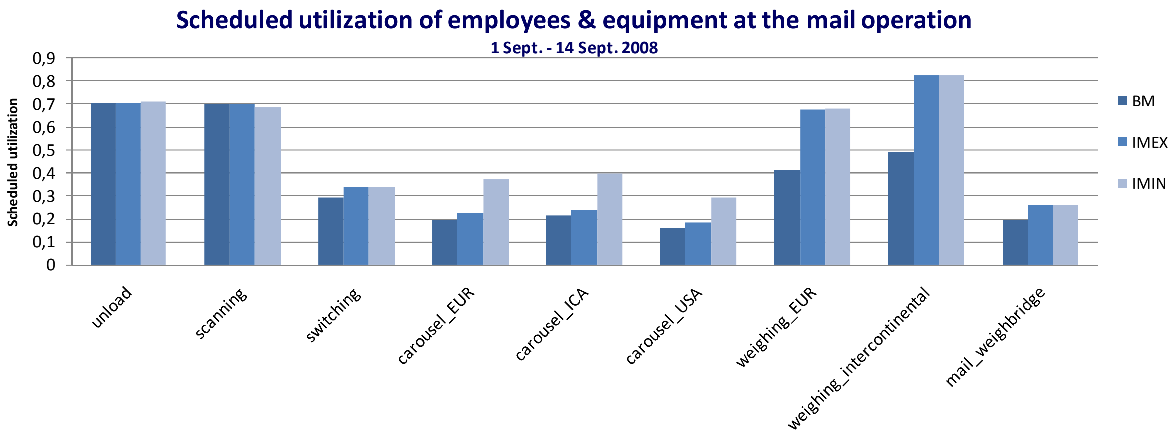


Figure 35: Scheduled utilization rates for all different functions at the mail department

Effects of the integration excluding new processes (IMEX)

Figure 35 indicated that the benefits of the integration will not be realized at the mail department. The workload will only be increased by the handling of small EQ AWBs. For each function at the mail department important changes will be described below.

Switching
All employees moving the cargo on collo level will face an increase in workload of approximately 15%; this is also the case at the switching table. At the switching table the workload will increase towards a utilization rate of 34% due to the integration.

Carousel employees
The increase in the utilization rates of the employees along the carousel vary between 13% and 17%. The majority of small EQ collo will be destined for the EUR carousel.

Weighing employees
The largest increase in workload will occur at the weighing process. Three mayor factors are contributing to this increase:

- The integration will results in a increased number of flights which have to be collected.
- The time required to bring one train of wagons to the transportation department will be extended by the introduction of the security check.
- The number of replacements of wagons along the carousel will increase. The load capacity of the wagon is reached more often by the addition of EQ AWBs.

During the simulation it is observed that the pressure on the weighing employees at the mail department is too high, because some lower priority tasks of the employees (e.g. replacing wagons along the carousel) are postponed until after the peaks in the mail collection. This is undesirable and this implies that the number of employees responsible for weighing will have to be increased in the integrated situation.

Weighbridges
The weighbridge at the mail department will be used more frequent due to the larger number of departing flight after the integration.

Effects of the addition of new processes to the integration model (IMIN)

Figure 35 shows the influence of the addition of new processes on the workload for all functions at the mail department.

Scanning and unloading
The integration will not raise the workload for the employees responsible for the unloading and scanning of mailbags at the input locations. These employees were most busy in the integrated situation. It is expected that all mail is still delivered separately from the EQ to the input locations.
The utilization of the scanning employees is even slightly reduced in IMIN. This will be caused by the wireless scanners, which are sending the captured data to Trips automatically. Therefore the scanning employee does not have to come into the office to upload registered data. This reduction in workload is partially counterbalanced by the extra time required to label the mailbags which were RIM-ed in the base case.

Carousel employees
The introduction of the exit scan will significant increase the workload of the employees working along the conveyor belt. The increase in workload is proportional to the increase in process time for the employees along the carousel.

7.4.2 Resource utilization at the EQ department

The benefits of the integration are realized at the EQ department. Figure 36 show drastic decreases in utilization rates for five functions.

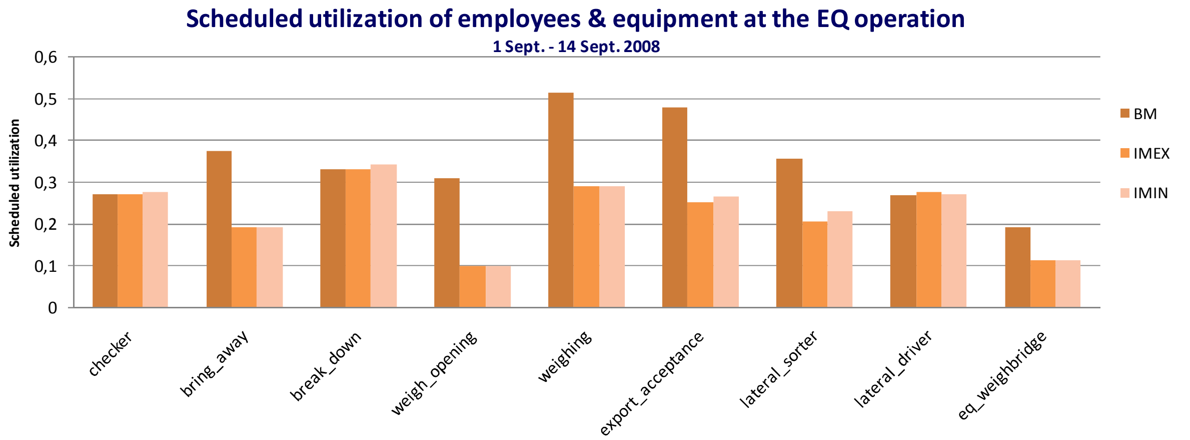


Figure 36: Scheduled utilization rates for all different functions at the EQ department

Effects of the integration excluding new processes (IMEX)

Figure 36 shows the influence of integration on the utilization rates at the EQ department.

Checker and breakdown

At the breakdown area, the work area of the checker and the break down employees, nothing will change at this stage of the integration.

Bring away EQ to the belly wagons

When all small EQ are unloaded to the conveyor belts system, less cargo is brought to belly wagon at the storage yard at EQ with FLTs. Therefore the utilization of the employees bringing away the AWBs to the belly wagons drops with 48% to 19%, with the same work schedule.

Weigh opening

The number of wagons that will be opened will decrease significantly, because only wagons are opened for the large shipments which arrive at EQ. The workload of the employee opening the wagons will decrease by 67%. The utilization of this function is very low after the integration and this workload could be taken over by employees performing other functions.

Weighing employees & weighbridge

When only the large EQ shipments are processed via the EQ department the number of flights which require weighing will drop. This results in a reduction of the utilization of the scheduled weigh employees of 43%. The weighbridge at EQ is used less as well, because the number of departing flights decreases.

Export acceptance

The employees at the export acceptance will still accept all EQ shipments, but their workload will drop by 47%, because it is not required anymore to bring the EQ to the belly wagon storage yard or temporary storage. All small EQ can be put on the conveyor belt to the sorting location, an activity which will take less time than bringing the cargo to the wagons or storage

Lateral sorter

For the lateral sorter the workload is reduced primarily due to the removal of the temporary storage. The lateral sorter was responsible to sort out all temporary stored cargo after the opening of the corresponding flight. In the integrated situation the lateral sorter is only responsible to sort out the incoming lateral cargo to the belly wagons or to one of the input locations of the conveyor belt system.

The results show that it is more effective to bring the cargo directly to the right location, instead of storing it temporarily. Temporary storing will require two handling moments. At the moment the removal of the temporary storage is not possible, because the capacity at the storage yard is too small to place wagons for all flights corresponding to the available cargo. The shift of cargo to the mail department and the introduction of the FIFO-principle will make the removal of the temporary storage possible.

Effects of the addition of new processes to the integration model (IMIN)

Figure 36 shows the influence of the addition of new processes on the workload for all functions at the EQ department.

Checker

In the new situation all packages, destined for the conveyor belt system, will be labelled with an IATA606(B) labels after the check at the breakdown area. At the moment only one label per shipment is attached, in the future this will have to be done at collo level. This will slightly increase the workload for the checker.

Breakdown employees

After the breakdown of cargo and the labelling of the small EQ on collo level, the breakdown employees will have to put the small EQ on the conveyor belt and scan the attached IATA606(B) as entry scan. The workload for the breakdown employee will increase by this activity with 3.9%

Export acceptance

The labeling of small export EQ shipments will take time. The labeling and the scanning of the small shipments increase the utilization of export acceptance employees by 5%.

Lateral sorter & lateral drivers

The lateral incoming small EQ has to be labeled with an IATA606(B) label and scanned, before it proceeds its journey on the conveyor belt. These activities will increase the workload of the lateral sorter with 12%. The utilization of the lateral driver is unchanged.

7.4.3 Combined utilization rates

For KLM Cargo the combined effect of changes in utilization rates at both departments is interesting. Therefore the sum of the products of scheduled hours and the utilization rate per function is calculated for all models. This value represents the total required working hours to perform the physical operation in FB1. The results of the calculations are displayed in Table 19.

Table 19: Required working hours for same operation

Required hours	EQ	Mail	Total	Index
BM - Base model	700	477	**1177**	**100.0**
IMEX - Integration excl new processes	496	586	**1082**	**91.9**
IMIN - Integration incl new processes	509	663	**1171**	**99.5**

The calculations show a trade-off exists between the workload at EQ and at the mail department. Although the decreases in utilization rates at EQ are larger, the effect on the total required number of hours is limited, because the number of scheduled hours at EQ is smaller than at the mail department.

The index value of the total number of required hours shows the integration excluding the new processes will be 8% more efficient on average. This efficiency gain will almost totally be undone by the addition of the new processes.

Net present value of the integration

The investment in the conveyor belt system and the cost reduction of the decrease in required hours are used to calculate the Net present value (NPV) for the integration. The initial investment of 900,000 Euro in the extension of the conveyor belt is taken over from the business case (KLM Cargo and M3 Consultancy, 2006). In this business case an earn back period of 2.5 years was assumed. Considering the current economic conditions, it seems unlikely KLM will move to a new location within this period at this moment. In this analysis an earn-back period of five years was assumed in combination with a discount rate of 5%. The longer earn back period increases the changes of earning the investment back.
The cost reduction is estimated, based on the reduction in the required hours as calculated in Table 19, with the following formula.

$$Annul\ cost\ reduction = \frac{\left(\dfrac{Reduction\ in\ required\ hours}{average\ utilization\ for\ all\ functions}\right)}{Simulated\ weeks * hours\ per\ fulltime\ workweek * \ annual\ cost\ of\ 1\ FTE}$$

Table 20 shows the NPV for the integration **excluding** the new processes and the NPV for the integration **including** new processes. The simple NPV analysis shows that the Capex in the physical operation cannot be earned back by the lower Opex in the physical operation. This proves the integration of the physical operation should not be executed for financial reasons. Only in case the investment is required to create possibilities to gain other financial benefits outside the physical operation, KLM Cargo could consider the investment in the conveyor belt.

Table 20: Calculated NPV for the physical operation

NPV integration excl. new processes	
Discount rate	5%
Investment extension conveyor	€ 900,000-
Cost reduction year 1	€ 156,250
Cost reduction year 2	€ 156,250
Cost reduction year 3	€ 156,250
Cost reduction year 4	€ 156,250
Cost reduction year 5	€ 156,250
NPV	**€ 223,519-**

NPV integration incl. new processes	
Discount rate	5%
Investment extension conveyor	€ 900,000-
Cost reduction year 1	€ 9,868
Cost reduction year 2	€ 9,868
Cost reduction year 3	€ 9,868
Cost reduction year 4	€ 9,868
Cost reduction year 5	€ 9,868
NPV	**€ 857,275-**

€ 633,756-

The difference between the NPV of the integration excluding the new processes and the NPV of the integration including new processes, approximately 630,000 Euro, is representing the labor costs required for the new processes in the operation for five years.

7.5 Handling times

The changes in the handling times for airmail, small EQ via the sorter belt and large EQ will be discussed in this paragraph. The handling times are divided into **short** and **long** duration times, in order to improve the visualisation with graphs.

7.5.1 Handling times Airmail

The handling times at the airmail department will be discussed below.

Short duration

The short handling times at the mail department will not benefit from the integration (see Figure 37). The time between the arrival at one of the input locations and the moment the cargo is ready in the right belly wagon along the carousel, will increase initially due to the increase workload for the employees at the switching location and along the carousels.

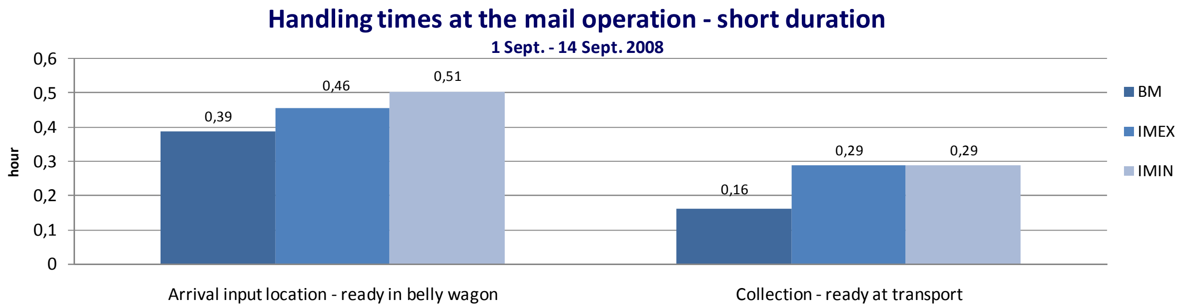


Figure 37: Handling times (short duration) at the mail department

Subsequently, the introduction of the exit scan increases this handling time again. The increase in the handling time between the input and the wagon is disproportional. The increase in average handling time is 0.07 hours, but the exit scan will only require 6 seconds on average. The disproportional change can be explained by the causal relation diagram in Figure 38. The figure shows that the exit scan could cause a disproportional increase in the utilization of the employees along the carousel, because the causal relation diagram contains a circle with only positive correlations (orange arrows).
For a conveyor system which sorts the cargo to different shoots automatically this circle will be disconnected, because the bags cannot go round and round on a carousel. At Sodexi in Paris the conveyor sorts the cargo to shoots.

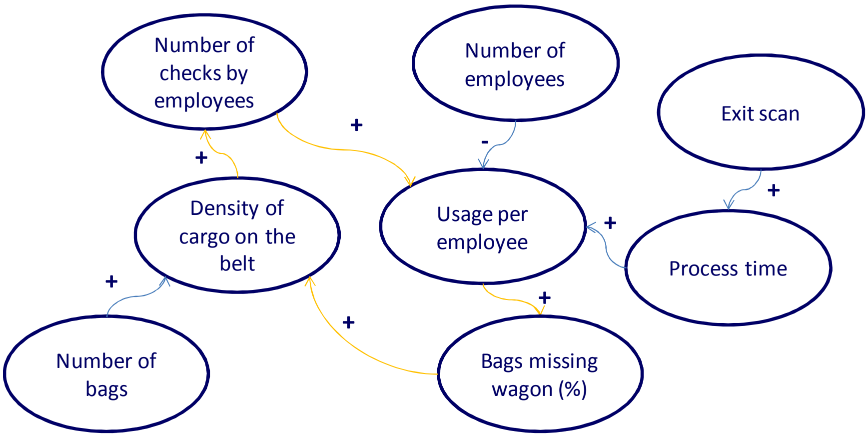


Figure 38: Expected interaction due to the introduction of the exit scan

The time between the collection of the wagons with mail and the arrival at a lane of the transportation department will increase significantly by security check (Figure 37, bars on right side). The introduction of new processes does not influence this handling time in IMIN.

Long duration

The effects of the integration on the long handling times are smaller. The decrease in waiting time in the belly wagon indicates that delays in the operation are compensated by a decrease in the waiting time in the belly wagon for most mailbags. Due to this compensation both turnaround times of airmail in FB1 is not significantly by the pure integration in IMEX (see Figure 39).
Besides the shorter waiting time in the belly wagons, the delay due to the security check is camouflaged by the increased time between collection and transportation. Nevertheless this measure will probably raise the number of mailbags that will miss their flight at the moment of collection (see paragraph 7.6.1).

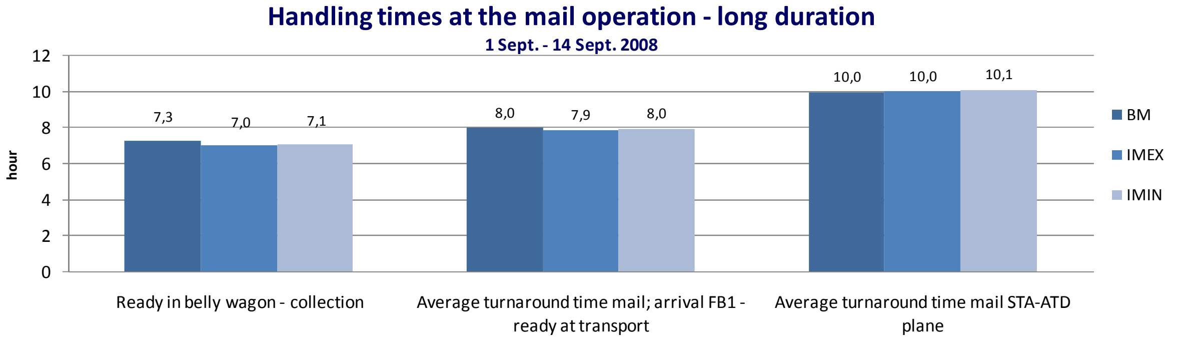


Figure 39: Handling times (long duration) at mail department

The introduction of new processes in IMIN will cause a significant rise in the average turnaround times, but the increase will be very small, less than 1%.

7.5.2 Handling times EQ

The relevant handling times at EQ are displayed in Figure 40 (short duration) and Figure 41 (long duration). In simulated two weeks 3,700 AWBs will still be handled at the EQ department. This excludes the handling times of **small** EQ shipment. The graphs clearly show a significant decrease in all handling times at EQ due to the integration.

Short duration

Figure 40 shows the large changes in the time required to get the cargo to a next step in the handling process. The required time to accept export shipments and bring them to the right belly wagon at the storage yard will drop by 36% in IMEX. The time between the arrival at the breakdown and the arrival in the right belly wagons at the EQ department will decrease by 49%. Import EQ will arrive at the landside of 37% faster after the integration.
The introduction of new processes in IMIN does not influence the short duration handling times of the large EQ shipment and import shipments significantly.

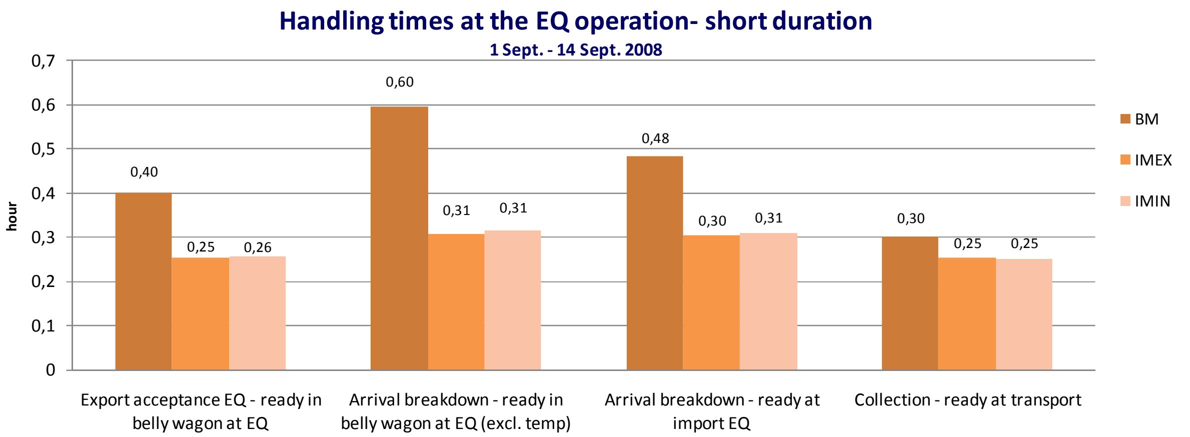


Figure 40: Handling times (short duration) at EQ department

Long duration

In Figure 41 the longer handling times for the EQ department are shown. These handling times will benefit from the integration significantly. The increased number of available flights, which can be used for transport and the reduced workload at EQ are the main contributors to this improvement. The simultaneous reduction in the handling times to get the EQ to the right belly wagon and the time between the arrival at the belly wagon and the collection of cargo proves the advantages of the FIFO-principle in combination with the possibility to use the departing EQ

and mail flights. The integration will decrease the average turnaround times by more than 5 hours.
The addition of new processes will not cause significant changes at the EQ department in IMIN.

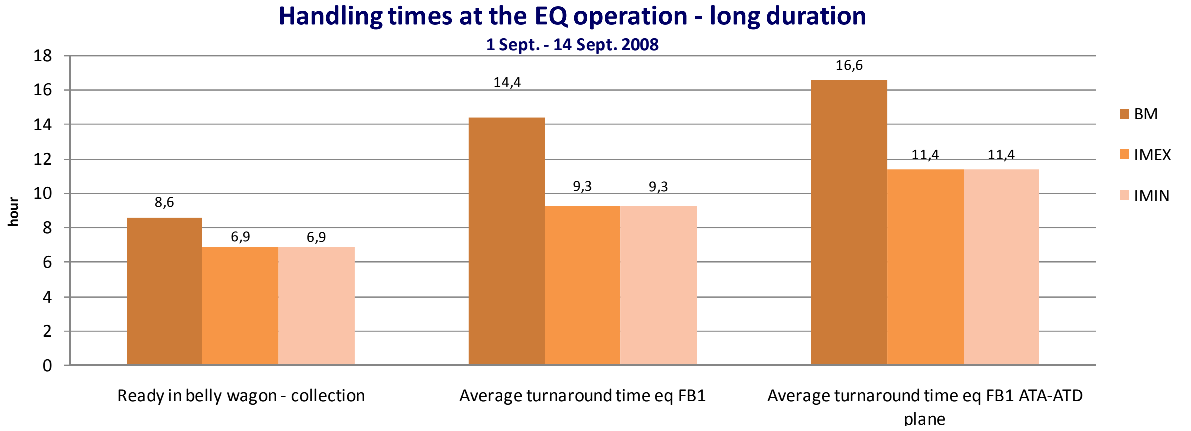


Figure 41: Handling times (long duration) at EQ department

Small EQ

After the integration around 4,530 AWBs will be handled via the mechanized conveyor with manual sorting at the mail department. No base case is available for small EQ shipments, because this is not a special flow currently, therefore the graphs in Figure 42 only contain two bars. Nevertheless, a comparison between handling times of all EQ shipments in the base situation and the small EQ shipments after the integration is made after the results of IMEX and IMIN for small EQ shipments are discussed.
The handling times for small EQ shipments to reach the right belly wagon along the carousel will increase immensely by the addition of new processes in IMIN (Figure 42, left side). All new processes involve the small EQ via the conveyor belt system and will delay the handling considerably.
The labelling on collo level, the entry scan and the exit scan are all processes encountered by small EQ on the way to the right belly wagon. The addition of the new processes even results in increasing turnaround times and a larger number of small EQ that will miss its flight, as will be shown in the next paragraph.

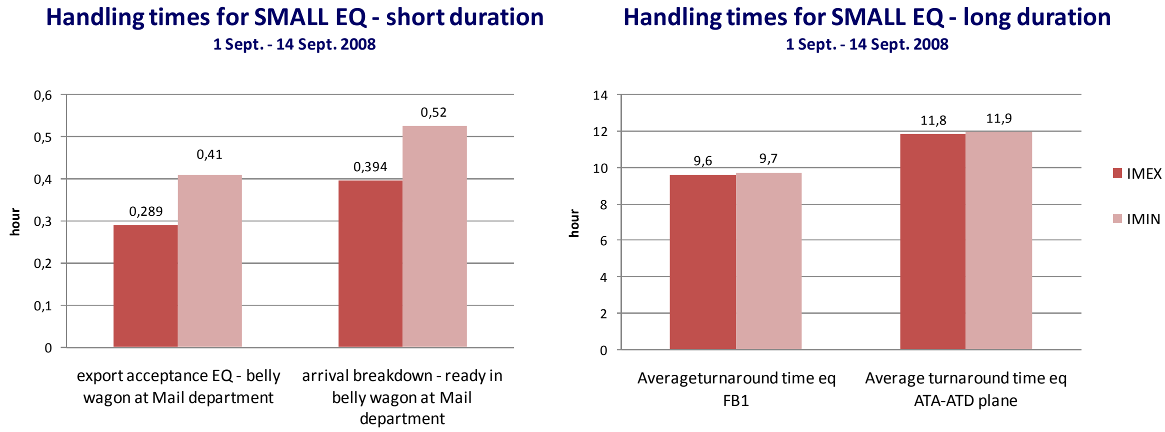


Figure 42: Handling times for small EQ form the simulation IMEX & IMIN

Comparing the handling times at the EQ department with those of the small shipments

A comparison of the handling times of the small EQ with the current handling times for all EQ shipments shows the handling times for small EQ will be improved or will not be changed by the integration. The introduction of new processes will only affect the handling times of small EQ.

The improvement of the handling times of small EQ is smaller than the improvement of the handling times for large EQ.

7.6 Number of re-bookings

The group re-bookings is divided into a positive effect and a negative effect on quality:

- It is an advantage when cargo will fly on an earlier flight than booked (EQ) on will fly with an earlier flight than it did in reality (mail).
- It is disadvantageous when cargo misses the flight it was booked on (EQ) or flew with in reality (mail).

7.6.1 Mailbags on different flight

In the simulated two weeks approximately 113,850 mailbags will pass the airmail operation. With the simulation is possible to monitor the number of mailbags which will depart earlier than reality and the number of bags that will miss the flight they made in reality. In this sub-paragraph these quantities will be discussed for the different models: BM, IMEX and IMIN.

Mailbags that will fly on earlier flight

The results of the simulation of IMEX show that the integration will increase the number of mailbags taking an earlier flight in total. This is mainly due to the increased number of departing flights and will be partially undone by the extended period between collection and departure by plane, which will decrease the number of bags on earlier flight. The sum of both effects results in 15% more bags taking an early flight. The new processes will decrease the number of bags making an early flight in IMIN with 2%.
As mentioned in sub-paragraph 4.7.2 the number of mailbags flying on an earlier flight is higher in the simulations than in reality, because the simulation models do not take capacity constraints of departing flights into account. This should be taken into account when interpreting the results.

Average number of mailbags flown on earlier flight	BM	Change	IMEX	Change	IMIN
Number of export mailbags collected to fly on earlier flight	**126**	21%	**153**	-6%	**143**
Number of transit mailbags collected to fly on earlier flight	**16,727**	15%	**19,276**	-2%	**18,952**
Sum of mailbags flown on earlier flight	**16,853**	15%	**19,428**	-2%	**19,095**

Table 21: The number of mailbags that will make an earlier flight (significant differences are marked grey)

Mailbags that will miss their initial flight

The simulation results for the mailbags that will miss their flight clearly indicate the influence of the changed collection moment (see Table 22). The earlier the collection of cargo is done before the flight departure, the more bags will miss their flight at collection. Nevertheless the same change has a positive effect, because there is more time for the transportation to the plane including the security check. The results show that the "current" collection moment is too late. Advancing the collection will certainly be beneficial to the results of BM as well. Certainly when the delay of the security check is taken into account.
The introduction of the exit scan and the labeling of mailbags in IMIN will increase the number of bags that will miss their flight again by approximately 7% and will partially undo the initial advantages of the integration in IMEX.

Average number of mailbags that will miss their flight	BM	Change	IMEX	Change	IMIN
Number of mailbags which will miss flight at collection	**1,474**	25%	**1,848**	19%	**2,195**
Number of mailbags which will miss flight at transportation	**3,881**	-64%	**1,384**	-9%	**1,263**
Sum of mailbags which will miss their flight	**5,355**	-40%	**3,233**	7%	**3,458**

Table 22: The number of mailbags that will miss their flight (significant differences are marked grey)

7.6.2 AWBs on different flight

Approximately 8,130 AWBs are processed in FB1 during the two simulated weeks. Some AWBs can make an earlier flight when FIFO is applied and some will miss their flight.

AWBs that will fly on earlier flight

In BM all EQ shipments are flown according to the booking, therefore no AWBs are taking an earlier flight. After the integration a considerable number of EQ shipments will be able to make an earlier flight (see Table 23), approximately 16%[6] of all AWBs. This will be a result of the larger number of available flights, but also because some bookings include spare time in Amsterdam, which leaves room for improvement.

Average number of re-bookings for EQ flown on earlier flight	BM	Change	IMEX	Change	IMIN
Number of rebookings of export SMALL EQ collected to fly on earlier flight	**n.a.**	n.a.	**347**	-1%	**345**
Number of rebookings of transit SMALL EQ collected to fly on earlier flight	**n.a.**	n.a.	**785**	-2%	**768**
Number of rebookings of EQ collected to fly on earlier flight	**n.a.**	n.a.	**193**	0%	**193**
Sum of rebookings for EQ flown on earlier flight	**n.a.**	n.a.	**1,325**	-2%	**1,305**

Table 23: Number of re-booked AWBs (significant differences are marked grey)

AWBs that will miss their booked flight

The number of AWBs that will miss their flight will increase by the integration in IMEX (Table 22). The scores for a location are hard to compare between the different models, because a shift for one location to another will take place due to the integration. Therefore only the total the number of AWBs missing their flight is considered. This number increases by the integration with 70% and remains almost the same after the addition of the new processes in IMIN.
The missed flight can also be a flight leaving much earlier than the booked flight in this the integrated situation. An AWB missing an earlier flight could still make the booking, which is the ultimate deadline. Therefore the commercial damage of the AWBs missing the flight in reality is expected to be smaller than indicated by the simulation results. A potential rise in the number of EQ actually missing their booking will concern KLM Cargo, because the booking is guaranteed to the customers.

Average number of missed bookings EQ	BM	Change	IMEX	Change	IMIN
Number of AWBs that will miss their booked flight due to flight closing	**94**	-86%	**13**	0%	**13**
Number of AWBs that will miss their booked flight at transportation	**47**	28%	**60**	-1%	**59**
Number of AWBs that will miss their booked flight at mail at collection	n.a.	n.a.	57	25%	71
Number of AWBs that will miss their booked flight at mail at transportation	n.a.	n.a.	109	-7%	101
Sum of missed EQ bookings	**141**	70%	**239**	2%	**245**

Table 24: Number of AWBs that will miss their booked flight (significant differences are marked grey)

7.7 Space requirements

The simulation runs have resulted in the required number of destination locations at both departments. The results of the simulation are shown in Table 25. In the next sub-paragraphs the space requirements at the EQ storage yard are discussed first, followed by the space requirements at the mail department. The change between IMEX and IMIN is not significant. Therefore, only the base case is compared to the integrated situation.

Average max. destination locations	BM	Change	IMEX	Change	IMIN
Max. destination locations at mail in simulation	**81**	26%	**101**	-1%	**100**
Max. destination locations at EQ in simulation	**187**	-73%	**51**	-2%	**50**

Table 25: Required number of destination locations (significant differences are marked grey)

[6] (1,325/8,130) * 100% = 16%

7.7.1 Destination locations at the belly wagon storage yard at EQ

Current the full capacity of 144 belly wagons locations is used at the storage yard (see paragraph 5.5). In the integrated situation, IMEX and IMIN only 50 belly wagons are positioned the belly wagon storage yard at the maximum. After the integration wagons are opened for flights only when actual cargo will arrive. Besides the new criterion for the opening of wagons, the demand for space is also smaller, because only "large" shipments stay at the current EQ department. Nevertheless no EQ is stored at the temporary storage anymore and this will shift some large EQ shipments to a belly wagon at the storage yard from the storage racks.
The results of the sensitivity analysis of the integrated situation (discussed in paragraph 7.2) show a larger number of belly wagons is required at the EQ department as a result of the exceptional items in small EQ shipments. The final space reduction for the integrated situation will be less than showed in Table 25. Probably around sixty positions will be required, which is still a reduction of more than 60%.

7.7.2 Destination locations along the carousel

Some small EQ AWBs, which will be sorted via the carousels after the integration, have a destination which is not yet represented along the carousel. For these unique EQ destinations new storage locations along the carousels have to be created (as described previously in sub-paragraph 6.6.1). The increase in the maximum number of 20 belly wagons in the simulation is expected to be higher in reality. The increase will be higher because the destination locations are not dynamic, which will imply that the variation in destinations determines the required number of wagons, not the maximum number of wagons present at one moment. After the integration this effect will become more important, because there will not always be EQ waiting along the carousels at all new destination locations.
Because of these limitations another approach to calculate the required number of destination locations is used as well. Below the volume per destination per flight is used to calculate the required maximum volumes for new destinations along the carousel. The demand for space per new destination is shown by the histogram Figure 43.

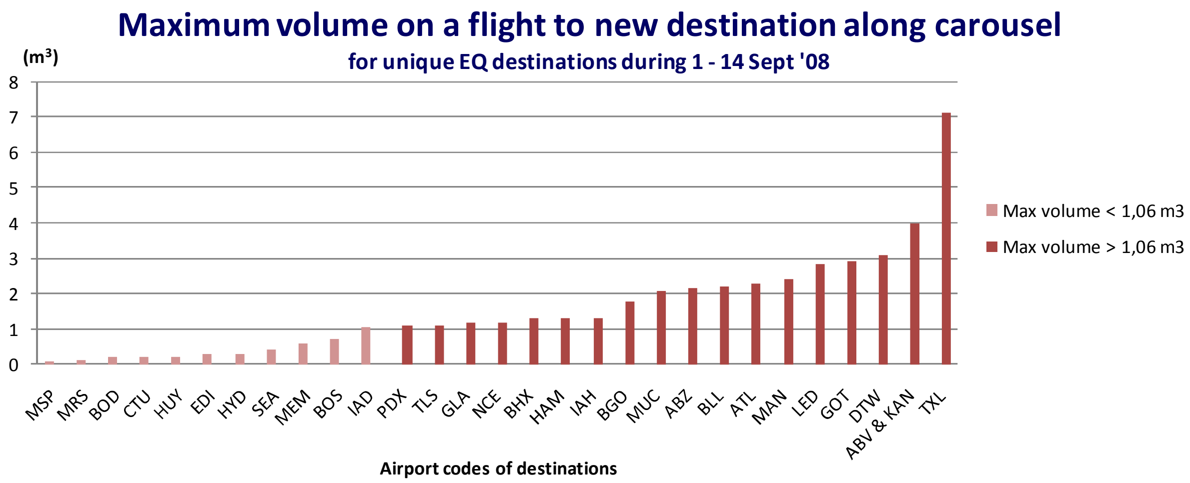


Figure 43: Maximum volumes per new destination along the carousel

In previous KLM analysis the positioning of roller cages along the carousel was proposed to reduce the required storage space along the carousels. The storage capacity of a roller cage equals 1.06 m^3 and previously it is assumed one belly wagon will need the space of three roller cages.
Figure 43 indicates 29 new destination locations are needed along the carousel. The histogram also displays which destinations need more space than the capacity of one roller cage. For the 18 destinations, which will demand more than 1.06 m^3 of storage capacity, a belly wagon is required along the carousel. A roller cage cannot store all cargo for these destinations. For the other 11

new destination locations a roller cage would provide enough storage capacity along the carousel. This would imply that the new destinations of small EQ alone would require the space of 22 belly wagons (18 + 11/3 ≈ 22).
The analysis of the space requirements of the new destinations along the carousel also shows that the majority of the small EQ cargo will use one of the existing mail destination locations. A new destination is always a unique EQ destination.
The extension of the conveyor belt creates room for 15 belly wagon positions. These extra positions will all be required to cover the location requirements for the overlapping destinations already, as explained in sub-paragraph 6.6.1. When the new EQ destinations will need 22 belly wagon sized locations as well, the extended carousel will **not** create enough room at the mail department to facilitate the integration. The required number of destination locations will be higher than the available after the extension of the carousel. This implies that not all small EQ AWBs with an unique destination can be sorted via the conveyor belt system. This problem has to be solved before the integration can be successful.

7.8 Summary of the simulation results of the integration

In this sub-paragraph the most relevant results of the simulation experiments are summarized for the four different performance areas.

Resource utilization
The simulation results show a higher efficiency after the integration of the mail and EQ department initially. The required number of working hours to perform the same performance will decrease by approximately 8%. The proposed addition of new processes however will undo most benefits. Adding the results of the sensitivity analysis with respect to the share of exceptions, the benefits of the integration will probably disappear totally.
The removal of temporary storage shows an important reduction in the workload at EQ, it prevents double handling for one AWB. Applying the FIFO-principle at EQ makes the removal of the temporary storage possible.
The NPV of the investment in the conveyor belt extension is negative. Only when other financial benefits can be realized outside the physical operation due to the extension, KLM Cargo could consider the investment in the extension. The addition of new processes will cost KLM Cargo approximately 630,000 Euro for the next five years.

Handling times
The average handling times are a good indicator of the quality of the operation. The integration including the required new processes will improve the handling times of small EQ; nevertheless the improvement is much larger for large EQ shipments. Therefore the integration will be relatively more beneficial for large EQ shipments than for small shipments. At the same time the small EQ product has a larger growth potential and a higher margin.
The introduction of the FIFO-principle and the increased flexibility with regard to the booking of EQ make early departures possible which reduce the average turnaround times with more than 5 hours.

Number of re-bookings
The number of mailbags which will miss the flight between the collection and arrival at the plane is reduced when the moment of collection is moved forward at the mail department. At the same time the number of bags missing the flight at collection is increased by this change. The sum of these effects however is positive for the performance of KLM Cargo and the change reduces the number of bags missing their flight considerably. Nevertheless the quantitative value is not repeated in this summary, because the validation indicated the number of missed bags is somewhat high.

The introduction of the FIFO-principle and the increased flexibility with regard to the booking of EQ are improving the quality of the operational performance, because these changes make early departures possible which reduces the turnaround times considerably. 16% of all AWBs can take an earlier flight.

Space requirements
The simulation results together with the composed tree diagram (Figure 30) prove that the required space along the carousels is larger than the available capacity after the integration. This indicates that **not** all small EQ AWBs with unique EQ destinations can be sorted via the conveyor belt.

7.9 Refining alternatives

The simulation results show a drastic change in efficiency due to addition of the required new processes. The addition of new processes will undo the initial efficiency benefits of the integration almost completely. The quality and speed of the operation will benefit from the integration however.
The following arguments induced the choice for the refinement of the current operation instead of the refinement of the integrated operation including the extension of the conveyor belt system:

- The simple NPV analysis, performed in paragraph 7.4.3, shows the reduction in the yearly Opex will not be sufficient to earn back the initial investment in the extension of the conveyor belt system.
- The required number of destination locations for the full integration are large than the capacity of locations along the carousel, even after the extension of one of the carousels.
- Nevertheless the simulation results indicate promising alternatives for the current operations without the integration of the operations with the help of the conveyor belt extension.

For these reasons the model of the current situation is refined with the help of the simulation results of the integration. The refinement of the **current** situation will require a change in the fourth sub-question of this research, because not the integrated situation will be improved, but the current operation is refined. The rephrased new sub-question becomes:

SQ4: What are the effects of refining the operational setup of the *current* operation?

Because the integrated situation will not be refined, the fourth step in the sequence of experiments has to be changed as well. To answer the fourth sub-question the sequence displayed in Figure 44 is used.

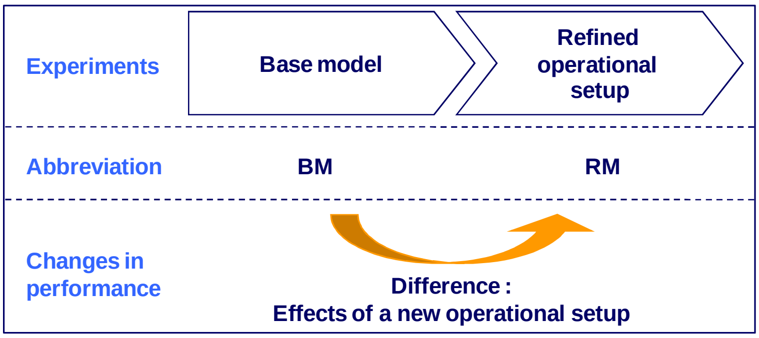


Figure 44: Sequence of experiments to answer fourth sub-question

7.9.1 Refining the current situation

A simulation of an adjusted base case is performed to identify the possibilities to improve the current situation. The following changes to the current operation are made:

- All departing flight are made accessible for both mail and EQ
- The time between collection and the flight departure of airmail is increased to 90 minutes
- Introduction of the FIFO-principle at the EQ department
- The temporary storage will be removed

With these changes it is possible to realize some benefits of the integration without making the investment in the new conveyor belt extension. In the next sub-paragraph the results of the refinement will be discussed.
KLM could even choose to implement the new processes at both departments beside the proposed refinements of the current situation. In case KLM Cargo values the improvement in customer service and the planning process are worth more 630,000 the coming five years. Nevertheless the addition of new processes is not modeled in RM.

7.9.2 Results refined alternatives

The simulated results of the refinement proves that various benefits ascribed to the integration can also be realized without a large investment in the conveyor belt system.The relevant changes of the refinement for the mail department are displayed in Table 26, in appendix Y.5 the results for all performance indicators of RM are displayed and compared to the results of BM.

Table 26: Relevant changes of the refinement at the mail department

Mail			
Advantages		**Disadvantages**	
Criteria	*Change*	*Criteria*	*Change*
Maibags leaving early	2762	Increased pressure on weigh employees	+/- 12 %
Mailbags missing flights	-2679	Increase time between collection and transportation	+ 18 seconds

Due to the larger number of departing flights the pressure on the weighing employees of the mail department is increased, in turn the higher workload will cause an increase in the handling time between collection and transportation. These disadvantages are very small, a higher workload could be seen as more value for money as long as the delays are acceptable as well. The delay of 18 seconds on average is acceptable, certainly when you consider the extra 15 minutes weigh employees have for the collection and transportation in the refined situation. The advantages are significant, in total more than 5000 mailbags will take an earlier flight.

Table 27: Relevant changes of the refinement at the EQ department

EQ			
Advantages		**Disadvantages**	
Criteria	*Change*	*Criteria*	*Change*
Lower utilization lateral sorter	-40 %	Higher utilization bring away employee	+6%
Sharp reduction of turnaround times	-27%	AWBs missing booking	+33
AWB flying earlies than booking	634	Increased time between BD and belly wagon	+11%
Required belly wagon location	-89 belly wagons		

The increased number of AWBs missing their booking could become a major problem of the proposed refinement. Although the AWBs missing their booking at collection are reduced the total number of AWBs missing their booking will increase by the increase in missed bookings at between collection and the plane. A quick analysis tells that especially export shipments will miss their flight more often. A suggestion for the cause of this effect is that more EQ (especially export) AWBs are collected for flight at peak times, but due to pressure on the weigh employees the wagons are not weighed and brought to the plane in time. As said before in paragraph 7.6 the commercial damage is less.
The advantages for the EQ department in other areas are large. Especially the sharp reduction in turnaround times and the large number of AWBs flying early, due to the FIFO-principle and more departing flights, is interesting. The lower utilization of the lateral sorter can compensate for the extra pressure at other functions. The utilization rate of the lateral sorter will even

decrease to 0.21, a rate which justifies the suggestion to sort out lateral cargo at the breakdown and remove the lateral sorter function.

7.10 Sub-conclusions on the simulation results

The simulation of the integration at various stages has provided clear insights in the effects of the integration and the interrelations between the relevant variables for the operation in FB1. The simulation outcomes of the first three models have indicated possibilities to realize various benefits of the integration with a refined operational setup for the current operation instead of the combined operation. Refining the current operational situation avoids the investment in the extension of the conveyor belt, but does not prevent KLM Cargo to proceed with other aspects of the integration outside the physical operation.

Table 28 summarizes the overall effects on the four performance areas for all simulation models compared to the base model.

Table 28: Score overview of performance of the alternative models compared to the base model

Performance indicator	Location or product	BM	IMEX	IMIN	RM
Resource utilization	Mail	0	-	--	-
	EQ	0	++	++	+
Handling times	Mail	0	-	-	0
	EQ	0	++	++	++
	Small EQ	n.a.	+	0	n.a.
Re-bookings	Mail	0	++	++	++
	EQ	0	+	+	+
Space requirements	Mail	0	--	--	0
	EQ	0	++	++	+

The table shows the efficiency gain at the EQ department will be counterbalanced by the efficiency loss at the mail department. The handling times at the EQ department are improved considerable due to the introduction of FIFO-principle and the larger number of available departing flights. This implies that small EQ not utilizes this improvement when sorted via the semi-mechanized sorter belt system at the mail department after the integration.

The improvement of the quality of the operation due to the number of re-bookings is realized in all other simulation models, but the results of RM show the operations do not have to be integrated to realize this improvement.

The required space along the carousel is not sufficient to store all small AWBs after the integration; therefore the full integration is not possible. The results of RM show the space currently required at EQ can be reduced by introducing the FIFO principle.

In the next chapter, the discussed simulation results in this chapter are used to derive the conclusions and recommendation of this report.

8 Conclusions & Recommendations

In this chapter the answers to the research questions are discussed. In the next paragraph conclusions derived from the answers to the sub-questions will be used to answer the main research question of this thesis.

MQ: What is the effect of the integration of the airmail and EQ departments on the overall performance of the KLM cargo operations in FB1?

The second paragraph contains the advice for KLM Cargo derived from the conclusions. Subsequently the recommendations for further research are discussed in paragraph 8.3, followed by the recommendations with regard to the JUMP in paragraph 8.4. Paragraph 8.5 discusses the limitations of this thesis.

8.1 Conclusions

The results of chapter 2 of this report are used to answer the first sub-question. The information on the commercial environment of KLM Cargo is used to place the integration proposal into context.

SQ1: Which forces from KLM Cargo's commercial environment influence the decision to integrate the airmail and EQ department?

The competition in the in the airline industry is severe. Consolidation is used to improve the competitive power by parties in the supply chain. The merger between KLM and Air France is an example of this development.
KLM Cargo can improve their competitive power by improving their handling process at freight building 1 at Schiphol. The integration of the airmail and EQ department fits well in this strategy and the integration will align the operations of Air France and KLM Cargo.
The market for express products is expected to grow above the market average. EQ is KLM Cargo's express product and in order to maintain the market share in the expanding market KLM Cargo wants to improve their handling process.
Stakeholders within the supply chain will not object to the integration at FB1. For the customers the integration is expected to be beneficial. Only the integrators, which are competitors and customers simultaneously, might be skeptical. However, they will need a reliable and good performing airline for the smaller flows in their own network in the end as well.
The integration project in FB1 could deliver valuable experience for the future handling process in a new freight terminal after the JUMP. Schiphol airport would like to see KLM move as soon as possible, but KLM Cargo will prefer to postpone the movement until the future perspectives for the air cargo industry are improved.

Integration excluding new processes

After a thorough analysis of the current and integrated operations it was possible to construct a simulation model of the operations in FB1. The results of the simulation models of the current situation, BM, and the integrated situation, IMEX, were used to answer SQ2.

SQ 2: What is the effect of the integration on the performance of the existing processes at the airmail and EQ department?

Workload

The integration will results in a shift of workload form the EQ department towards the mail department. At the mail department especially the weigh employees face an increase in workload due to the security check and the higher number of departing flights. The reduction in workload

at EQ will especially be experienced by the employees which will have to bring the cargo to the wagons at the belly wagon storage yard. This is applicable for the export acceptance and lateral sorting employees.
In total combined workload for the same performance will decrease with 8% by the integration.

Handling times
The handling times at the mail department are increased by the security check and the increased number of collo the employees will have to handle along the carousel and at the switching location. The larger number of available flights reduce the turnaround times for mail marginally.
The short handling times of large EQ AWBs are strongly reduced, because the workload has become much lower for EQ employees. The long duration handling times are reduced significantly as well, which is mainly due to the enlargement of the number of available departing flights for EQ. The average turnaround times for EQ AWBs decrease by more than 5 hours.
The time between export acceptance and storage in the right belly wagon of small EQ is smaller after the integration than is currently the case. Nevertheless all handling times for small AWBs via the belt are larger than the handling times for large AWBs at the EQ department after the integration. This implies that the quality of the process for the product with the highest growth expectations and the highest margin becomes worse.

Number of re-bookings
The simulation results show that advancing the moment of collection would reduce the total number of mailbags missing their flight and will raise the number of mailbags flying on an earlier flight.

Space requirements
The integration will demand more destinations locations along the belt. The analysis of the required number of locations in sub-paragraph 6.6.1 together with the analysis of the maximum required volumes along the belt for new unique EQ destination of the small AWBs, have proven that the space created by the extension of one carousel will not be sufficient for the extra demand for destination locations after the integration (with or without the addition of new processes)

Integration including new processes

The simulation model of the “pure” integration, IMEX, is expanded with the new processes, to IMIN, to answer SQ3.

SQ3: What is the effect of the addition of new processes on the integrated performance?

Workload
The addition of new processes will undo the benefits of the “pure” integration almost completely. The required new processes will increase the workload again at both departments and especially along the carousels the workload is increased by the exit scan.

Handling times
The changes in handling times at EQ by the introduction of new processes are not significant. The handling times at the mail department will increase significantly. Especially due to the introduction of the exit scan, which has a disproportional delay on the handling times of mail and small EQ. The delay of entry scanning and labelling mailbags is counterbalanced by the removal of the required uploading of data at the office, when the scanners become “live”.
All additional processes are introduced in the flow of small EQ shipment. This product will be delayed most by the new processes. The product with the largest growth potential and highest margin is put at a disadvantage again by the addition of new processes.

Number of re-bookings
The introduction of new processes has a limited effect on the number of missed and early flown AWBs and mailbags. The advantages of the integration for the number of re-bookings are still large even after the introduction of new processes, but the results also indicate that these advantages can be realized in the current situation.

NPV analysis

The negative NPV of the investment in the extension of the conveyor points out that the expected efficiency gain due to the integration will not be able to earn back the initial investment. The cost of the additional new processes will be approximately 630,00 Euro for the coming five years.

Refinement of the current situation

The results of the simulation of the integrated situation revealed possible improvements of the current situation. The application of the FIFO-principle at EQ and the accessibility of all departing flight for mail and EQ will realize most advantages of the integration in the current (non-integrated) situation as well. This will require rephrasing the fourth sub-question of this research to:

SQ4: What are the effects of refining the operational setup of the *current* operation?

The following changes to the operational setup of the ***current*** operation are made:

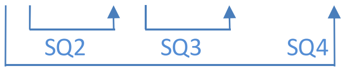
- All departing flights are made accessible for both mail and EQ
- The time between collection and the flight departure of airmail is increased to 90 minutes
- Introduction of the FIFO-principle at the EQ department
- The temporary storage will be removed

These possible improvements in the current operational setup can be realized without large investments in the extension of the conveyor belt system. KLM Cargo can proceed with the integration of other aspects besides the physical operation. In this way the KLM Cargo can gain experience with some aspects of the integration before the JUMP.

The results of the simulation of the refined alternative are summarized in Table 26 and Table 27. The results show that large amounts of mailbags can take an earlier flight with the new setup. The disadvantages are limited, because although the weigh employees will become busier, they have also more time for the same processes due to the advancement of mail collection.
The new operational setup in the current situation will realize: a space reduction at the EQ department, a sharp reduction in the turnaround times at FB1 and a large number of AWB flying on an earlier flight. The disadvantages of the new setup are: a higher workload for the weighing employee at EQ, more AWBs missing their booking and an increase in the handling time between break down and the right bell wagon. Nevertheless it seems plausible to assume that the lateral sorter employee can help at other positions and this could undo these disadvantages to a large extend. Table 29 summarizes the overall results for all four performance areas.

Table 29: Score overview of performance of the alternative models compared to the base model (repeated)

Performance indicator	Location or product	BM	IMEX	IMIN	RM
Resource utilization	Mail	0	-	--	-
	EQ	0	++	++	+
Handling times	Mail	0	-	-	0
	EQ	0	++	++	++
	Small EQ	n.a.	+	0	n.a.
Re-bookings	Mail	0	++	++	++
	EQ	0	+	+	+
Space requirements	Mail	0	--	--	0
	EQ	0	++	++	+



8.2 Advice to KLM Cargo

The results of this study give no reason to assume large efficiency gains can be realized by the full integration of the physical operation of airmail and EQ. This contradicts the expectations of the business case on the integration, which were based on older work schedules.
The NPV analysis shows that the Capex in the physical operation cannot be earned back by the lower Opex in the physical operation the coming five years. This proves the integration of the physical operation should not be executed for financial reasons. Only in case the investment is required to create possibilities to gain other financial benefits outside the physical operation KLM Cargo should consider the investment in extension of the conveyor belt.
The introduction of new processes requires an investment as well, which will not be earned back. However KLM Cargo could value the new opportunities of the new processes to be worth the investment of approximately 630,000 Euro for the coming five years. The new processes enable KLM Cargo to raise the quality of the information exchange with their customers and improve the planning process with the real-time and accurate information from the operation.
The simulation of the refined current operations has shown that benefits ascribed to the integration can also be realized without integrating the physical operation.
This leads to the advice to postpone the investment in the extension of the conveyor belt system, proceed with the integration on all other areas and adjust the current operational setup. The new operational setup will realize advantages of the integration without large investments in new infrastructure. The improved performance could improve the competitive position of KLM Cargo in case the customers are accepting the FIFO principle. At the same time the operation of KLM Cargo can get used to some aspects of the integrated operation, which will results in valuable knowledge and experience for after the JUMP.

8.3 Recommendations for further research

In this paragraph the possibilities for further research are discussed, which were identified during this research.

Efficiency gains at the transportation department

The benefits of the integration will also be realized outside FB1. Due to mixed loading the number of wagons which are dropped off at the transportation department will become smaller. The smaller number of wagons will decrease the average length of a train of wagons for a flight. This reduction in length could increase the flexibility to combine trains for different flight in one large train. The formation of longer trains could reduce the number of trips to the planes, which could reduce the required number of employees working at the transportation deparmtent. The financial benefits of the higher efficiency of the transportation department could improve the financial cost benefits analysis of the integration project.

Acceptance of FIFO principle by EQ customers
The customers of EQ have to accept the introduction of the FIFO principle at EQ. FIFO will imply that the booking made by the customer is used as deadline, but KLM Cargo could send the AWB on an earlier flight. KLM Cargo has to make sure this is accepted by their most important customers; otherwise the FIFO principle could make them lose customers.

Effects of capacity constraints of departing flights
This research proves cargo could take earlier flights than it currently does. Nevertheless the capacity constraints of the flight leaving Schiphol are outside the scope of this research. Further research should indicate whether it is actually possible to allocate the cargo on earlier flights. This analysis could limit the benefits of the proposed changes to the current operational setup.

The attraction of new cargo due to the introduction of the FIFO principle
KLM Cargo assumes that applying the FIFO could increase the load factor of departing planes. This study proved there is room to advance the departure of a part of the existing cargo. Nevertheless this will only result in a higher load factor when the total amount of cargo is increase by the FIFO principle.
It is possible that early notification of available capacity on flights increases the demand for capacity. At the moment no proof for this increase is available, let alone an indication on the size of this possible increase. Therefore the effect of the FIFO-principle on the average load factor had to be studied.

Security check
An analysis on the effects of security checking airmail has to be made, for the combined weighing of mail and EQ. The effect of the integration on the alarm rate is uncertain. The number of checked collo becomes much larger and the percentage of suspicious collo could become higher as well, because the sender of airmail is more anonymous.
Therefore it is possible that the dogs will alarm for dangerous goods more often and that more areas should be available to isolate the cargo taken out by the dogs. In this study the possibility of a x-ray scan at the export acceptance should also be taken into account.

8.4 Recommendations with respect to the JUMP

KLM Cargo has the opportunity to build a state-of-the-art cargo terminal, when moving to a new freight building. The current software, building or processes are often the constraints when studying the integration of airmail and EQ. KLM Cargo could try leaving all legacy behind by applying business process reengineering (BPR)for the design of the new terminal. Furthermore, this research has also resulted in more practical applicable recommendations for KLM Cargo with respect to the JUMP. These recommendations are discussed below.

The new conveyor system after the JUMP
A conveyor belt configuration with shoots will increase the efficiency of the employees along the carousel for three reasons:

- The employees along the carousel will not waste their time anymore by checking bags which are not destined for a belly wagon in the vicinity of the employee.
- Collo cannot go several rounds on the carousel. This will probably reduce the required time to get collo to the belly wagon and it will decrease the demand for capacity on the belt.
- The number of destinations per shoot will be limited and this will make it possible to sort out the bags per destination at the shoot. In this way the employee can scan and load the wagons in a kind of "routine". Handling ten bags for one wagon can be done faster than ten bags all going to different wagons.

The advantageous of the integration of mail and EQ are probably bigger for another conveyor belt layout, which includes shoots instead of the continuous carousels.
When KLM will invest in a new conveyor belt system at the new location, an extensive new study to the right type of sorted belt is required anyway. This study has to give due weight to the choice between a continuous belt and a configuration with shoots.

Communication with KLM Cargo's customers
The importance of the communication with the customers when integrating the mail and EQ operation was emphasized during the visit to Sodexi at Charles de Gaulle in Paris. The customers will accept minor decrease in performance when they are aware of the fact KLM is making the transition to an integrated operation which will be beneficial for the handling of their product in the future. Probably the customers will cooperate by labeling the mailbags and EQ packages with IATA 606(B) before they arrive at KLM, but this will require an investment of KLM Cargo in explaining the potential benefits for the forwarders. KLM Cargo should start with investing in the promotion of IATA606(B) labels as soon as possible. The larger the acceptance of this label type the better for the efficiency of the operation after the JUMP.

Cargo hub near the gates at Schiphol
Another research subject would be to develop a transportation hub located near the gates at Schiphol, in order to make large scale bundling of all transport between KLM Cargo's freightbuildings and the gates possible. With a hub close to the gates KLM Cargo would follow the example of Sodexi. Sodexi plans to develop a hub near the gates at Charles de Gaulle. The possible benefits of the hub are larger at Charles de Gaulle airport due to the larger distance between the freight building and gates; nevertheless it might be worthwhile to investigate the option for the new location of KLM Cargo after the JUMP

Unmanned export acceptance
The customers are made responsible for the labeling on collo level and the placement of the colli on the conveyor belt at the export acceptance of Sodexi. Currently this is not possible at KLM Cargo, but it would take away most work for the export acceptance employees. This possibility should be investigated when designing the new terminal, because it could reduce the costs of the operation.

8.5 Limitations of this research

The performed simulation study has its limitations; this has resulted in some recommendations for further research in paragraph 8.3 already. The recommendations for further study implicitly indicate the limitations of this research. In this paragraph attention is paid to some other limitations of this study:

- As discussed before no link exists between with the available capacity of the departing flights and the actual demand for capacity. In reality the available capacity on the flight is crucial for the final allotment of mail and EQ on the flight.
- Another limitation is the small number of time measurements for some processes in the operation. The small number of measurements could result in less reliable estimates of the process times. The results of the study did not give reason to suspect the estimates were wrong, nevertheless the results of the study should be approached with some reserve.
- Only data of two months in 2008 were collected and transformed into the input files for the simulation model. Only two weeks of these months were used as replication length. The large amount of work to make new input files will limit the flexibility to use the models to simulate other periods. This will limit the possibilities to vary with periods and react on recent developments (e.g. the decrease in demand due to the economic recession).

- A model always remains a model of reality and although the simulation model of FB1 is very detailed, reality will always be different. During the project the flexibility and on the job problem solving ability of the employees was observed in the operation. A model, which is always consequent cannot grasp this dynamic attitude.

These limitation emphasis once again that the results of the simulation model should not be considered the truth, nevertheless the results give a good indication of the effects of the integration.

9 Epilogue

This chapter will discuss the academic contribution of this master thesis and will contain a personal reflection this thesis project.

9.1 Academic reflection

The handling processes at FB1 are unique, the measured process times, the distance to the gates, the flight schedule etc. are all only applicable for the operation in FB1. The uniqueness of the simulation model will limit the generic use of this research.
Nevertheless, the results of this research could indicate opportunities for similar research at other (air) cargo terminals around the globe. The size of the effects is unique for the terminal at KLM Cargo, but directions of the relation between changes in the operation and the operational performance could very well be the same.
A large number of scientific studies used discrete simulation to evaluate and compare different policies (DeLorme et al, 1992) (Nsakanda. and Turcotte, 2004) (Ou, Zhou and Li, 2007).
This study has shown again that discrete simulation can be a powerful tool.

Other methods could have been used to determine the effects of the integration as well. A trade-off probably exists between the time consumption and the level of detail. I think other methods could have resulted in a similar advice to KLM Cargo with less effort. However, the interrelations between processes in FB1 are nicely identified with the simulation model in the end. The dynamics of the processes is in this way incorporated in the results.

Most time spend on the master thesis project comprised out of getting to know the air cargo industry and mapping all aspects of the operation in FB1. Especially the mapping of the operation was time-consuming due to the large number of aspects and exceptions within both operations. All aspects had to be studied first in order to decide whether or not specific aspects were relevant for the study.
Furthermore, I have chosen a very detailed approach from the start for all activities in FB1; this choice incorporated a large workload. At the time this choice was made I did not realize the large amount of work which had to be done. The chosen detail level has resulted in a very detailed and specific simulation model. Future (simulation) models could be made more generic and simpler in order to increase the accessibility of the model. Nevertheless this would also result in more general results. I could also have focused on one specific area from the start. However I am proud of the results, which are detailed and are covering various important aspects of the integration.

9.2 Personal reflection

At the end of this master thesis project it is possible to look back and evaluate your own role in the project and think about what you would differently when performing a similar project in the future.
My role at KLM Cargo was quite distant and independent from the normal organization, because KLM Cargo offered me a lot a freedom and the initial project team was dissolved halfway this thesis. This resulted in a low number of feedback moments with representatives of KLM Cargo. Afterwards I could have claimed more time to discuss my progress and check the preliminary results. Now, all results were communicated at the end of the project and this made the amount of new information during the presentations very large, which made the exchange of all information and details difficult.

The independent position during the project made me more responsible for the progress, planning and results. Afterwards this is satisfying, because the project is really your own project and you will learn a lot, because you have to find out everything yourself.

In case I was commissioned to investigate the integration of airmail and EQ as commercial party I would have teamed up with employees of KLM. This would increase the speed of the project immensely, because the specific knowledge of the industry and the processes in FB1 is available from the start.
At the end of the model construction the experience with the program is much larger than at the start. When I would build a simulation model of the operations in FB1 again I would construct some aspects in a different way. The development of experience with simulation is one goal of the master thesis and in this case the time spend on the simulation model was not useless.

Literature

Airbus (2007). *Flying by nature, Global Market Forecast 2007 – 2026*. Blagnac Cedex, France.

Air France Cargo - KLM Cargo (2008). *Cargo Business plan 2008/2009. France.*

Air France KLM (2008a). *Press release Financial year 07-08*. Roissy, Amstelveen, May.

Air France KLM (2008b). *Corporate responsibility report 2007-08*. France.

Balci, O. (1990). *Guidelines for successful simulation studies*. Proceedings of the 1990 Winter simulation Conference, pp. 25-32.

Banks, J. (1998). *Handbook of Simulation: Principles, Methodology, Advances, Applications, and Practice.* John Wiley & Sons, New York.

Bhalla, S. and Malik, S. (2008). *Project Mail and Equation Integration.* KLM Cargo, Schiphol.

Boeing commercial airplanes (2006). *World air cargo forecast 2006-2007*. Seattle.

Boeing commercial airplanes (2008). *Boeing Current market outlook 2007-2027*. Seattle.

Buyung A., Klein W. de (2002). *The dynamics of airline alliances.* Journal of Air Transport Management. Vol.8 , No. 4 , pp. 201–211.

Chen, C.H. and S. Chou (2006). *A BSC framework for Air Cargo Terminal Design: Procedure and Case study.* Journal of Industrial technology. Vol. 22, No. 1., pp. 2-10.

DeLorme, P., Procter, J., Swaminathan, S. and Tillinghast, T. (1992). *Simulation of a combination carrier air cargo hub*. Proceedings of the 1992 Winter Simulation Conference, pp. 1325-1331.

Doganis, R. (2002). *Flying Off Course.* Routledge, Third edition, London.

Forster, P. and Regan, A. (2001). *Electronic integration in the air cargo industry: An information processing model of on-time performance*. Transportation Journal, Vol. 40, No. 4, pp. 46-61.

Franke, M. (2004). *Competition between network carriers and low-cost carriers—retreat battle or breakthrough to a new level of efficiency?*. Journal of Air Transport Management. Vol. 10, No. 1, pp. 15-21.

Groover, M.P. (2001). *Automation, production systems and computer-integrated manufacturing*, Prentice Hall, Second edition,. New Yersey, USA.

IATA (2007a). *Economic briefing; passenger and freight forecasts 2007 to 2011*. October.

IATA (2008a). *Financial forecast; significant losses continue into 2009*. September.

IATA (2008b). *International Scheduled Operations Traffic Analysis*. July.

KLM (2007). *2006 | 2007, Een jaar in perspectief.* Amstelveen.

KLM (2008a). *Annual Review 2007/2008 Towards smart leadership.* Amstelveen.

KLM Cargo and M3 Consultancy (2006). *Speed products; Integrating mail, equation, Dip and most aerospace brings distinct advantages in speed and reliability*. Team meeting.

Law, A. (2003). *How to conduct a successful simulation study*. Proceedings of the 2003 Winter Simulation Conference, pp. 66-70.

Lobo, I. and Zairi, M. (1999). *Competitive benchmarking in the air cargo industry. Part I.* Benchmarking: An International Journal, Vol. 6, No. 2, pp. 164-190.

McGuire, F. (1994). *Using simulation to reduce length of stay in emergency departments*. Proceedings of the 1994 Winter Simulation Conference, pp. 861-867.

Morrel, P.S. and Pilon, R.V. (1999). *KLM and Northwest: a survey of the impact of a passenger alliance on cargo service characteristics*. Journal of Air Transport Management, Vol. 5, No. 3 , pp. 153-160.

Nsakanda, A.L. and Turcotte, M. (2004). *Air cargo operations evaluation and analysis through simulation*. Proceedings of the 2004 Winter simulation Conference, pp. 1790-1798.

OECD (2001). *Liberalization of air cargo transport*. report used as input for the Workshop on liberalization of Air Cargo in January 2002.

Ou, J., Zhou, H. and Li, Z. (2007). *A simulation study of logistics operation at an air cargo terminal*. Proceedings of the 2007 International conference on Wireless Communications, Networking and Mobile Computing, pp. 4403- 4407, Shanghai, China.

Pielage, B. (2005). *Conceptual design of automated freight transport systems*. Delft.

Ramachandran, G. and Tiwari, S. (2001). *Challenges in the air cargo supply chain*. Communication of the ACM, Vol. 44, No. 6, pp. 80-82.

Robinson, S. (1997). *Simulation verification and validation: increasing the users' confidence*. Proceedings of the 1997 Winter Conference, pp. 53-59.

Rosenberger, J.M., Schaefer, A.J., Goldsman, D., Johnson, E.L., Kleywegt, A.J., and Nemhauser, G.L. (2000). *Air transportation simulation: SimAir: a stochastic model of airline operations*. Proceedings of the 2000 Winter Simulation Conference, pp. 1118-1122.

Rotan Khan, M.R. (1999). *Business process reengineering of an air cargo handling process*. International journal Production Economics, Vol.63, No. 1, pp. 99-108.

Sage, A. and Armstrong, J. (2000). *Introduction to systems engineering*. Wiley and Sons, New York.

Sargent, R.G. (2005). *Verification and validation of simulation models*. Proceedings of the 2005 Winter Simulation Conference, pp. 130-143.

Schiphol group (2007a). *Ruimtelijk ontwikkelingsplan Schiphol 2015*. Schiphol

Schiphol group (2007b). *Lange termijnvisie Schiphol*. Schiphol

SkyTeam Cargo (2004). *Together, we go further; seamless global logistics from the world's largest airline cargo alliance.*

Schwartz, G. (2006). *Enabling global trade above the clouds: restructuring processes and information technology in the transatlantic air-cargo industry.* Environment and Planning A, Vol. 38 No. 8, pp 1463-1485.

Universal postal Union (2005). *TRIPS 151,Physical Data Model (PDM). Document version 1.0.* Bern Switerzerland.

Verbraeck, A. and Valentin, E. (2002). *Simulation building blocks for airport terminal modeling.* Proceedings of the 2002 Winter Simulation Conference, pp. 1199-1206.

Verbraeck, A., Heijnen, P.W. and Bockstael-Blok, W. (2005). *Reader epa1331 Discrete Modeling.* Delft, Fifth edition (partially revised).

Verbraeck, A. and Valentin, E. (2005). *Reader spm2320 Discrete modellen, deel II – Discrete Simulatie.* 8th revised edition, Delft.

Zhang, A, Van Hui, Y. and Leung, L. (2004). *Air cargo alliances and competition in passengers markets.* Transportation Research Part E 40, pp. 83-100.

Zhang, A. and Zhang, Y. (2002a). *Issues on liberalization of air cargo in international aviation.* Journal of Air Transport Management Vol.8 No. 5, pp. 275–287.

Zhang, A. and Zhang, Y. (2002b). *A model of air cargo liberalization: passenger vs. all-cargo carriers.* Transportation Research Part E 38, pp. 175–191.

Zhu, K., Ludema, M. and Heijden, R. van der. (2000). *Air cargo transport by multi-agent based planning.* Proceedings of the 33rd Hawaii international conference on system sciences.

Websites

http://www.acn.nl/reindex.asp?FileName=http://www.acn.nl/pages/luchtvaartwet.asp, 3-10-2008
http://www.airfranceklm-finance.com/air-france-klm-group.html, 28-7-2008 & 29-9-2008
http://www.arboportaal.nl, 10-3-2009
http://www.businessdictionary.com, 11-2-2009
http://corporate.klm.com/en/newsroom/press-releases/archive-2008/air-france-and-klm-winter-schedule-0809, 20-3-2009
http://www.iata.org./whatwedo/cargo/efreight.htm, 1-10-2008
http://www.iata.org/about/priorities.htm, 6-10-2008
http://www.tntpost.nl/overtntpost/postwet, 2-10-2008

List of figures

List of tables

Integration of the airmail and equation operations at the KLM Cargo terminal

Determining the performance of the integrated Airmail and Equation operations at the KLM Cargo's freight building 1 by means of discrete simulation in Arena

Appendices

Schiphol, 15 June 2009

Name:	Gijs van Amstel
Student number:	1104292
Company:	KLM Cargo
University:	Delft University of Technology
Faculty:	Technology, Policy and Management
Chair:	Transport, Infrastructure and Logistics

Table of contents Appendix

A Limitations of previous analyses of KLM Cargo

Some elements of the integration were studied by KLM Cargo itself in the past years. The results of these analyses have not convinced KLM Cargo's management. The results still incorporate too much uncertainty, because none of the calculations have been able to incorporate all the different aspects of the integrated process to their full extend. The reasons for this are:

- Some decisions regarding the organization of the processes are not yet made. There are still challenges for future operation which has to be dealt with (6.5.3).
- The effects of the new processes for the integrated operations were not yet incorporated in previous calculations (6.5.2). These calculations were restricted to existing operations and did not consider new processes.
- Different potential bottleneck locations have been looked at individually, without taking the dependencies between them into account.
- Previous calculations were primarily to determine if the capacity of the infrastructural works in FB1 (e.g. conveyor belts and pallet breakdown areas) would be sufficient in the new situation. Calculations were focused on retrieving infrastructural constraints, rather than determining the future possible performance of the system. This did not give due weight to the importance of the performance of the combined operations.
- The final conveyor belt layout differs significantly from the assumed layout used for previous calculations.

B Airline industry supply chain analysis

The composition of the airline industry has been changing during the last decade, liberalization and deregulation has increased competition, which forced down the profit margins. The low profit margins, together with the capital-intensive and demand-sensitive character of the airline industry, make it hard to survive in the airline business. As a result a wave of consolidations has gone through the airline industry (KLM, 2007).
International transport of cargo by air is a complex business: it will involve many firms, different languages, time differences, strict and location specific regulation, different economic systems and cultures. This will require intense coordination of the physical flow of goods and the virtual flow of information. In this sub-paragraph the supply chain of the air cargo industry will be described, making the difference between the traditional supply chain and the more often observed supply chain of the integrators. This will be followed by an introduction of most important development in the relevant regulations.

B.1 Traditional supply chain

The traditional air cargo supply chain will exists out of the shipper, forwarder, airline and consignee (Figure 45). Five different intermediaries are involved to send a shipment from its origin, the shipper, to the destination, the consignee. The exporting shipper will contract a forwarder, who manages most aspects of the transport.
The traditional forwarder plays a mediating role between a shipper and the airline, the function of forwarder is based on coordination and the exchange of information. The forwarder will book capacity on flights of a carrier. This is often performed in advance with long-term contracts; in that case the forwarder can bundle the demand of different shippers and improve its bargaining position towards the airlines. Sometimes reservation of capacity will be done on ad hoc basis, depending on the demand for freight capacity.
The forwarder also has to organize the required handling and transport to take the shipment from the shipper to the airline. This will involve the organization of trucking, warehousing and airport ground handling in most cases.
Airlines will transport most cargo in the holds of scheduled passenger flights, some airlines will operate full-freighters for air cargo besides their passenger flights and some airlines will only transport cargo. Cargo on passenger flights can be transported in the belly of the aircraft or on the upper deck, in this case the airline has substituted passenger chairs for extra cargo capacity, these aircraft are called combination aircrafts.
After arrival on the airport of destination the forwarder will organize the transport and handling required to get the shipment at the consignee.

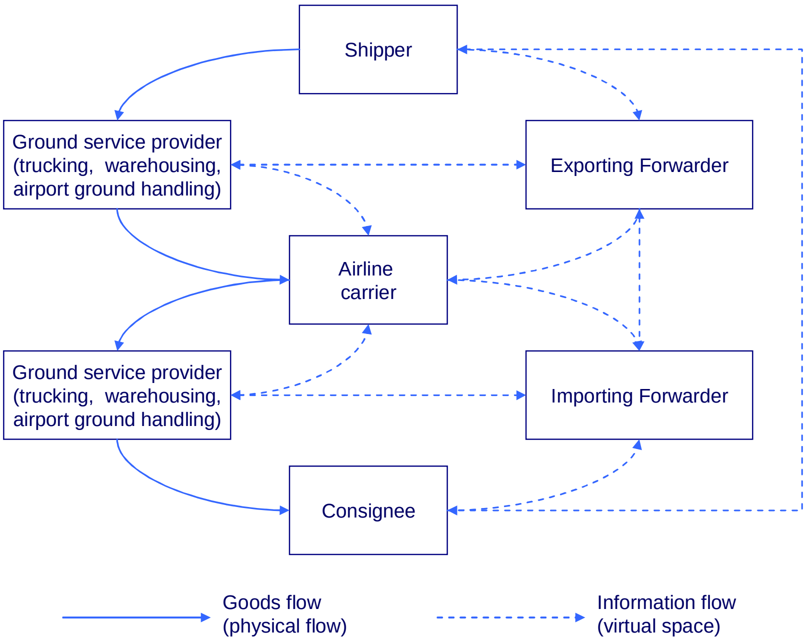


Figure 45: the traditional air cargo system (Schwarz, 2005)

Regulation

The airline industry is one of the more heavily regulated sectors of the global economy (Schwarz, 2005). Air traffic is regulated through bilateral air service agreements between individual countries, this negotiated agreements often determined everything between tariffs to capacity. These agreements were in most cases negotiated from the perspective of passenger transport. The regulations often prevented foreign airlines from operating domestic flights within other countries, and operations between third countries was also often restricted. Additional foreign-ownership limitations prevented foreign companies to gain a controlling interest in an airline of another country or starting a new airline there (Schwarz, 2005). This reduced the competition between airliners in the past; each carrier was in a way protected from competition of foreign carriers on their home ground.
Air carriers may not be allowed to perform activities at ground level related to cargo transport in other countries; this is often restricted to particular firms or the airport authority. These regulations prevented air carriers to enter this related markets. Besides these protective regulations only locally owned firms may be allowed to clear cargo through customs.

In the past decades liberalization took place in the airline industry. Within the EU the restrictions have been gradually been removed until the complete abolishment in 1997 (OECD, 2001). On the intercontinental routes restrictions remained in place for a longer period. Bilateral 'Open-Skies' agreements were made between individual countries, which removed capacity and price restrictions. This resulted in a situation that some European countries could fly to the USA without restrictions where other could not. This has been ruled illegal by the European court of Justice in 2002, because it caused unequal competition between European airlines.
Regulatory restrictions slowed down the global consolidations of the air cargo industry. The regulations will influence the pattern of air cargo flows and the position of individual firms (Schwarz, 2005). Liberalization should level the playing field in the air cargo industry.

B.2 Consolidation in the Supply Chain

In the last decade consolidation occurred in the air cargo industry on three levels: between forwarders, between airlines and by companies which vertically integrated all activities in the supply chain.

In the past the forwarding industry was highly fragmented. Recently large international forwarders have emerged, which are expanding their market share fast. This is done by entering the market for the physical transportation of cargo instead of remaining a coordinating non-asset firm. Besides that the forwarders are taking over the transport activities they are also extending their services and are offering other value-added services to customers (e.g. warehousing).
The number of real mergers between airlines is limited because the extensive legislation is often preventing this. Nevertheless airlines were looking for market consolidation, this resulted in alliances between airlines, close cooperation of airlines without merging, These alliances can be focused on passenger transport (e.g. SkyTeam, Star Alliance, and OneWorld) or on cargo only (e.g. WOW cargo alliance)
Nevertheless the largest challenge for the existing parties in the traditional supply chain came from the 'integrators'. These companies are vertically integrating the whole supply chain and offer door-to-door transport by one company. The integrators pursued innovative strategies for infrastructure, product and information technologies. They focus on high value business documents or parcels, enabling standardized packaging, simplified pricing and documentation. Their technology strategy developed tracking and tracing technologies and internal information systems for monitoring system-wide performance (Forster and Regan, 2001). The integrators take over functions of forwarders, ground handlers and the airlines. In this way they provide the physical transport, all coordination and information flows. In some cases they encounter regulations which force them to outsource activities to other (local) parties, but they strive towards control over the whole supply chain (Figure 46).

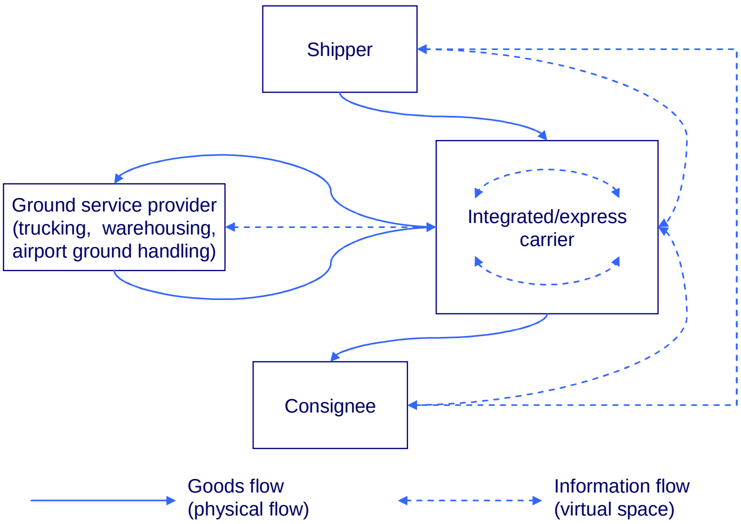


Figure 46: The supply chain with integrator (Schwarz, 2005)

At the start these companies realized strong growth of market share in the market for parcel and express shipments; recently they tend to focus more on general air cargo as well. The strong growth of these integrators took place simultaneously with the increase of outsourcing of logistics by manufacturers to third parties. The integrators can achieve economies of scale by bundling flows of cargo, but at the same time integrators are competing with a lot of different players, because they offer services in various areas (Schwarz, 2005) and it comes at a high cost, asset specific investment, reduced organizational flexibility and market responsiveness are risks associated with vertical integration (Forster and Regan, 2001).

C Stakeholder analysis integration project and JUMP

In this paragraph the interest of all stakeholders involved in the integration project in FB1 in particular are described. First, the general strategy of Air France-KLM will be described briefly, because this places the integration project into perspective. This will be followed by an overview of the stakes of parties within KLM Cargo, the internal stakeholders. After this the stakes of KLM Cargo's customers are described. The customers of KLM Cargo will be shippers, forwarders and integrators. The competition of KLM Cargo will exist of out of competitive airlines and other ground handlers at Schiphol. The final sub-paragraph will consist out of the opinions of KLM and Schiphol with respect to the JUMP.

C.1 Air France - KLM

Air France-KLM is working on the integration of certain activities of both airlines in order to realize the expected synergies of the merger. The group's strategy is described as: "one group, two airlines, three core activities". These three core activities are passenger transport, cargo transport and aircraft maintenance. In this report the focus will be on the cargo transport, therefore the passenger and maintenance department are outside the scope of this stakeholder analysis.

C.1.1 Air France Cargo – KLM Cargo

The Air France-KLM Group has built a number of fundamental strengths. The airline has two powerful hubs (Paris-Charles de Gaulle and Amsterdam-Schiphol) linking the medium-haul network to long-haul routes. It results in a well-balanced network that offers natural protection against economic and geopolitical risks (www.airfranceklm-finance.com, 29-9-2008). Due to the large network both carriers are sorting and distributing airmail and EQ for transit flows via their hubs, besides serving their home market.
Cost reduction and the ongoing integration and alignment of the operations of the two cargo organizations will remain important in the strategy of the AF/KL Cargo. The integration of the EQ and airmail in FB1 could contribute to this reaching these goals. At Charles de Gaulle the operation of mail and EQ are already combined (see paragraph 6.2 and appendix S) and the integration of both flows is expected to result in cost reductions, due to realizing synergy effects.
The strength of the KLM Cargo operation at the moment is the quality of the cargo handling. KLM Cargo is renowned for their flexibility and is seen as a very reliable cargo airline and the leading carrier in the transportation of airmail (Lobo and Zairi, 1999). Because of this reputation KLM Cargo is often used for specialized cargo transport, for example transport of live animals, art, valuables, and perishables.

Air France Cargo just moved to a new cargo terminal at Charles de Gaulle airport, which has been an improvement for their cargo handling process. The handling of EQ and airmail is performed by Sodexi at Charles de Gaulle, a subsidiary company of Air France-KLM. By improving the process for express cargo the airlines are trying to compete with integrators. Equation is the product of AF/KL Cargo which has to compete with the services of the integrators.

C.2 Internal project stakeholders

In the overview of the Cargo organization (Figure 47) within Air France-KLM the airmail and EQ department are highlighted.

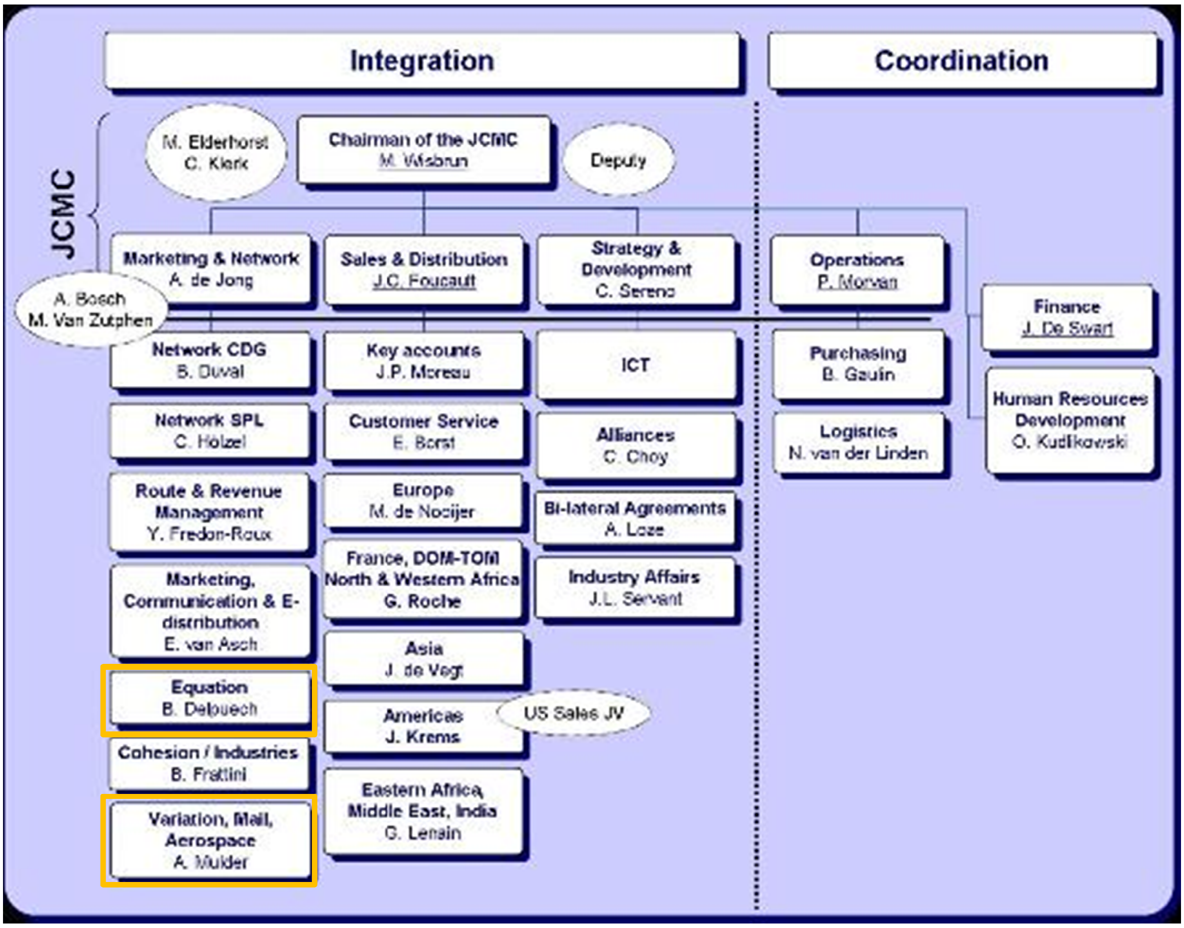


Figure 47: Organization chart of the cargo organization of Air France Cargo-KLM Cargo

The changes due to the integration will be experienced by these two departments. Andre Mulder is responsible for the integration project within KLM Cargo. He has to justify the choices made in the Schiphol Executive Regie Meeting (SERM), which is also attended by the chairman of the JCMC of Air France cargo-KLM cargo, M. Wisbrun.
The initial organization of the integration project can be visualized by an organization chart on a lower level (Figure 48). Here a project team, responsible for the design and preparation of the integration, is working besides the implementation team, responsible for the implementation of the proposal.

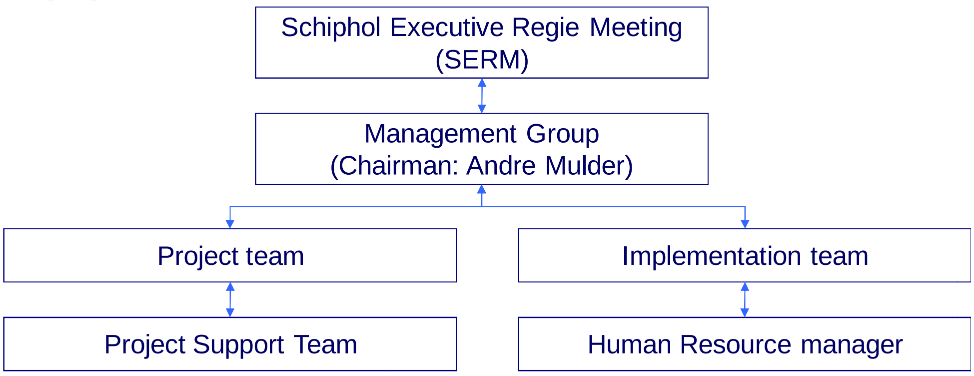


Figure 48: Organization chart of the integration project

In this analysis the stakeholders are distinguished into four internal stakeholder groups: KLM Cargo management, the operational management of airmail and of EQ, the workforce of both departments and the transportation department.

C.2.1 The management of KLM Cargo

In general the management of Air France-KLM strives towards alignment of the operations, in order to exchange best practices and offer the same products and quality to customers. Increasing the efficiency of the operations will help to reduce the costs, this is necessary in these challenging times for airlines.

The management of KLM Cargo will try to contribute to these goals of the group. Therefore it initiated the study to integrate the mail and EQ flows, which is expected to result in efficiency gains due to synergy effects. At the same time the integration will lead to higher customer service performance, which will help KLM Cargo to protect its market share and attract new customers.

The management of KLM cargo is already considering the movement of KLM Cargo to the proposed new location at the other side of the Kaagbaan. The gained experience with the combined operations of mail and EQ at FB1 will be useful knowledge for the design of the new freight terminal.

The integrated situation will raise issues around safety of the premises and safety of the employees in the freight building. The integration project has to become safer for KLM employees. The safety on board of the plane and in the freight building should be according to the regulations in the industry or better. In the Netherlands the "Arbeidsomstandighedenwet", the so-called Arbo-wet, sets the rules on working conditions with regard to safety.

Whereas airmail is under a different department than EQ at the moment, the integration will change the organization structure. This implies that one of the managers will lose a part of his/her responsibility.

From a commercial perspective it is important that the integration will not endanger the continuity of the operation. Discontinuity would damage the reliable image of KLM as a cargo carrier.

C.2.2 Operational management

The operational management will become responsible for the integration and the continuity of the operations during the implementation phase. When difficulties arise in the process after the integration it will be the responsibility of the operational management to find a solution for them, without harming the operational performance. Therefore the operational management is focused on the prevention of difficulties beforehand, instead of after the integration project. They want to reduce the risks of future problems.

The synergy effects of the integration project would partially result from the overlap of functions in the operational management. This will result in the possibility to lose responsibility or even jobs for the management, because it is expected some functions will become superfluous.

Having seen new initiative fail and having experienced the delay of the project the operational management is concentrating on their day-to-day responsibilities.

C.2.3 Operational workforce airmail and EQ

The workforce of the operations at the mail and EQ departments exists out of KLM employees and temporary workers. The employees in the operation should adapt to the new situation. At the moment they have experience with the current activities and the operations are routine jobs for them, they are not used to mayor changes in the process. In this environment change is always regarded with some reserve, afraid of changes and a possible higher future workload.

On the other hand there is also a fear to lose jobs when the efficiency increases. Therefore the employees are trying to be amenable for the new initiatives. The employees know that fast adapting and willingness to cooperate will be appreciated by the management.

It is relatively hard to find employees for the work in the freight buildings. At the moment KLM Cargo is hiring temporary workers. The presence of the temporary workers will comfort the KLM Cargo employees, because they know that the temporary workers will be the first to leave the organization when the increased efficiency reduces the required number of employees for the operations.

C.2.4 Transportation department

The transportation department, "Rijderij", is responsible for bringing in the belly wagons at the EQ operations, the mail department will be responsible for this themselves. The integrated operations will require a decision on how to perform this activity in the future; this will influence the workload for the transport department.
The operational manager of the mail operations recently became responsible for the transportation department, in order to improve the communication and coordination between the mail and transport department.

C.3 External stakeholders

C.3.1 Customers

In the Netherlands, TNT is using KLM as their main carrier (besides their own fleet) for the distribution of the international airmail and express packages. Nevertheless competition is severe at the moment and the forwarders or postal companies have power to negotiate over price. KLM Cargo is offering service to the large integrators as well as other types of forwarders, which implies that KLM Cargo will transport for all customers types.
The most important customers for KLM Cargo are large postal companies and integrators and consolidated forwarders from around the world (Table 30), which are using Schiphol and the KLM Cargo terminal as one of their hubs. The revenue per shipment will be determined on the weight, flown distance and the tariff for the connection. Shippers are considered as well in this sub-paragraph, because the demands of the forwarders are the derivative of the shipper's demands.

Table 30: Top 10 customers based on 07/08 revenue (KLM Cargo)

	Airmail	Equation
1	U.S. Postal sevice	DHL
2	TNT (Dutch post)	TNT
3	German mail	Bridges
4	South Korean mail	Kuehne + Nagel
5	China mail	DGF
6	Hong Kong mail	Panalpina
7	Canadian mail	Schanker
8	Italian mail	KLM
9	Japanese mail	UTI
10	Taiwan mail	EGL

In general customers are demanding fast, reliable and cheap transport, but besides these general demands other factors are important. Customers are looking at the professional reputation of an airline as well. Customers will also value the customer service and after sales contact (Interview J.J.G. Maarschalk, appendix R.1). KLM Cargo has a good reputation in the industry; it is displaying expertise and is showing interest in new developments of the supply chain. Of course it has to be possible for a trip to use KLM Cargo as carrier for a shipment; this will be dependent on network configuration, frequency of flights and special handling (live animals) or transport requirements (dangerous goods) in some cases.
Future innovations will take place in the electronic communications with the customers, track & tracing of shipments will gain importance and electronic documentation exchange and billing will grow. The integration project will improve the tracking of mail bags, due to the extra scanning of the bag at the terminal. In this report the effect of the integration on the performance indicators

will have to be determined, changes in the performance will have an effect on the satisfaction of the forwarders.

Shippers

The original shipper of the transport will be the customer of the forwarder. The shipper can be everyone who wants to ship a parcel or mail by plane. Because only registered agents are allowed to deliver cargo to airlines for transport (www.acn.nl, 3-10-2008), the shipper should contact a registered agent. This registered forwarder will organize the transport of the shipment. In this way the airline is not directly communicating with the shipper, unless the shipper is a registered agent itself. The requirements of the forwarders can be seen as a derivative of the shippers' demands.

The dependency on air freight for efficient inventory management in a global economy, as described in sub-paragraph D, has boosted the demand for express products. In general companies using the Just-In-Time (JIT) principle will demand for short delivery times and reliable transport for the lowest price. For mail it will be important that it will arrive on time at the right destination.

Forwarder

Relationships between forwarders and airlines are complex. In the past forwarders acted as licensed agents, selling space for only particular airlines. Although this situation has changed the airlines looked upon forwarders as direct agents, with a paternalistic attitude towards the forwarders. Other airlines see the forwarders as purely consolidators which do not add value to air cargo products and are competing with forwarders for the orders of shippers. The relationship between forwarders and airlines can be characterized as traditionally distrustful and uncooperative (Forster and Regan, 2001). Airfreight forwarders are a very diverse group of companies, varying in size and strategy; this influences their perspectives on the industry.

Relation between forwarder and airline

In this description the relation with an airline is described from the perspective of small and large forwarders.

Small forwarders are competing particularly on service. Infrequent shippers of small volumes of air cargo are often small manufacturers. Small manufacturers should still be able to receive the best air-cargo service from locally based forwarders. For these customers, long-term relationship and trust-based partnerships with a forwarder, the service attributes where local forwarders are positioned best, may be the most important considerations in selecting an air-cargo provider (Schwarz, 2005). Similarly, another niche in which small forwarders hope to succeed is the market for products requiring special handling, such as perishables or hazardous goods.

Small forwarders, focusing on service, are not afraid of the large integrators, because these integrators are targeting large volumes. The small forwarders are afraid of the disintermediation of the air cargo system, which is stimulated by traditional combination airlines like KLM. Although this fear is widely shared between forwarders the share of cargo directly sold by carrier s to shippers is negligible. Forwarders expect the combination carriers to compete with the integrators by evading the forwarders in the supply chain (Schwarz, 2005).

Competition between the small forwarders and the airlines results in a difficult situation for the forwarders, while trying to get a good deal for the cargo they want to transport by the airlines and competing for cargo with the airlines at the same time (Schwarz, 2005).

The competitive strategy of the transnational freight forwarders centre on offering a complete package of value-added logistics services, backed by highly developed information systems. The large forwarders know they have leverage towards the airlines, because they are controlling large volumes. The large forwarders see a threat from integrators, to counterbalance this they want to

improve the partnerships and increase the coordination between transnational forwarders and traditional airlines, in order to compete with integrators and their 'one-stop-shop' business model (Schwarz, 2005). Between the large consolidated forwarders there is a lot of competition because the offered spectrum is similar and therefore interchangeable (Lobo and Zairi, 1999).
Large forwarders emphasise the importance of IT interoperability between the in-house systems of different companies is still a challenge, although it is improving steadily. Communication between forwarders and the airlines will primarily go through electronic channels. Only the largest and best customers, like the multinational forwarders can still expect personal treatment from key account managers at the airline. The electronic communication closes out the cooperative deliberation between forwarders and the airlines, which will in most cases be beneficial to shippers (Schwarz, 2005). Nevertheless the electronic exchange of information between the parties in the industry will become more and more important. Information technology will be the driving force for change. Different initiatives are taken to replace the hard-copy exchange of documents in the supply chain. For example the e-freight project, launched by IATA in 2004, is designed to eliminate the need to produce and transport paper documents for air cargo shipments by using a simpler and industry-wide electronic system (www.iata.org, 1-10-2008). It will be less likely that small forwarders can afford the changes they have to make to adapt to the electronic communication in the business, than large forwarders (Schwarz, 2005).

Forwarders perspective on the integration project
For the project it is important that the forwarders will agree that EQ shipments will not be booked on a certain flight but will be handled using the First-in-first-out (FIFO) principle. For the mail department the possibility to keep better track of the shipments in the integrated situation is an advantage. For the EQ department the efficiency gains could help KLM Cargo to improve their position in the express market, due to reduced costs and possibly a higher operational speed of the handling of shipments.

For airmail the large national postal companies are the forwarding companies between the airlines and the shippers. In this case the position of the forwarders is different than normal. The postal companies are collecting, sorting and distributing the letter mail through for their home markets and this is an activity which will not be easily taken over by competitors. At the moment the postal companies' position is protected by legislation in most countries, this is expected to changes in the near future (www.tntpost.nl, 2-10-2008). After the liberalization of the postal market other parties could join the market for forwarding airmail.
The postal companies are looking for airlines which are able to deliver the mail before de Latest Arrival Time (LAT) for a certain connection. The latest arrival time (LAT) time, this time is set by the national postal services. At that time the postal companies will collect the incoming mail for the last time that day at the air cargo terminal, in order to distribute the mail the next day to the final recipient. The faster the handling the more mail could arrive before LAT.

Integrators

Integrators are offering door-to-door transport to shippers. Integrators own all assets of production including physical assets like trucks and planes, labour assets and information assets (Forster and Regan, 2001). Integrators pursued innovative strategies for infrastructure, product and information technologies. Their customer target group are the shippers of voluminous, valuable and frequent cargo flows. The integrators offer services to a wide range of customers, from private individuals to multinational companies, in the last case the integrators are supporting the supply chain of the manufacturers as a third logistic party in most cases.
For airlines the integrators became important competitors, but often the integrators are important customers simultaneously. The integrators operate their own fleet of aircrafts to transport the cargo between their distribution centres, but the integrators are using the dense network of

airlines to distribute their cargo on other connections with lower volumes. In this way the integrators are supplying cargo to airlines as a customer, but when the integrator can fly profitable on the same connection in the future the integrator will likely become a direct competitor for cargo on the connection.
The bargaining power of the integrator is very strong; everybody would like a share of the large pie they are dividing. Integrators will decide which carrier to use on the basis of costs, after their unconditional requirements on reliability and travel times are met by the airlines.

Integrators perspective on the integration project
The integration project at FB1 will be seen as a project to improve the competitiveness of KLM Cargo towards other airlines and integrators. Nevertheless integrators will probably not see this as a large threat for their own market share because of the relative small scale. At the same time it can improve the service they can offer to their customers when they ship their cargo with KLM Cargo.

C.3.2 Competition

As explained in the previous sub-paragraph, integrators are customers as well as competitors of KLM Cargo. Beside the integrators with their own fleet most direct competitors of KLM Cargo are other airlines which transport cargo to and from Schiphol. On the ground other ground handlers can be competitors for KLM Cargo.

Competitive airlines

Important competitors of KLM Cargo are other cargo carriers; this can be all cargo carriers (Jade, The Great Wall) or combination carriers (e.g. Lufthansa). Being an all cargo carrier allows clear focus on one product unlike other carriers (Lobo and Zairi, 1999). This can be an advantage for the all cargo carriers. At airports, other than their home base, the carriers will use the terminal of local ground handlers, because it is not beneficial to operate an own terminal. The contacts and facilities airlines can use at other airports will determine the service the airline can offer on routes to the forwarders. At Schiphol KLM has a very strong position, because of its size and the variation in the network, KLM can offer the best connections via Schiphol.
For airmail KLM offers good service at Schiphol airport, KLM can make use of capacity on the KLM network and more and more on the Air France network. The ability to sort incoming mail within a short time has attracted large volumes of international mail from postal companies around the world. This together with the fact that KLM is the supplier of air transport to the Dutch postal company TNT, has made KLM market leader for the transport of airmail at Schiphol and made Schiphol an important hub in the airmail network. Not all airlines will have the facilities to sort transit mail.
For EQ and other cargo this hub-function is less strong, because individual shipments will travel more directly from origin to destination. The competition of cargo transport to and from Schiphol is more severe than for mail.

Ground handlers at Schiphol

Other airlines do not have similar ground handling facilities at Schiphol, certainly not for airmail. This implies that KLM will have competitive power for cargo destined or originating from The Netherlands.
KLM Cargo offers the use of facilities at Schiphol to partners in the SkyTeam alliance. Other airlines have to use other ground handlers at Schiphol. Schiphol has various other cargo handlers (e.g. Aero ground, Menzies).
From the transit flows of cargo and airmail airlines can use another airport as transfer point; this will depend on the differences in offered service and price between international airports.

The choice between KLM Cargo and other ground handlers will not be made on basis on the performance of the ground handling, forwarders will choose an airline which can supply the required transport, which ground handler will be used will be a consequence of the choice for an airline.
The performance of the ground handling is integrated in the offer of an airline to the forwarder; indirectly the performance on the ground will have an influence. Therefore the expected improvement of the handling at FB1 due to the integration will be beneficial for KLM Cargo, but the position opposed to other handlers is of minor importance.

Competition with other modalities

Road transport, rail transport and sea shipping can be competing with air transport to and from Schiphol. Road and rail can compete with air transport within Europe, intercontinental transport by air will compete with sea shipping.

Road transport
Road transport is an alternative for air transport within Europe. Air transport is much more expensive, but the gain in travel time is limited within Europe. Trucks can offer door-to-door transport, where air transport will require pre and end road haulage.
In general one can says that within Europe priority mail and express products will be flown, because it will remain faster than road transport and other intra European transport will not be flown, this will be too expensive.
KLM Cargo uses trucks to operate air cargo transport within Europe to other airports. This transport by truck can be executed at low costs and KLM Cargo can offer transport to more airports in Europe than are in the KLM network of air connections. KLM has a logistic partner to perform this road transport. Road transport is also used to collect cargo from around Europe and bring it to Schiphol for departure on a KLM flight.
The increase in costs of flying by legislation or by an increase in the price of jet fuel can push customers towards road transport for intra European transport. The congestion on motorways could be an opportunity for KLM Cargo to gain market share on intra European transport.

Rail transport
Rail transport is not seen as a real competitor for mail or express products by air. The small cargo products are rather transported by road or by plane within Europe. At the moment Schiphol does not have a rail terminal for cargo, there are plans to build one at Hoofddorp in the future (Schiphol, 2007a), but this decision has not been made yet.

Sea shipping
For intercontinental transport it is not possible to use rail and road transport. It is possible to ship the cargo over sea. There is a large difference between sea shipping and air transport in speed and price. Sea shipping is a lot slower, but also much cheaper. In general products with a high value are often transported by air, lower value products with a long delivery time are transported by sea. The different character of the transport limits the possibilities for competition between the modes.
In addition, congestion in ports is another factor, which has limited the booming growth in maritime transport. This saturation represents an opportunity for KLM Cargo (Air France Cargo - KLM Cargo, 2008).

C.3.3 Regulatory bodies

At Schiphol several authorities are influencing the air traffic. Schiphol Airport Group, as airport regulator, will set the landing charges and restrictions on noise and pollution for airlines that want to make use of Schiphol. The Dutch government is legislator for all air traffic in the Netherlands on a higher level. Beside the regulatory bodies at Schiphol the International Air Transport Association (IATA) will set the standards for the air transport industry.

IATA

The international air transport association (IATA) is the global trade organisation for the aviation industry. The IATA is representing the industry and tries to improve the understanding of the industry among decision makers.
Important goal of the IATA is to simplify the business (www.iata.org, 6-10-2008). Introducing electronic communication and documentation for as well passengers as for cargo is one of the main means for IATA to achieve this goal. The label (IATA606(B), see main report paragraph 3.4) that will be used in the integrated situation is introduced by the IATA in order to set an uniform standard in labelling throughout the whole air cargo industry.
Although the integration project in FB1 will not directly have effects on the communicating and documentation between parties in the supply chain, it raises opportunities to exchange more information in the supply chain, because more information will be stored electronically.

Schiphol Airport Group as airport regulator

Schiphol Airport is strongly dependent on transit passengers and cargo. The domestic market base of Schiphol is the Netherlands, which is relatively small. In order to grow Schiphol has to focus on the hub-concept (Schiphol Group, 2003).
The growth of Schiphol is encountering resistance of the surrounding municipalities. The noise and pollution are the main problems of the neighbours of Schiphol and therefore the government has set limitations to the growth of the airport and made arrangement to reduce noise and pollution for the surrounding areas.
Schiphol has chosen the strategy of selective growth to benefit the most of the allowed growth. Schiphol selects proposals for expansion on the basis of the noise and pollution produced by the new flights; this will vary per type of aircraft. Besides noise and pollution the network function of the new flights is important, will the new connection improve the network of Schiphol, attracting new potential cargo and passenger flows.
Schiphol tries to stimulate cargo transport in two ways: create conditions to facilitate the organization function in the logistic supply chain and bring together of activities which strengthen each other in the value chain.
Cargo transport is important for Schiphol for two reasons: cargo will contribute to the cost-effective of links in the network and cargo will be a great stimulus for employment. Around half of the air cargo is transported as combi-transport on intercontinental passenger flights. In this way freight transport contributes to the profitability of those flights and this will be beneficial to the network of Schiphol. Cargo transport will generate employment to a larger extend than passenger transport, especially logistic activities will be stimulated (Schiphol, 2007a).
Air cargo at Schiphol will primarily be intercontinental transport. Within Europe most cargo will be transported by truck. Schiphol is supporting alternatives to increase the share of rail transport; a rail terminal at Schiphol is regarded as an important incentive to enlarge the modal shift for rail.

In the spatial planning of the airport Schiphol has reserved space for the cargo terminals and related activities at Schiphol ZuidOost, a location on the other side of the Kaagbaan (Figure 2). This movement, or so-called JUMP, of KLM Cargo will make room for expansion of the number of gates at Schiphol Centrum (Schiphol group, 2007a).
The "Vliegtaks" (sub-paragraph D) is threatening the competitive power of Schiphol, because flying through Schiphol will become more expensive. Customers will decide to use other airports in neighbouring countries, which decreases Schiphol's growth. The effect of the 'Vliegtaks" will also have a negative effect on the supply side of capacity, while Schiphol will become less

attractive for airlines to use as transit hub. Airlines will reduce the number on flights on Schiphol, which will harm the hub-function of the airport.

Dutch government as legislator of aviation on environmental issues

The Dutch government has introduced the "Vliegtaks" in the Netherlands. In this way they are trying to reduce the use of air transport. The motivation to do this is that air transport is associated with negative environmental effects. At this time (October 2008) the charge applies to passenger transport, but the levy could apply to air cargo in the future.
The Dutch government is still discussing the future growth of Schiphol. Noise and pollution are accompanying growth of the number of flights on Schiphol. The civilians living around Schiphol want the growth of the airport to stop. The growth of Schiphol will on the other side generate employment and economic activity in the Netherlands, especially in the area surrounding Schiphol. In the long term the government should allow growth at Schiphol to make it possible to serve the future demands.

C.3.4 Stakeholders involved in the JUMP

The coordination of the JUMP will be arranged in a negotiation between KLM and Schiphol.

KLM Cargo

KLM is not obligated to make the JUMP to another location and there is no urge to make the move. Nevertheless the movement of the cargo terminal to a new location will offer a unique opportunity to build a "best in class" new hub as well. The key design principles of the new cargo facilities would be: flexibility, simplicity, cost-effectiveness and safety and security (Air France Cargo - KLM Cargo, 2008). On the other hand it will take a large investment to build the new terminal. The JUMP has been postponed multiple times in recent years, because the economic situation does not leave room for investing in a new terminal.

Transportation department

The transportation department has a crucial role in the ground handling of cargo. Schiphol is a large airport and the travelled distances to retrieve cargo from planes can vary considerably. The movement of the terminal of KLM Cargo to another location at the airport premises could have great impact on the travel times of the transport between plane and terminal. At this moment the time between the arrival of the plane and the arrival of the cargo at the terminal can be guaranteed to be less than 60 minutes by transportation.

Schiphol airport

Cargo transport is important for Schiphol for two reasons: cargo will contribute to the cost-effective of links in the network and cargo will be a great stimulus for employment. Around half of the air cargo is transported as combi-transport on intercontinental passenger flights. In this way freight transport contributes to the profitability of those flights and this will be beneficial to the network of Schiphol. Cargo transport will generate employment to a larger extend than passenger transport, especially logistic activities will be stimulated (Schiphol, 2007a).
Air cargo at Schiphol will primarily be intercontinental transport. Within Europe most cargo will be transported by truck. Schiphol is supporting alternatives to increase the share of rail transport; a rail terminal at Schiphol is regarded as an important incentive to enlarge the modal shift for rail.
In the spatial planning of the airport Schiphol has reserved space for the cargo terminals and related activities at Schiphol ZuidOost, a location on the other side of the Kaagbaan (Figure 2). This movement, or so-called JUMP, of KLM Cargo will make room for expansion of the number of gates at Schiphol Centrum (Schiphol group, 2007a).

D Demand for air transport

The demand air freight and travel by air are closely related to consumer confidence and consumer spending (IATA, 2008a). This implies that the demand for air transport is very cyclical and at the same time the industry is very capital-intensive. The forces determining demand are numerous, which makes it difficult to forecast demand (Figure 49). The combination of a volatile demand and a capital-intensive industry incorporate risks, because the costs of the planes for an airline cannot be changed on the short term, because the average economic lifetime of an airplane is more than 10 years (Air France KLM, 2008a, p. 9), while the demand can change drastically. During times of low demand, the airlines have to make sure they do not get stuck with a lot of overcapacity and when demand is high they should have the capacity to meet demand in order not to lose market share to competitors which have sufficient capacity. This will make it very important to predict the future demand, but predicting demand for air transport will be very complicated.

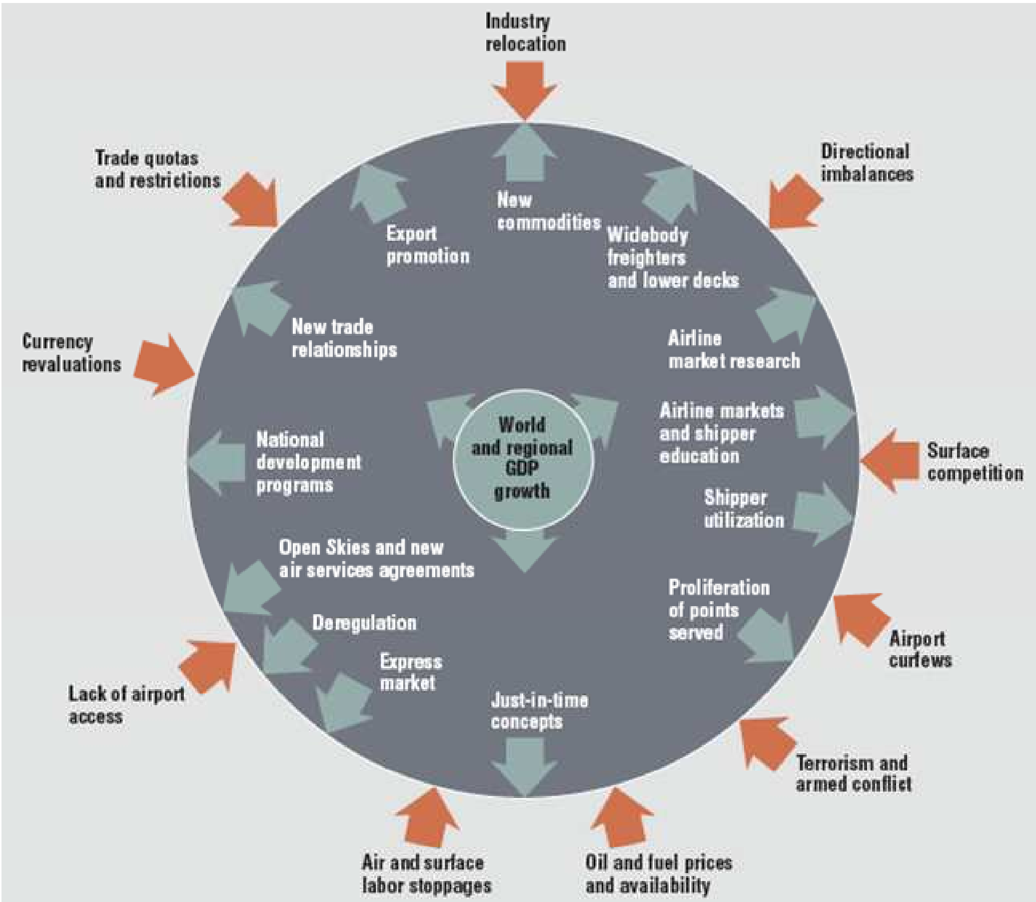


Figure 49: Forces and constraints for air cargo growth (Boeing, 2006, p. 13)

The emergence of low-cost carriers resulted in another challenge for the established airline carriers. The established carriers, which often operate a large hub-and-spoke network, were confronted with low-cost carriers, which offered dedicated point-to-point flights on profitable routes. The low-cost carriers were offering 80% of the service quality at less than 50% of the cost. The success of the low-cost carriers took away market share from the traditional carriers and put the pressure on the profit margins of airliners (Franke, 2003). By means of increasing in scale and consolidation, traditional airlines are trying to realize efficiency gains, in order to improve the market position compared to other alliances and realize additional growth (Schiphol 2007a).

D.1 Recent developments

Besides the fundamental characteristics of the industry, which make it hard to survive as an airliner, there were five other causes for difficulties in the industry in the past decade: the terrorist attacks on the 11th of September 2001 in the US, the SARS epidemic and Iraq war in 2003, expansion of safety measures, the severe rise in oil prices and imposed environmental taxes made surviving even harder for the airliners (Schiphol, 2007a).

The direct cause of the fall in demand in 2000 was an economic downturn combined with large overcapacity in the industry, following on a flourishing period for aviation in the nineties. The terrorist attacks on the 11th of September deepened the existing crisis considerably. The attack by commercials aircrafts on several important buildings in New York and Washington in 2001 changed the landscape for the commercial airliners immensely. Never did an incident have such a severe and sudden impact on the demand (Figure 50). The unexpected events and the following decline in demand caused great problems for airliners, which still incurred the costs of their fleet. Several airlines balanced on the verge of bankruptcy and some did go bankrupt.
In 2003 the SARS epidemic and the start of the war in Iraq caused the demand to fall again for the second time in a short period (Figure 50). In the beginning of 2004 there came an end to the decrease in the demand.

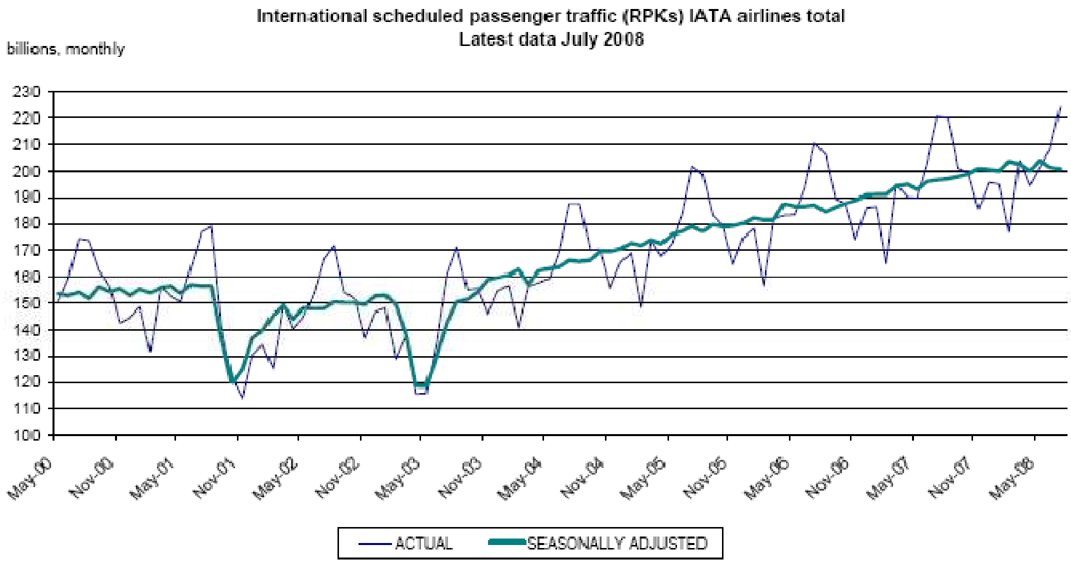


Figure 50: International scheduled passenger traffic (RPK= revenue passenger kilometres), (IATA, 2008b)

The airline industry is very sensitive for developments like the emerging terrorism and epidemics. Protection against these threats will be accompanied by higher costs for safety. After the 11th of September in 2001, safety regulations for air transport became stricter. Airlines were partly responsible for the costs of the new safety requirements. (Schiphol, 2007a)
The costs of jet fuel represented 20,6% (Air France KLM, 2008b) of the total costs for AF/KL. The large increase in the price of oil in the last couple of years has had a negative influence on the demand, because flying became a lot more expensive because of it. At the same time this put the margins in the industry under pressure, because the rise in cost could not be fully passed on to the customers.
The introduction of environmental taxes in many countries contributed as well to the higher price customers have to pay for flying. On 1 July 2008 the Dutch government imposed an extra charge on tickets for passenger transport, the so-called "Vliegtaks". The Vliegtaks is an extra charge on a ticket, which should decrease the use of an aircraft, in that way it should contribute to the avoidance of environmental damage. This charge in the Netherlands is relatively high compared to the surrounding countries (www.fd.nl, 18-9-2007), which is a disadvantage for the carriers

using Dutch airports as their home base. AF/KL, as an airline with a strong position at Dutch airports is arguing that airlines serving the Dutch market are encountering a disproportional disadvantage and that a situation of unequal competition will emerge. Customers will look for possibilities to avoid paying the charge and fly from airports just on the other side of the border, the first passenger numbers are reflecting this already.

D.2 Expectations for the airline industry

Estimates of future demand for air transport are in general be based on macro economic variables like Gross Domestic Product (GDP), exports, imports, unemployment rate, inflation, private consumption and disposable personal income. Estimates of future demand can not only be based on macro economic variables only, it will also depend on several other factors, which will be different around the world: e.g. the price of air travel (e.g. penetration of Low-cost carriers), population growth, demographic changes, network developments, market liberalization and deregulation (Airbus, 2007)(Boeing, 2006, p.13 & 2008). The dependence of demand on various factors can also be used to explain the difference between the forecasts for cargo and passengers demand.

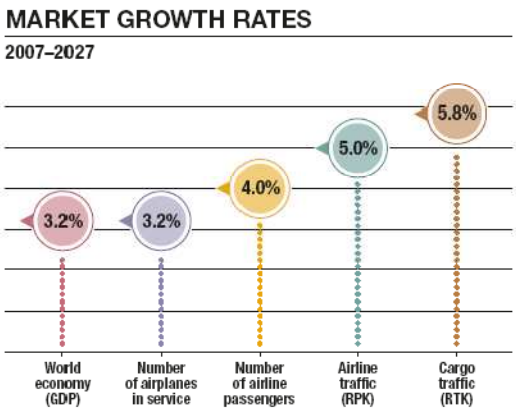


Figure 51: Summary of growth rates in the aviation industry (Boeing, 2008)

The annual growth of passenger transport is estimated on 5.0% worldwide (Figure 2). The annual growth will differ between regions in the world (Table 31). Europe is seen as a mature market with a limited growth potential. The growth worldwide will be higher; the strongest growth will originate from emerging economies, especially from Brazil, Russia, India and China (Schiphol, 2007a).

Table 31: Annual growth of passenger traffic (Boeing, 2008)

ANNUAL TRAFFIC GROWTH

2007–2027 (RPKs)

Regions	Growth
Asia-Pacific, including within China	7.0%
Asia-Pacific, excluding within China	6.2%
Within North America	2.8%
Within Europe	3.5%
Within China	8.9%
North Atlantic	4.7%
Europe to Asia-Pacific	5.7%
Transpacific	5.6%
North America to Latin America	4.8%
Within Latin America	6.7%
Europe to Latin America	4.7%
Within and to Russia and Central Asia	5.3%
Africa to Europe	5.4%
Middle East to Asia-Pacific	5.7%

The global economy demands rapid and reliable business-to-business exchange. Air cargo transport can make such exchange possible. Manufacturers depend on air freight for efficient inventory management and to source components and assemblies from world markets, two logistic elements which have gained importance the last twenty years. The growth of air cargo has been benefiting from recent developments in logistics. Using transport by air can help to reduce inventory and will reduce the time to put product into the market. The reduction of product lifespan in many industries (clothes, computers, pharmaceutical) makes it more important to decrease transport time from manufacturer to the shop. Outsourcing of production building blocks to countries, that passes a comparative advantage in that type of productive activity, stimulates the demand for transport services, and intensifies the search for a more efficient trade regime in international air cargo services (Zhang and Zhang, 2002). Besides the commercial grounds to use air transport, airlines will also provide transportation of even basic commodities in many areas of the world where ground infrastructure is lacking (Boeing, 2008).

Freight demand is driven mainly by economic growth, globalization and trade, but freight is also facing increased competition from other modes such as shipping. Air cargo is expected to grow with 5.8% on average every year (Boeing, 2008). The most dynamic freight markets are those associated with economies that are both fast-growing and rapidly integrating into the global economy (IATA, 2007a).
Interesting aspect of cargo flows is that the flows are unbalanced. In Asia more products are produced, because of the low labour costs, these products have to be transported to Western countries; this transport is often performed by plane. The demand for passenger transport will be balanced, because passengers tend to return to a location. The unbalance explains that rates for cargo transport can differ significantly based on flight direction (Zhang and Zhang, 2002), where they will not differ much per direction for passenger transport.

D.2.1 Future developments for air mail and EQ products

The international express represents 11% of total international air cargo (Boeing, 2006, p.4) . Average international express shipment size grew from 2.7 kg in 1992 to 5.4 kg in 2005, further enlarging the overall express component of international air freight traffic. As businesses continue to expand beyond domestic or close regional markets, the international express sector will continue to grow, although the growth rate will become a more sustainable, long-term rate.
The distinction between express and general air cargo will continue to blur as traditional providers expand their time-definite offerings, air cargo firms consolidate, and postal authorities make inroads as full-fledged logistics providers. Ultimately, the air cargo customer benefits from improvements, increased service options, and lower prices as market pressure brings competing products into the market. The market share of express products s likely to increase, the growth rate of the express products will therefore be higher than the overall growth of air cargo of 5,8% (Boeing, 2008).
The growth of airmail will be below the average market growth. The growth of airmail is strongly correlated to the GDP and less dependent of other variables. The airmail sector is expected to grow with 2,5% per year through 2025 (Boeing 2006, p.16).

E Lay out FB1

E.1 Present layout FB1

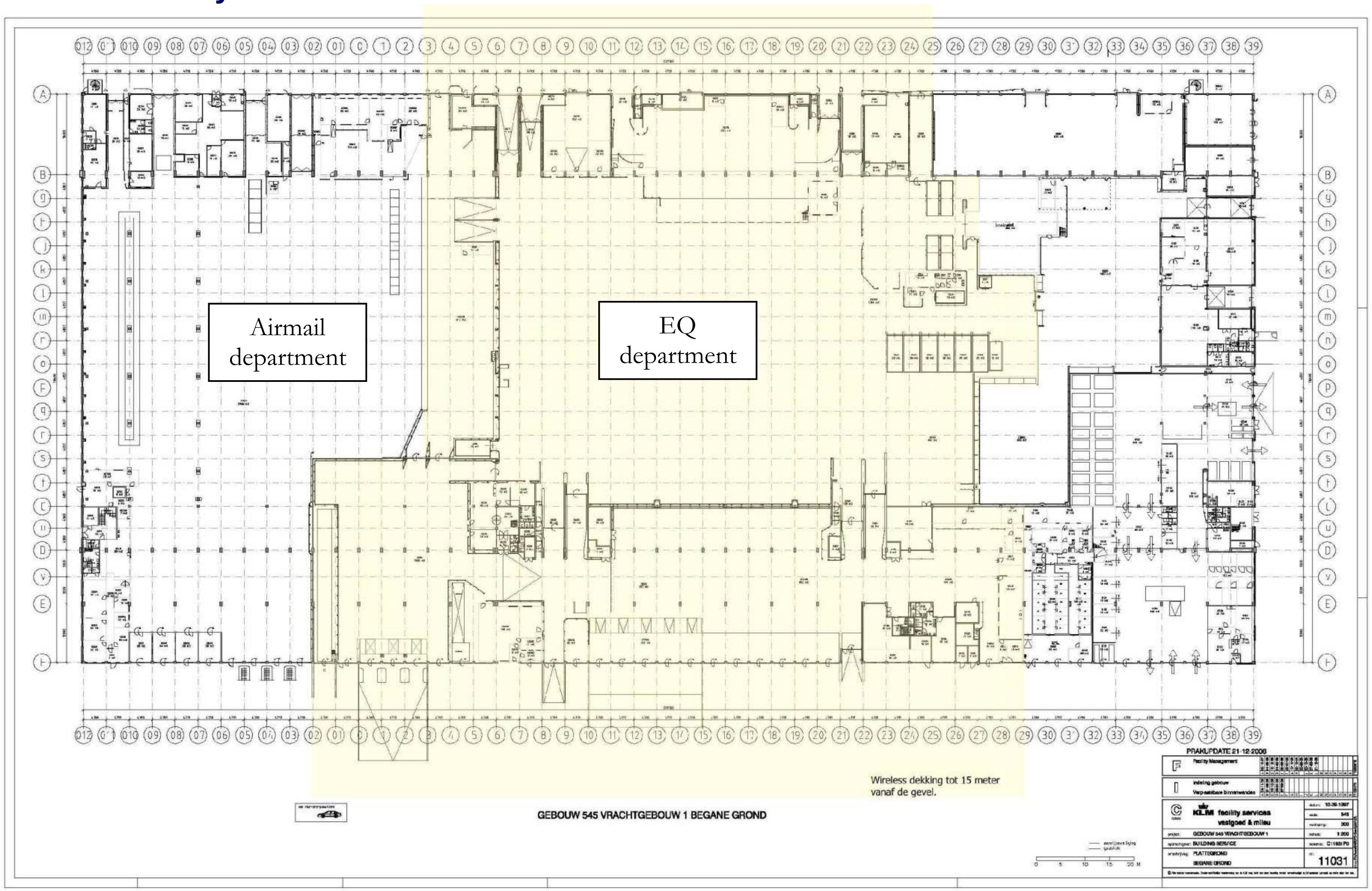


Figure 52: Map of FB1 with the airmail and EQ department (yellow surface)(KLM Cargo)

E.2 Plan of FB1 with future conveyor belt system

This map is placed upside-down on purpose to make it comparable with the map of the current situation (Figure 47 in appendix E.1)

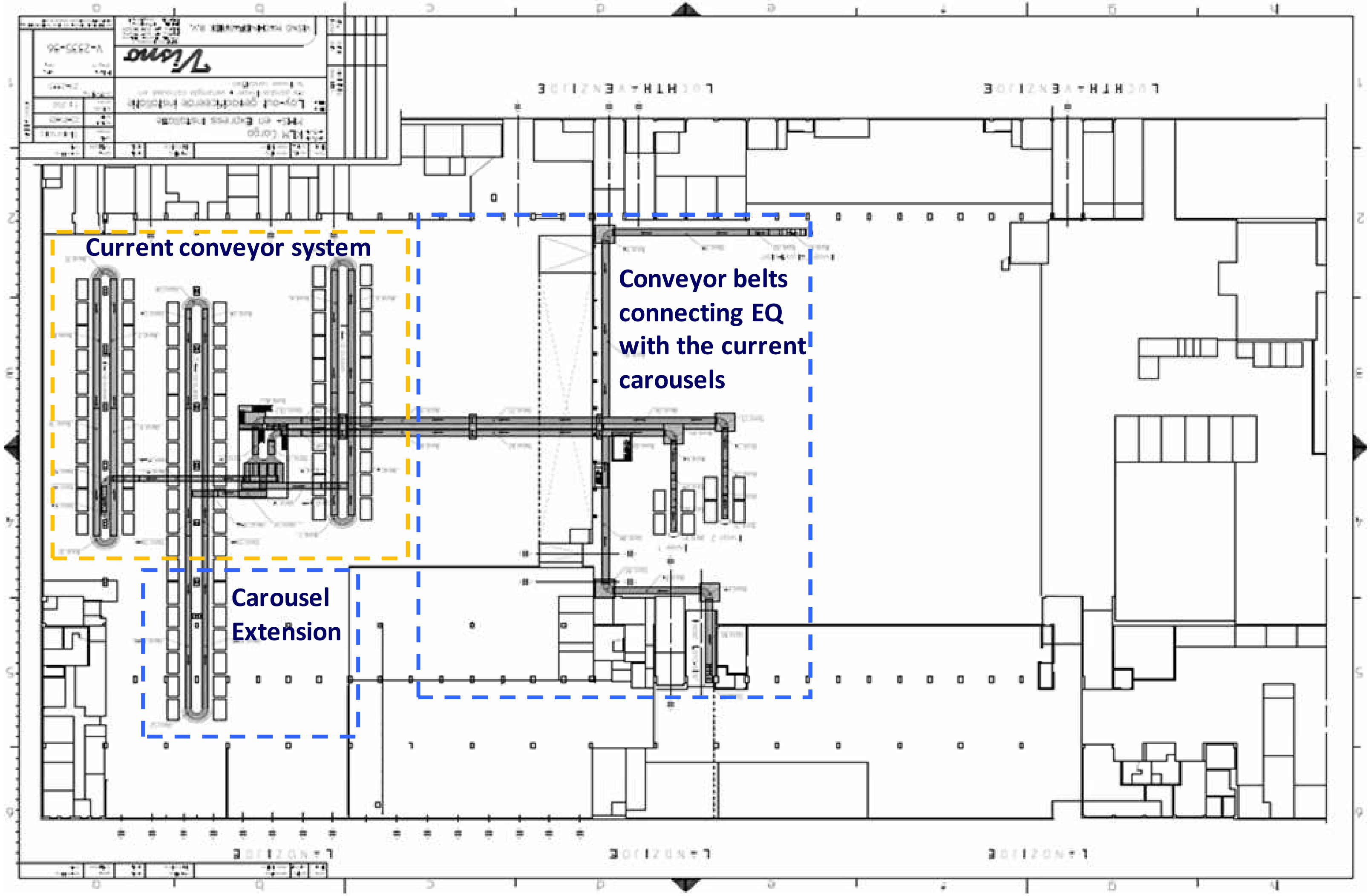


Figure 53: Layout of FB1 with extension (blue squares) of the current conveyor belt system (orange square) (KLM Cargo)

F Via locations for mail from Schiphol

Table 32: Table of destination airports which travel via another airport

Via via for in current mail process	
Code of destination	Code via airport
AKL	KUL
ALY	CAI
AMM	CDG
AMM	AMS
ASM	NBO
AST	ALA
ASU	CDG
AXA	SXM
BAK	IST
BDA	YYZ
BEY	CDG
BGF	CDG
BGI	YYZ
BGW	CDG
BJL	AMS
BJM	NBO
BKO	CDG
BLZ	NBO
BNE	KUL
BOG	CDG
BOR	SIN
BTS	VIE
BUQ	NBO
BWN	KUL
BZV	CDG
CAN	PEK
CAY	CDG
CGN	FRA
CHA	NBO
CHQ	ATH
CKY	CDG
CMB	BKK
CMN	MAD
CMN	CDG
COO	CDG
CTA	FCO
CVT	LHR
DAC	BKK
DAM	DXB
DAM	CDG
DKR	CDG
DLA	NBO
DUR	JNB
EZE	CDG
FAA	cdg
FDF	CDG
FIH	NBO
FNA	NBO
FNJ	PEK
FRU	SVO
FUK	KIX
GBE	JNB
GEO	SXM
GIB	MAD
HAN	KUL
HAV	CDG
HFA	AMS
HRE	NBO
ISB	DXB
ISB	DXB
JED	DMM
JIB	CDG
JIB	DXB
KBL	DXB
KGL	NBO
KHI	DXB
KHI	DXB
KIN	YYZ
KLA	EBB
KTM	DEL

Via via for in current mail process	
Code of destination	Code via airport
LAD	JNB
LBE	NBO
LBV	CDG
LCA	ATH
LFW	CDG
LFW	ACC
LIN	MXP
LJU	VIE
LLW	NBO
LPB	
LUN	NBO
LUX	AMS
MAA	DEL
MAA	DEL
MAI	CDG
MAR	FCO
MBA	NBO
MEL	KUL
MFM	HKG
MGQ	DXB
MIA	SFO
MLW	NBO
MMA	CPH
MPM	JNB
MRU	JNB
MSQ	WAW
MSU	JNB
MTS	JNB
MVD	CDG
NAP	FCO
NDJ	CDG
NIC	LCA
NKC	CDG
OUA	CDG
OXB	AMS
PAP	SXM
PAP	JFK
PER	KUL
PNH	KUL
POS	SXM
PPT	CDG
PSA	FCO
PSD	CAI
PTP	CDG
RAI	LIS
RGN	KUL
RIO	CDG
RUH	FRA
RUH	DMM
RUN	CDG
SEZ	NBO
SJJ	VIE
SJO	MAD
SJO	PTY
SOF	CDG
SYD	KUL
SYD	NRT
TAS	IST
TER	LIS
TIA	ATH
TIP	FCO
TLL	HEL
TLV	AMS
TLV	FRA
TMS	LIS
TNR	CDG
TUN	CDG
VNO	AMS
VTE	BKK

G Photos of equipment and activities at KLM Cargo

Figure 54: Belly wagon with airmail (KLM Cargo)

Figure 55 Scanning mail with fingertip scanner (KLM Cargo)

Figure 56: Sorting mail at sorter table (KLM Cargo)


Figure 57: Forklift truck (taken in FB1 Dec '08)


Figure 58: Spijkstaal or "Hond" (taken in FB1 Dec '08)

Figure 59: Dolly with AKE on the weighbridge (taken in FB1 Dec '08)

H Required output

H.1 Output of the simulation model

In Table 33 the format of the output files of the EQ and airmail department for the base model are displayed. After the integration the characteristics of the small EQ are registered at the mail department as well and therefore output file will be extended with some unique EQ characteristics.

Table 33: Output of entity details for EQ and mail department

Entity	EQ shipment
Attribute	entity_id
Attribute	product_type
Attribute	flow_code
Attribute	AWB
Attribute	pieces_AWB
Attribute	weight_AWB
Attribute	volume_AWB
Attribute	origin
Attribute	destination
Attribute	incoming_carrier_code
Attribute	incoming_flightnr
Attribute	incomingATA_month
Attribute	incomingATA_day
Attribute	incomingATA_hour
Attribute	incomingATA_minute
Attribute	outgoing_carrier_code
Attribute	outgoing_flightnr
Attribute	outgoingATD_month
Attribute	outgoingATD_day
Attribute	outgoingATD_hour
Attribute	outgoingATD_minute
Attribute	incomingULD_type
Attribute	incomingULD_id
Attribute	outgoingULD_type
Attribute	outgoingULD_id
Attribute	nr incoming ULD
Attribute	missed_booking
Attribute	eq_flight_index
Attribute	final_flight_index
Attribute	time_actual_ATA
Attribute	time_incoming_lat_at_FB2_3
Attribute	time_arrival_at_temp_storage
Attribute	time_arrival_at_BD
Attribute	time_at_bellywagon
Attribute	time_collected
Attribute	time_arrival_at_weighbridge
Attribute	time_arrival_at_transportation
Attribute	time_arrival_at_plane
Attribute	time_arrival_at_FB2_3
Attribute	time_import_available_for pickup by customers
Attribute	time_processed_cargo
Attribute	time_of_removal
Attribute	location_removal
Attribute	nr_AWBs_on_TULD
Attribute	STD_month
Attribute	STD_day
Attribute	STD_hour
Attribute	STD_minute
Other	Replication number

Entity	Mail receptacle
Attribute	entity_id
Attribute	product_type
Attribute	flow_code
Attribute	AWB
Attribute	pieces_AWB
Attribute	weight_AWB
Attribute	volume_AWB
Attribute	origin
Attribute	destination
Attribute	incoming_carrier_code
Attribute	incoming_flightnr
Attribute	incomingSTA_month
Attribute	incomingSTA_day
Attribute	incomingSTA_hour
Attribute	incomingSTA_minute
Attribute	outgoing_carrier_code
Attribute	outgoing_flightnr
Attribute	STD_month
Attribute	STD_day
Attribute	STD_hour
Attribute	STD_minute
Attribute	incomingULD_type
Attribute	incomingULD_id
Attribute	outgoingULD_type
Attribute	outgoingULD_id
Attribute	mail_flight_index
Attribute	final_flight_index
Attribute	tot_volume_dest1
Attribute	tot_volume_dest2
Attribute	tot_volume_dest3
Attribute	carousel
Attribute	whole round
Attribute	time_actual_ATA
Attribute	time_arrival_at_FB1_mail_department
Attribute	time_arrival_at_input
Attribute	time_arrival_switching_table
Attribute	time_arrival_carousel
Attribute	time_arrival_belly_wagon_along_carousel
Attribute	time_collected
Attribute	time_arrival_at_weighbridge
Attribute	time_arrival_at_transportation
Attribute	time_arrival_at_plane
Attribute	time_processed_cargo
Attribute	time_of_removal
Attribute	location_removal
Attribute	missed_booking
Other	Replication number

Table 33, Table 34 and Table 35 display the information from the simulation model on the flight details of both flight carrying EQ and flight carrying mail.

Table 34: Output of flight details for EQ department

EQ flights	Model variable or attribute	Row	column
Attribute	flight_index	-	-
Variable Array (2D)	flight details	eq_flight_index	opened or closed flight
Variable Array (2D)	flight details	eq_flight_index	T_opening
Variable Array (2D)	flight details	eq_flight_index	T_closing
Variable Array (2D)	flight details	eq_flight_index	Volume storage yard
Variable Array (2D)	flight details	eq_flight_index	Weight storage yard
Variable Array (2D)	flight details	eq_flight_index	Nr_of pieces storage yard
Variable Array (2D)	flight details	eq_flight_index	Nr_of_AWBs storage yard
Variable Array (2D)	flight details	eq_flight_index	Nr of wagon required storage yard
Variable Array (2D)	flight details	eq_flight_index	Volume total
Variable Array (2D)	flight details	eq_flight_index	Weight total
Variable Array (2D)	flight details	eq_flight_index	Nr_of pieces total
Variable Array (2D)	flight details	eq_flight_index	Nr_of_AWBs total
Attribute	time_generation_dep_flight	-	-
Attribute	flight_departure	-	-
Attribute	departing_flight_destination	-	-

Table 35: Output of flight details for mail department

Mail flights	Model variable or attribute	Row	column
Attribute	flight_index	-	-
Variable Array (2D)	flight details mail	flight_index	Volume storage yard
Variable Array (2D)	flight details mail	flight_index	Weight storage yard
Variable Array (2D)	flight details mail	flight_index	Nr_of pieces storage yard
Variable Array (2D)	flight details mail	flight_index	Nr_of_AWBs storage yard
Attribute	time_generation_dep_flight	-	-
Attribute	flight_departure	-	-
Attribute	departing_flight_destination	-	-
Attribute	departing_flight_destination2	-	-
Attribute	departing_flight_destination3	-	-

Table 36 displays the output file of the utilization rates of the employees at the freight building.

Table 36: Output of resource utilization for both departments

EQ department	Functions	Mail department	Functions
Scheduled utilization	hr_eq_checker	Scheduled utilization	hr_mail_unload
Scheduled utilization	hr_eq_bring_away	Scheduled utilization	hr_mail_scanning
Scheduled utilization	hr_eq_break_down	Scheduled utilization	hr_mail_switching
Scheduled utilization	hr_eq_weigh_opening	Scheduled utilization	hr_mail_carousel_EUR
Scheduled utilization	hr_eq_weighbridge	Scheduled utilization	hr_mail_carousel_ICA
Scheduled utilization	hr_eq_export_acceptance	Scheduled utilization	hr_mail_carousel_USA
Scheduled utilization	hr_eq_lateral_sorter	Scheduled utilization	hr_mail_weighing_EUR
Scheduled utilization	hr_eq_lateral_driver	Scheduled utilization	hr_mail_weighing_intercontinental
Scheduled utilization	equipment_eq_weighbridge	Scheduled utilization	equipment_mail_weighbridge

I IDEF-0 Diagrams

In this appendix the A0 diagram (Figure 60)of the current mail handling process is worked out in more detail. This description will follow the numbering of processes in the first decomposition of the A0-diagram (Figure 61). Per process the different sub-processes, transformations of input to output, required resources and controls will receive attention (For lower level diagrams, see appendix I.1).

I.1 Mail department

A0 diagram of mail handling

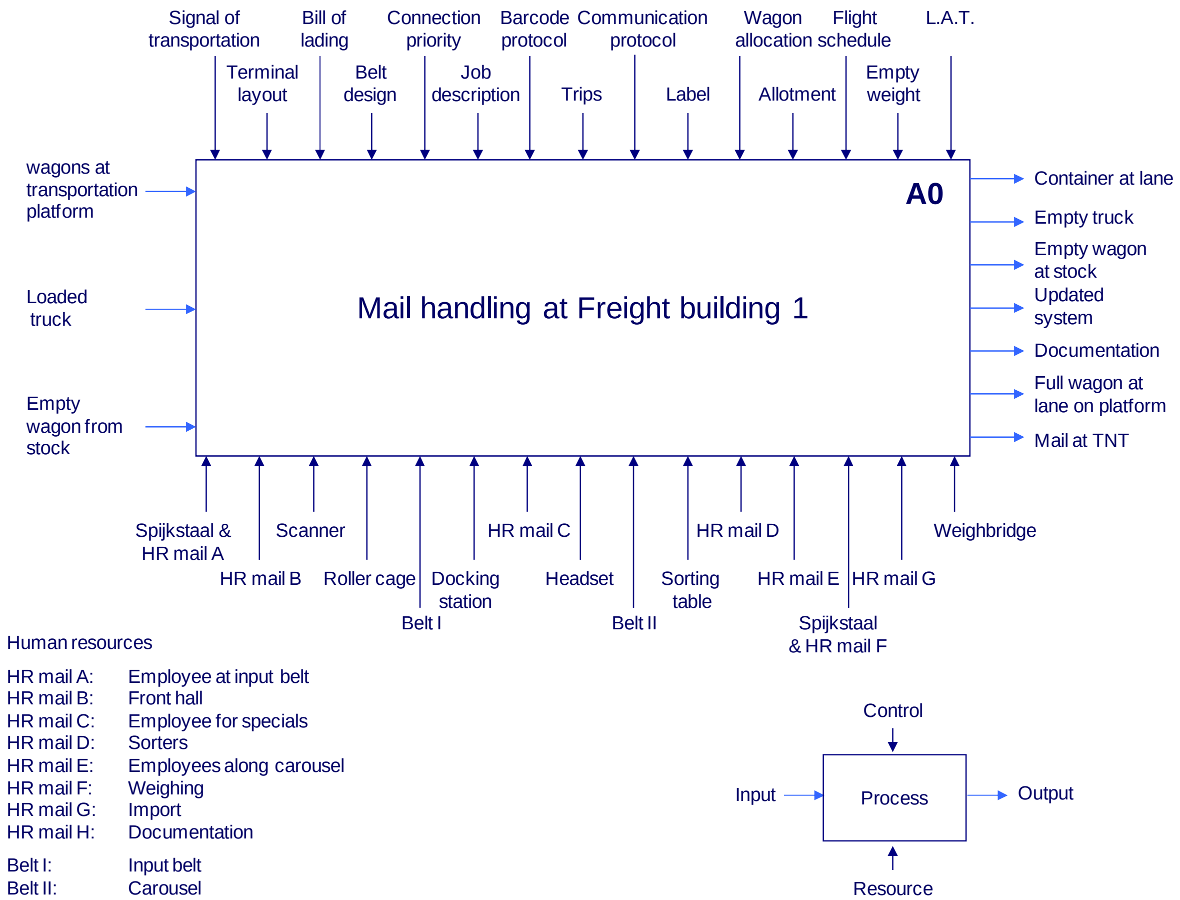


Figure 60: A0 diagram of mail handling, summarizing IDEF-0 diagrams of mail

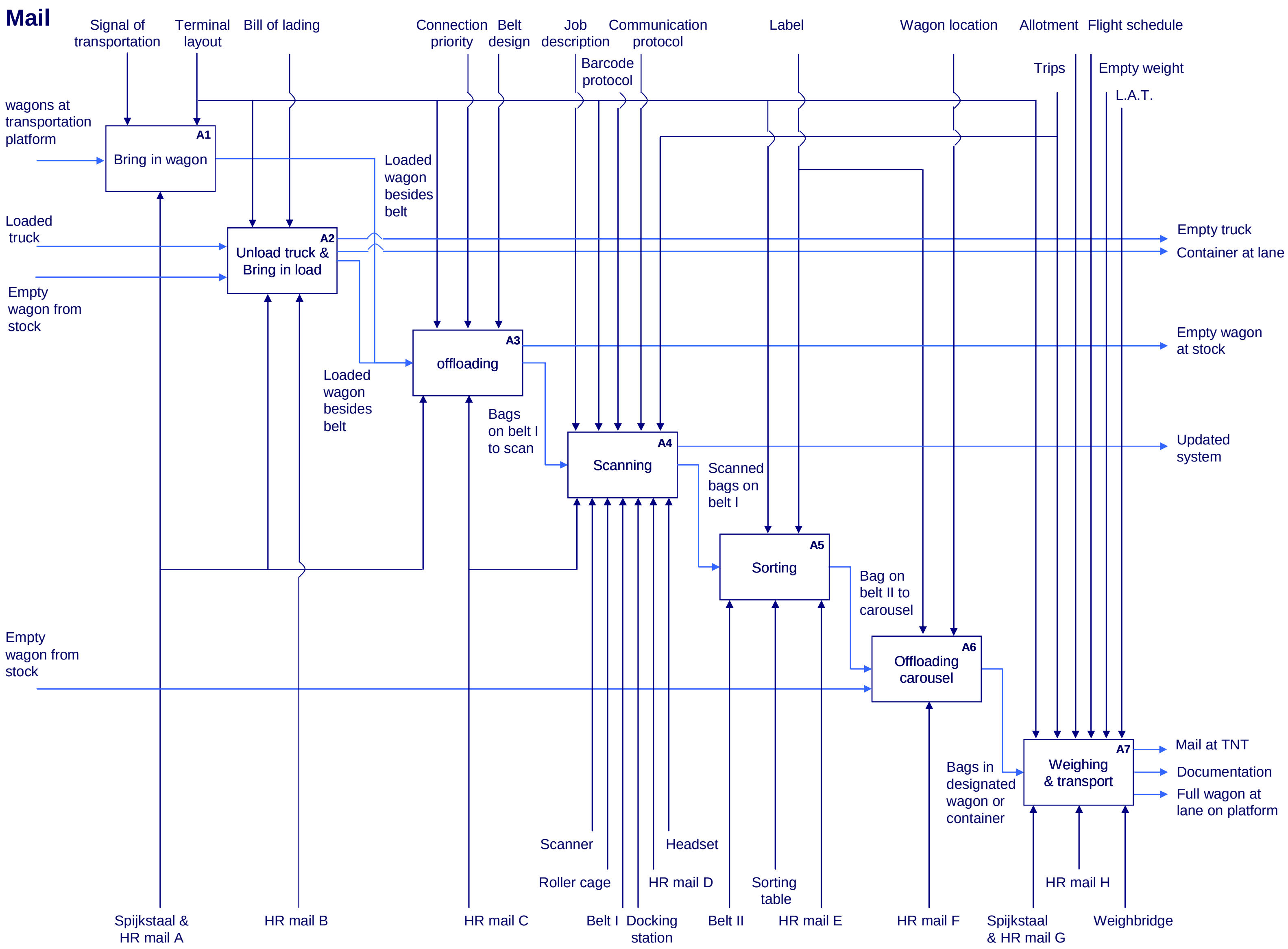


Figure 61: First decomposition of the A0 diagram of mail handling

A1. Bring in Wagon

At the mail department the cargo is brought in by the employees of the department itself (A11). The mail department is at this moment strictly separated from other activities. TNT, the Dutch postal company can pick up and deliver domestic mail to and from the platform at the airside of the terminal, because it has a distribution centre on the Schiphol premises itself. The majority of the incoming mail will arrive at the airside of the FB1; an exception will be the mail arriving per truck at FB1 (A2). Once the belly wagon with arrived mail is dropped off by TNT or by the transportation department at the airside of the terminal, the airmail employees can pick-up the mail with a Spijkstaal vehicle. The arrival pattern of the mail will resemble the flight schedule of the relevant planes, only a certain time later.
Once there is room for a loaded belly wagon with incoming mail at the input locations besides the conveyor belts it will be positioned along the belt (A12). When the wagons are brought in as a train, it will be necessary to reposition the train before the unloading of a new wagon can begin.

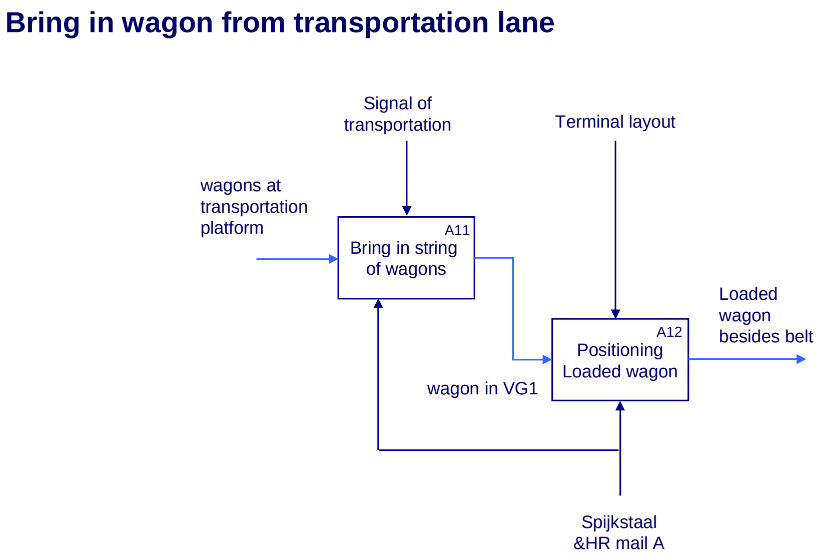


Figure 62: Mail activity A1 in detail: bringing in belly wagons from transportation

A2. Unload truck & bring in load

Trucks are arriving with mail from three other airports in Europe (Brussels, Frankfurt and Rotterdam) during the morning shift. In the morning shift a dedicated airmail employee will handle the acceptance and unloading of this cargo (A21). This cargo will be brought in batched on an ULD: this can be aviation pallets, roller cages or aviation containers. Sometimes it will be necessary to transfer loose bags onto an empty belly wagon. The unloading of mail is done at the landside at often at the EQ department, because the facilities to unload a truck are better over there.
Once there is room for the ULD's at the input locations an employee of the mail department will retrieve the loaded wagons and will position them along the belt for offloading (A22).

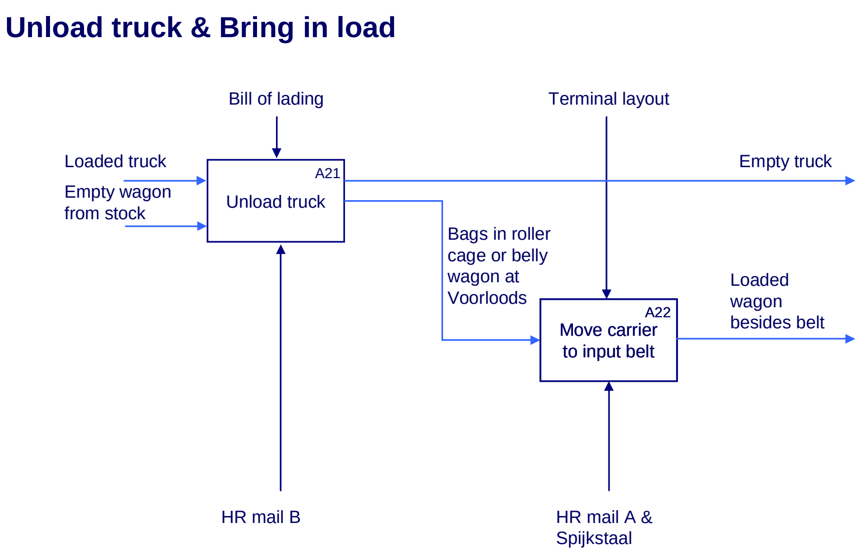


Figure 63: Mail activity A2 in detail: Unload truck and bring in load

A3. Offloading

The wagons with mail are now located besides the entry points of the conveyor belt system (after activities A12 and A22), ready for unloading. In general the wagons will be unloaded according to the FIFO principle, but when the employees know that mail on a specific wagon has a short connection time the wagon will receive priority treatment.

The unloading is in most cases done by one employee which takes the bag out off the wagon and places it on the moving belt, which will transport the bags to the employee with a scanner downstream. The same type of employee (HR Mail A) will remove the empty wagons form the input location and will bring it to the empty wagon storage (Figure 8, nr. 21) outside the terminal or besides the EUR carousel depending on the available space besides the carousel.

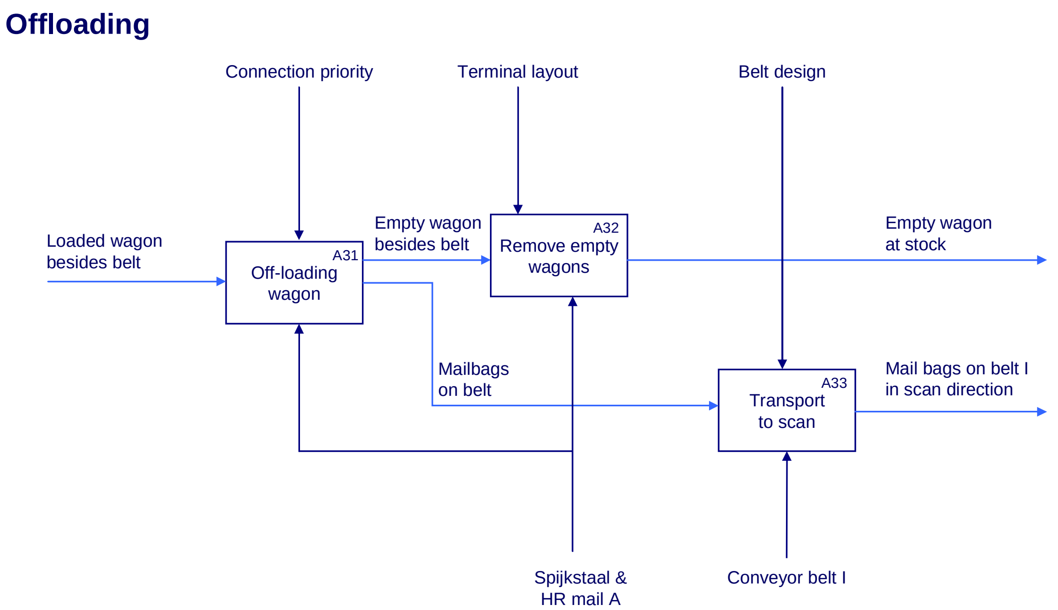


Figure 64: Mail activity A3 in detail: Offloading of belly wagons at input location

A4. Scanning

The bag will travel to the employee with the scanner on the conveyor belt after it is put on there. The employee with the scanner (also HR mail A) will try to scan the UPU-label of the mailbag, at this point the process can continue in three ways.

When no label is on the bag or when the bag is damaged the bags are put in a special roller cage (A42). The bags which will end up in the roller cage are investigated at a special office by trained employees (HR mail C) in order to retrieve the destination of the bags. When the destination is determined a new label is put on the package and the bag is brought to the input belt.
When the label is present and in a good state the employee with the scanner can scan the bag when it comes along on the conveyor belt. The collected information of the scanning of labels will be saved on the scanner. After unloading several belly wagons the employee with the scanner will have to bring in the scanner and upload the data in order to update the data in Trips for the electronic communication to the receiving airport handler.
The third and last option to continue the handling is when the label is present, but cannot be scanned, this can for example be due to small damage or because is applied partly double folded. In this case the label is registered manually, which means that an employee will read out loud the information on the label through the headset. In the office this information is received and an employee in the office will make sure the information in saved in the database of Trips.

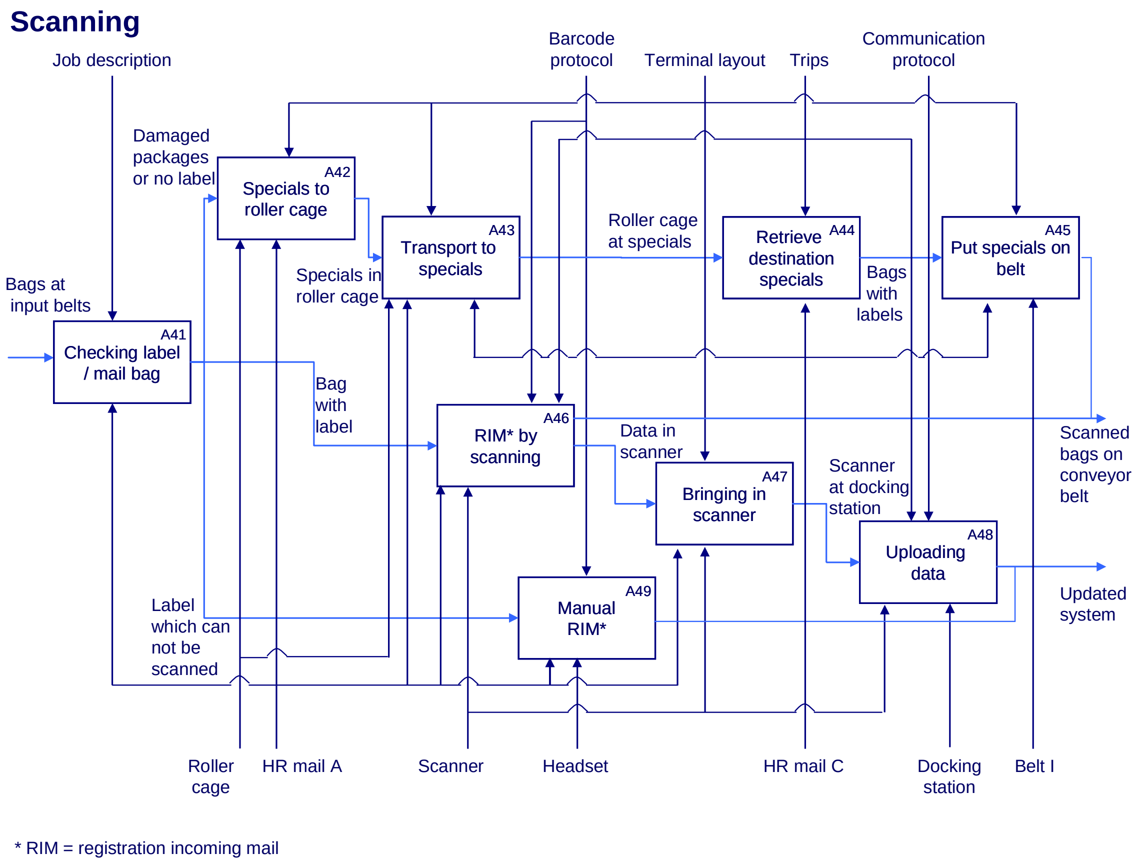


Figure 65: Mail activity A4 in detail: Scanning of mail bags

A5. Sorting

The bags are transported to the sorting location after they are scanned and thus registered. At the sorting location the employee will look for the destination on the labels of the bags and will determine which of the three carousels has a wagon besides it designated for that destination.
At the sorting location, employees are sitting along the belt besides a sorting table in the belt system (see appendix 0, Figure 56 p. 146). The bolt in the surface of the sorting table makes it easy to move the bags vertically. In this way he can push the bags to one of the three belts going to the one of the carousels after he has determined what the right carousel is.

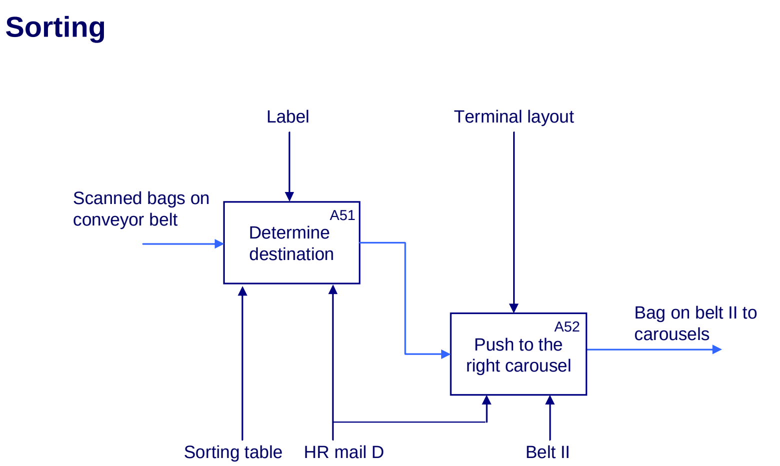


Figure 66: Mail activity A5 in detail: Sorting of mail bags at the switching location

A6. Offloading carousel

Along the carousel there are employees walking from one end to the other checking the labels of the bags coming along on the carousel. They are matching the destination of the belly wagons besides the carousel with that of bags on the carousel.
Most of the time the employees will wait between two belly wagons and put the bags with the same destination in the wagon one after another. But this strategy will not work properly when there is a small number of bags on the belt, in that case the employees should move more pro-active along the belt matching bags and wagons.
To be able to put mailbags in the belly wagons the wagons have to be placed along the carousel. This is done by the employee who is weighing the outgoing mail of that carousel. It is often possible to bring in empty wagons from outside during the same trip as the delivery of loaded departing wagons at a lane of transportation.

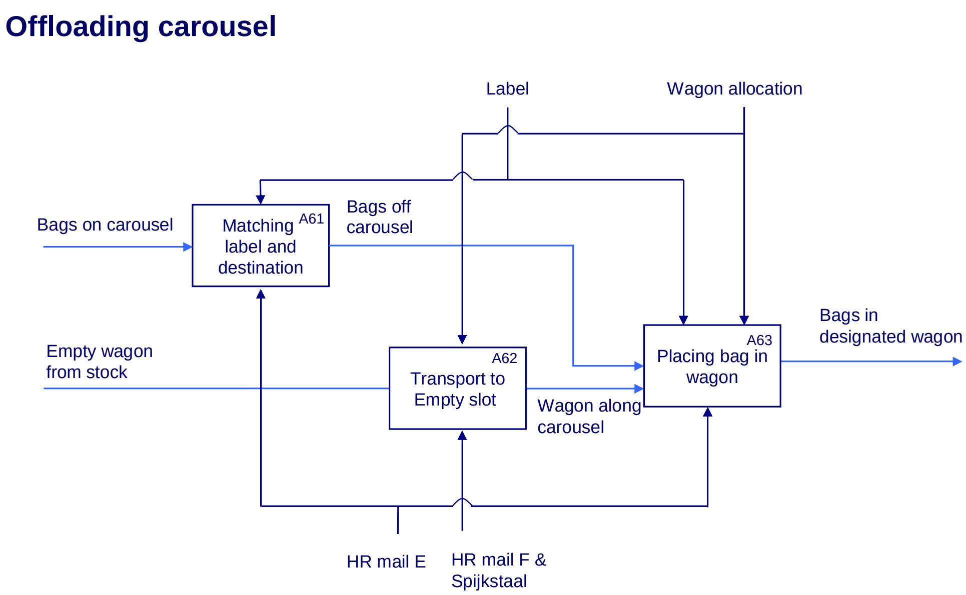


Figure 67: Mail activity A6 in detail: Offloading bags from the carousels

A7. Weighing & transport

A certain period before the departure of a flight the belly wagons along the carousel for that flight will be collected by the employee responsible for the weighing of the outgoing mail for that carousel.

In general the employee will collect a train of wagons, with a maximum of 6 wagons, which are all leaving around the same time. The wagons in the train can have different destinations. The train is moved to the weighbridge and all wagons are individually weighed. The weighed weight of the wagons is compared to the allotment, the reserved weight for mail in a plane, when these numbers are comparable the wagons are transported to a lane at the transportation department. The location of the train and the destinations of the wagons will be communicated with the transportation department by the driver.
The employee collecting the train will have to take the gate of the corresponding flights into account. The wagons destined for the furthest gate, will be hooked on to the Spijkstaal vehicle first, followed by the second furthest and so on. In this way the drivers of transportation can also unhook the wagon at the end of the train on their way to the farthermost gate.
Sometimes a wagon is collected even earlier than the normal period before flight departure. In those cases the allotment for airmail on that flight will be limited and the wagon for the destination is weighed and moved outside when the weighed is reaching the allotment. Other mail for that destination on will be put on a new wagon along the carousel and will have to wait for the next flight(s).
The import mail will not be compared to an allotment, because the load will not fly. The import mail is transported via the airport platform to the TNT terminal at the airport grounds, "CAS" by HR Mail G.

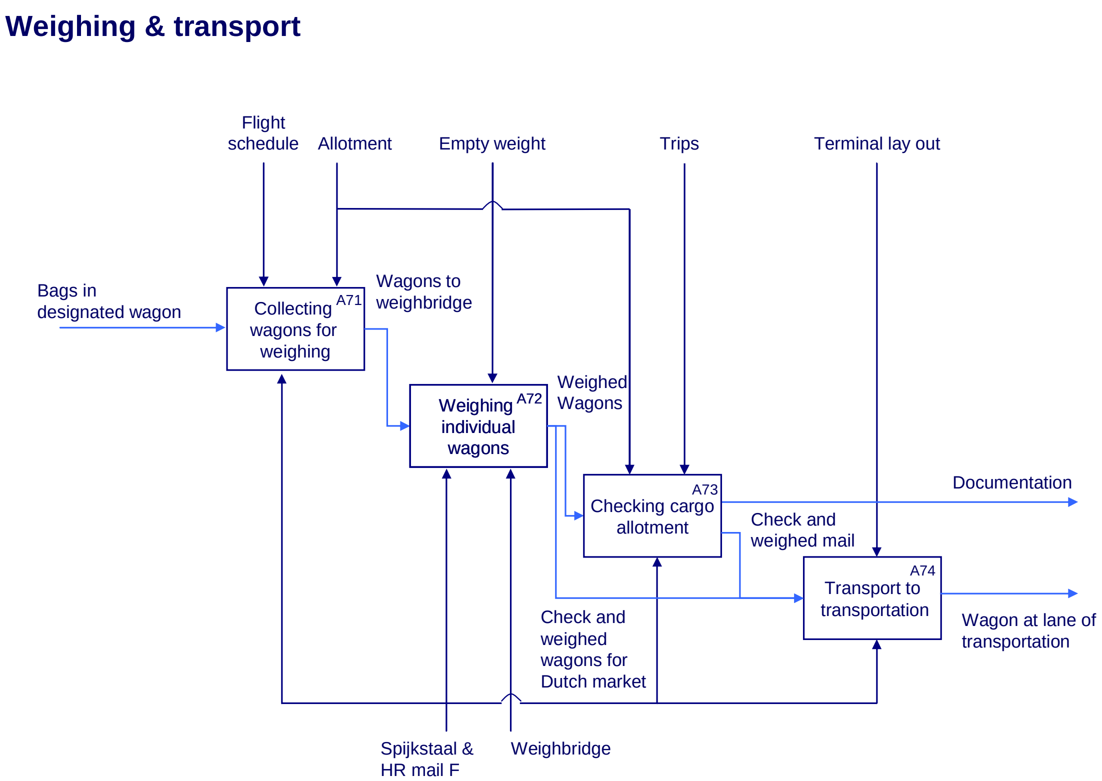


Figure 68: Mail activity A7 in detail: Weighing and transport of departing mail bags

I.2 Equation department

In this appendix the A0 diagram (Figure 69) of the current EQ handling process is worked out in more detail. This description will follow the numbering of processes in the first decomposition of the A0-diagram (Figure 70). Per process the different sub-processes, transformations of input to output, required resources and controls will receive attention

A0 diagram of EQ handling

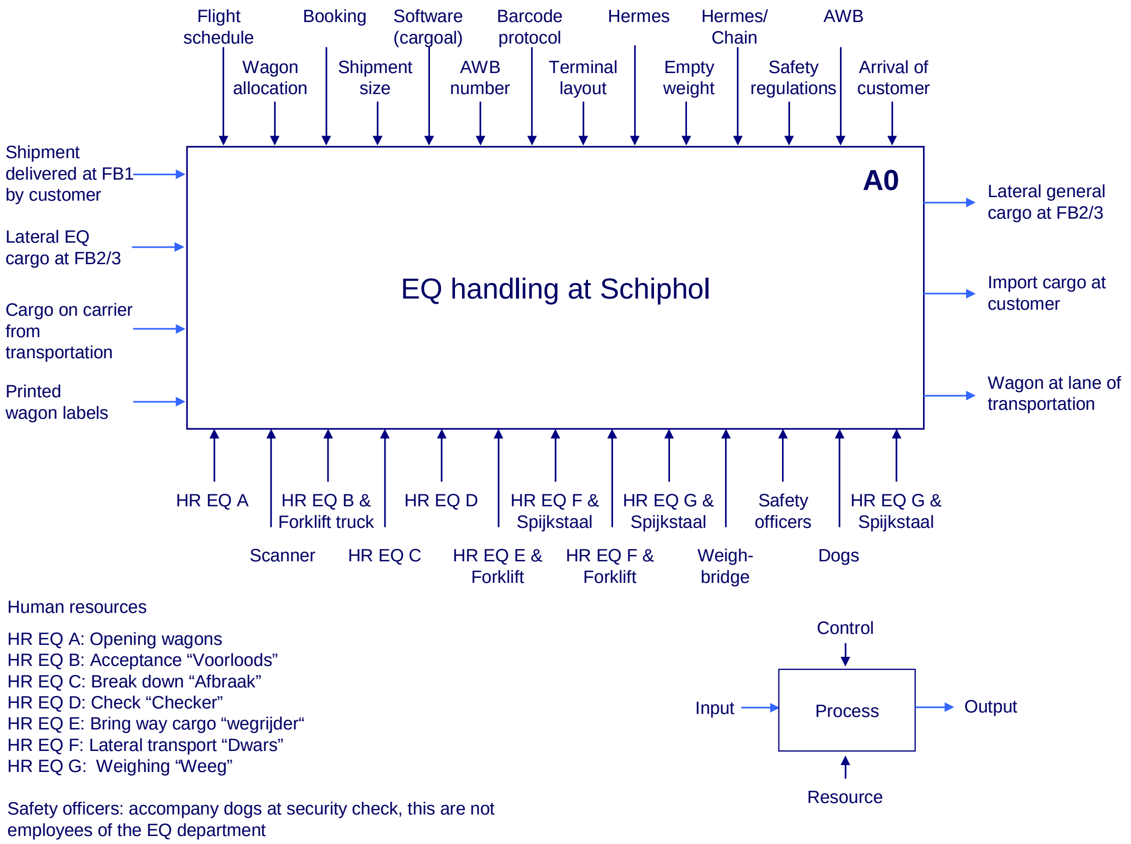


Figure 69: A0 diagram of EQ handling, summarizing IDEF-0 diagrams of Equation

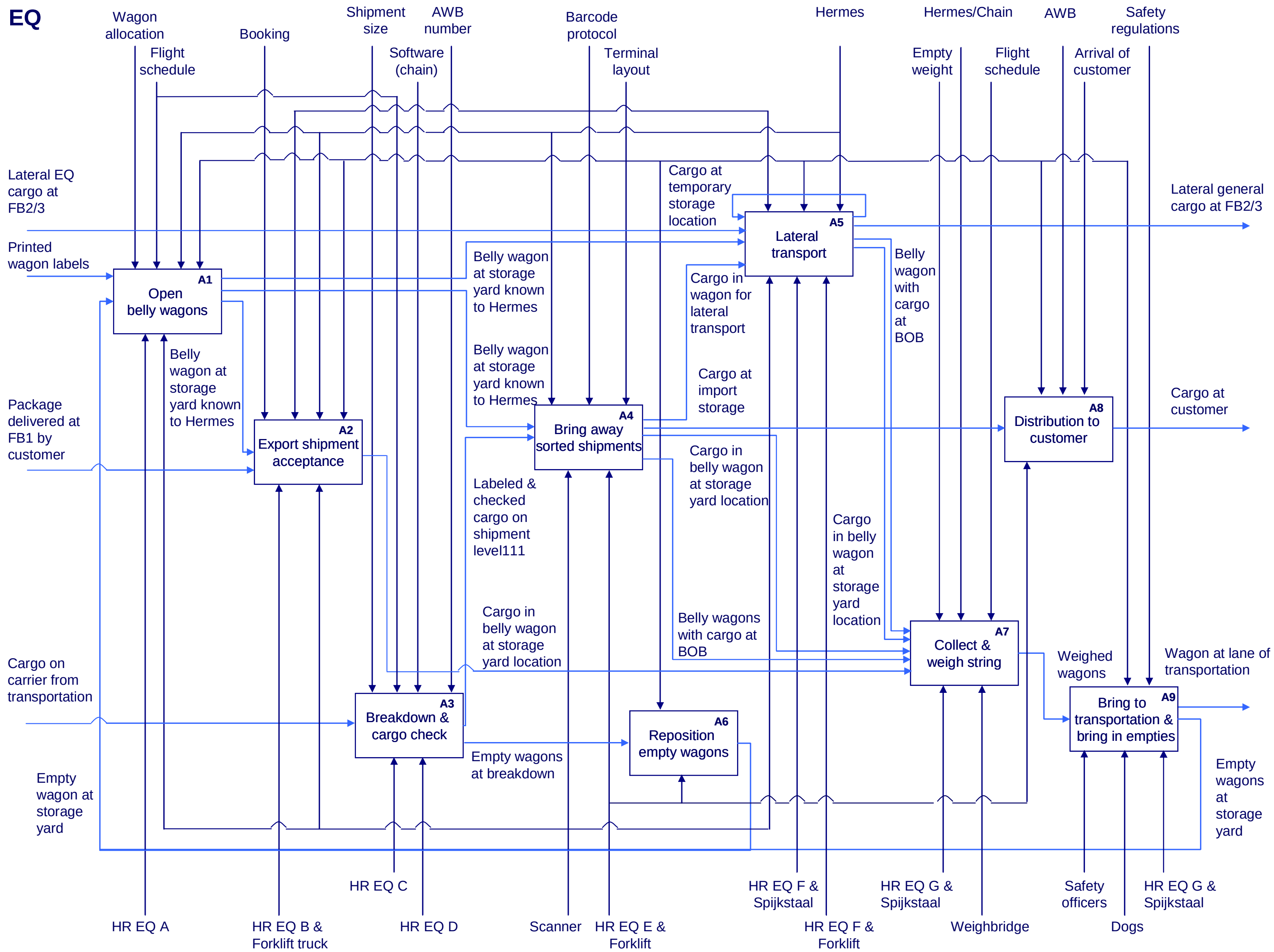


Figure 70: First decomposition of the A0 diagram of EQ handling

A1. Open belly wagons

In the hall of the EQ department there are 144 possible positions for belly wagons, which can all be linked to a flight departing in the near future. The EQ products booked on this flight will be collected in the wagons.

To make the collection of cargo in the belly wagons possible it is required to have a wagon at the storage yard which is linked to a specific flight. This is the responsibility of HR_EQ_A. He will put labels on the wagons stating the destination, flight number, and departing time. These labels will have to be printed for the next departing flight, which are not yet linked to a wagon. A unique barcode is also placed on the label; with the barcode it is possible to identify the wagon with a scanner.

When the label is ready the employee will walk to empty wagons (not dedicated to a flight yet) at the storage yard and will place the label on the wagon. After the label is placed the employee will use a handheld scanner to scan the wagon and link the empty wagon to a flight. From now on the wagon is allocated to a flight and the wagon will be available through the software (screen dump of wagon allocation at EQ, see appendix J)

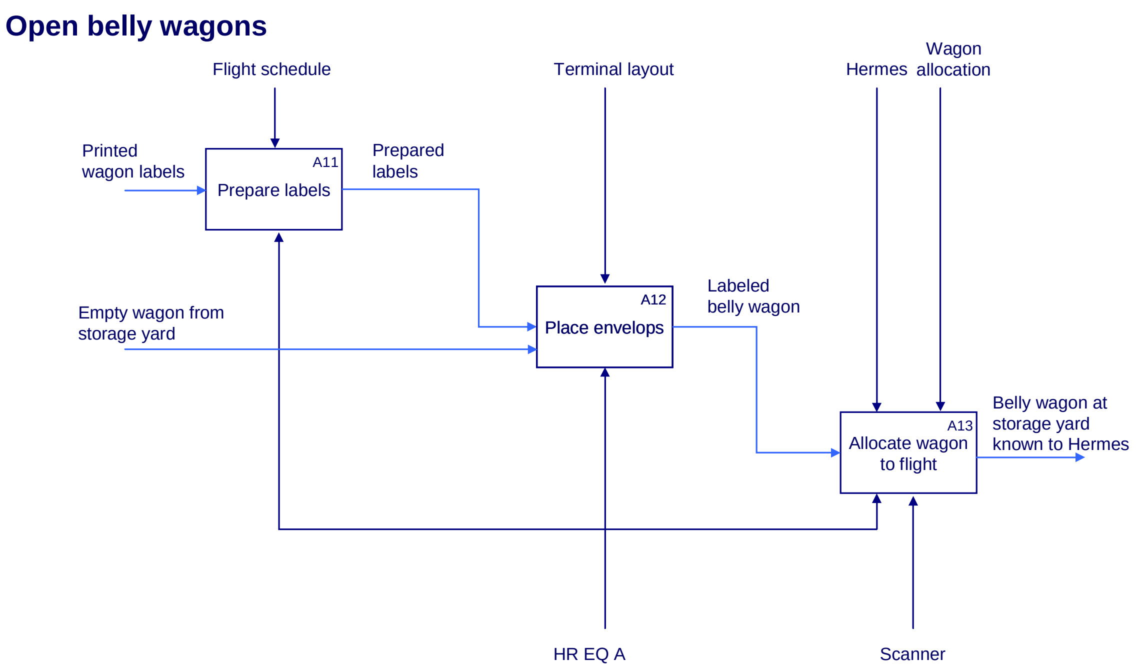


Figure 71: EQ activity A1 in detail: Open belly wagons

A2. Export shipment acceptance

When a customer arrives at the landside of FB1 it will go into the office to confirm the booking. The KLM employee in the office (outside diagrams) will place a paper with a barcode ready for HR_EQ_B at the door for acceptance.

HR_EQ_B will check the cargo of the customer and will label the packages with a barcode sticker. By scanning the barcode on the applied label on the package and the barcode on the paper (given by the employee in the office), the employee can link the available data in the warehouse software to the barcode on the package and in the display of the scanner the next location is showed to the employee. Now the employee can bring away the packages to the next location with a forklift truck. The next location can be a belly wagon at the storage yard, linked to a flight, or it can be a temporary storage location, when the belly wagon for the booked flight is not place and known yet to the warehouse software. At the new location the employee will use the scanner to scan the package and the barcode of the new location and link the two to each other.

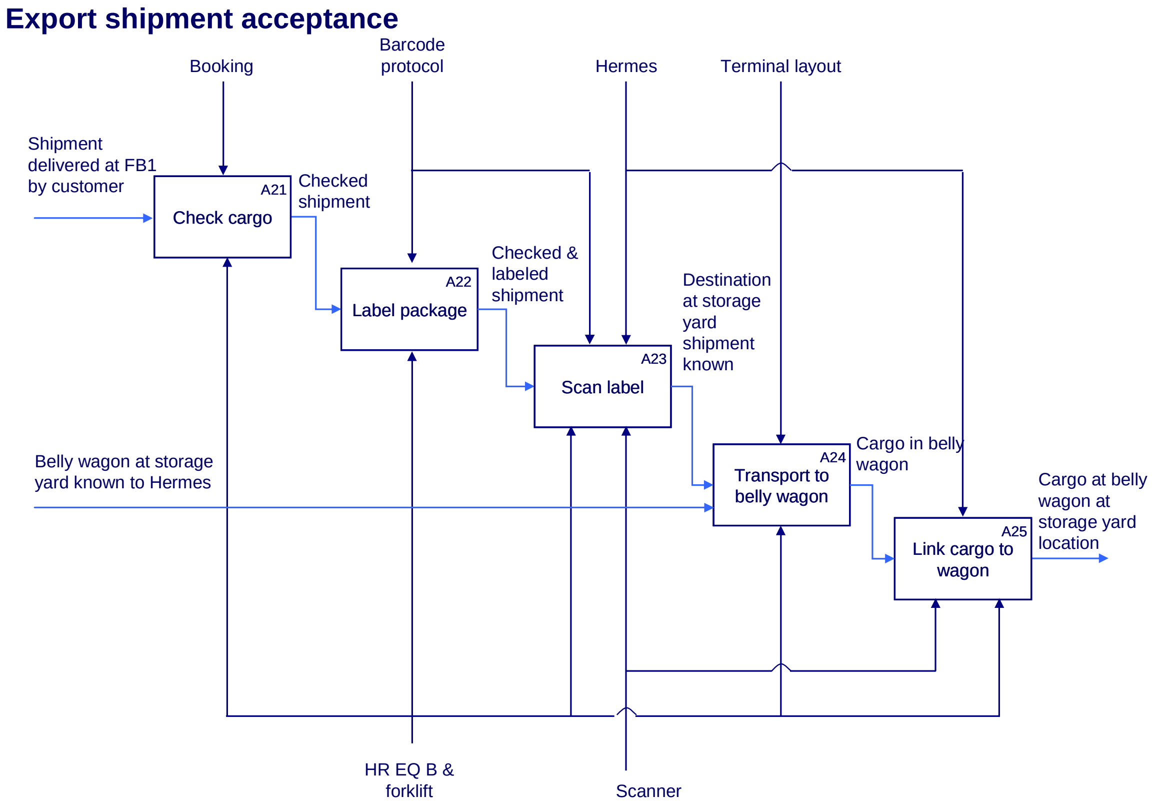


Figure 72: EQ activity A2 in detail: Export shipment acceptance

A3. Breakdown & cargo check

Cargo coming out of an airplane will be brought into FB1 by the transportation department at the EQ department. The cargo can be on different carriers, from belly wagons to large aviation pallets.
At the breakdown area, employees will unload the cargo, sort the cargo and place the cargo per shipment on Euro pallets. When a shipment is too large to be put on one pallet more pallets will be used. Shipments consisting out of one box or a couple of very small boxes will be placed together on one pallet. This pallet with multiple shipments will be sorted by the forklift driver bringing away the pallets from the breakdown.
But before the cargo is taken to the next location it will be necessary to count the packages and check whether the shipment is complete and not damaged. This job will be performed by the HR_EQ_D "checker"; this employee will also be responsible to plan the break down process. Sometimes a shipment will get priority because of a short connection window. When the shipment is complete a label with a barcode is put on one of the packages of the shipment.
When the load of a wagon is primarily from one large shipment the "checker" can decide to leave this shipment on the wagon and send the wagon to the BOB (see main report Figure 8, nr 8) location, where wagons which are loaded with cargo and are ready for the weighing process are stored temporarily.

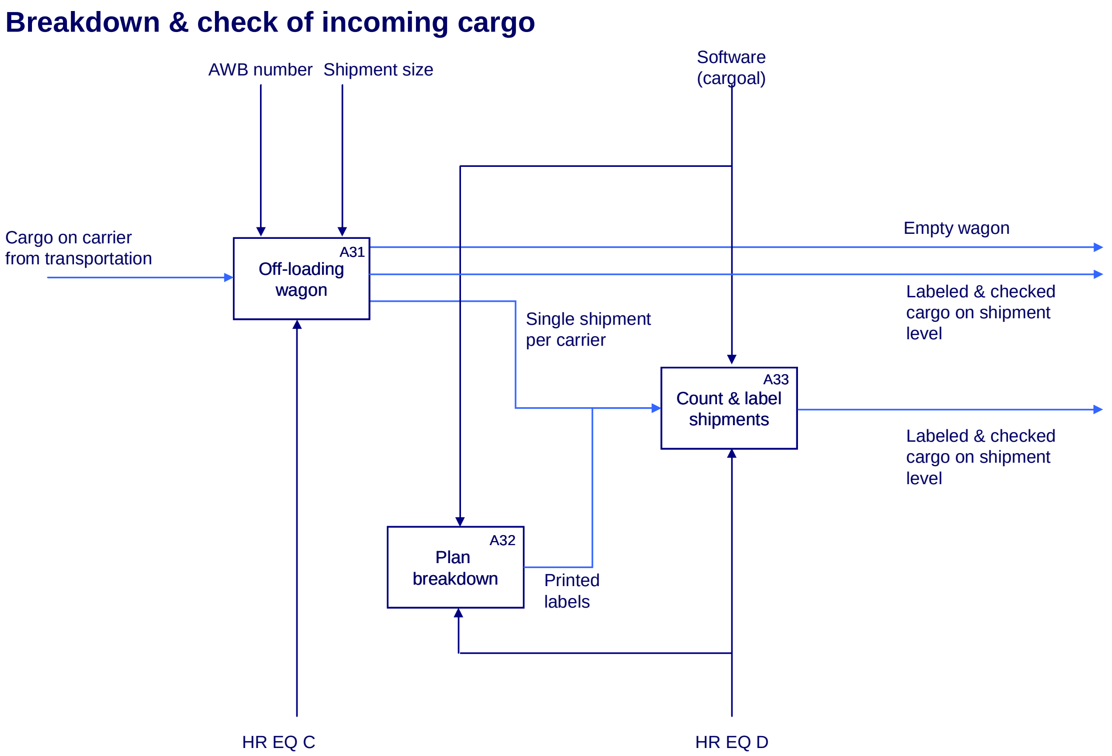


Figure 73: EQ activity A3 in detail: Breakdown and check of incoming cargo

A4. Bring away sorted shipments

When the cargo is sorted, counted, checked and labelled at the breakdown location a forklift truck driver will bring away the shipment to the next location. This location will be displayed by the scanner as soon as the FLT driver will scan the label applied by the "checker". The next location can be (Figure 8, p.31): temporary storage (Figure 8, nr. 8), BOB location (Figure 8, nr. 6), belly wagons for lateral transport (Figure 8, nr. 11), belly wagons at the storage yard (Figure 8, nr. 9), import (Figure 8, nr. 7) and directly to weighing when the connection is tight.

When the driver has placed the cargo at the next location the barcode of the location and packages are scanned again, linking them to each other in the warehouse software.

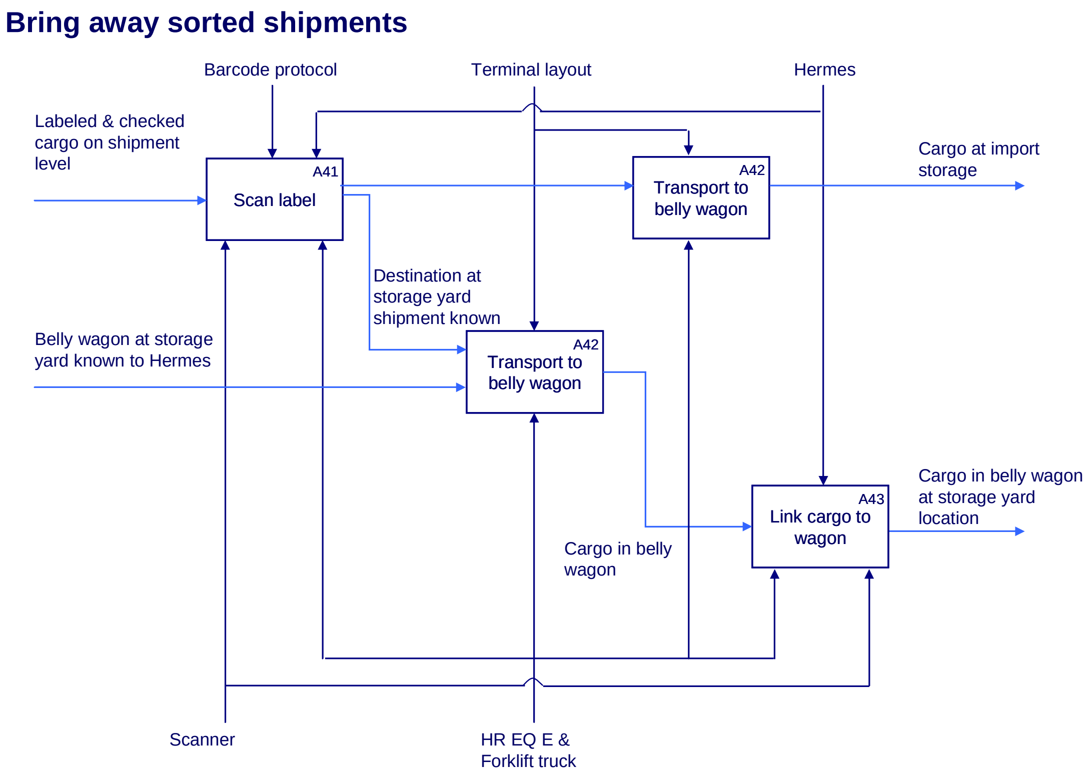


Figure 74: EQ activity A4 in detail: Bring away sorted shipments

A5. Lateral transport

There is lateral transport of cargo required between FB1 and FB2&3. General cargo transported in the belly of a KLM plane will be put in the belly wagons at the storage location at EQ for the transportation to the plane. This general cargo will come from FB2&3 towards FB1 (A52. There is also a flow of cargo the other way around, from FB1 to FB2&3 (A56. This flow will consist of general cargo which is placed on the same ULD as EQ shipments. This ULD will be broken down at EQ, but the general cargo on the ULD will be brought to FB 2 or 3 for the remaining of their journey to the final destination.

This lateral transport is collected on one side in FB1 (Figure 8, nr. 11) and on the other side at FB2 and FB3. One employee of EQ will drive and transport trains of belly wagons between the collection points (HR EQ G). The full wagons from FB2&3 will be placed besides the storage yard at EQ. From here one employee will drive away the cargo to its next destination. Again this destination is showed on the display of the scanner after scanning the barcode on the package.

The employee (HR_EQ_F) will bring the shipments to the right location. Arrived at that location he scans the barcode of the packages and the location, in order to link them for the warehouse software.

The employee which sorts out the lateral transit also checks the cargo at the temporary storage location, which was located there when the flight of the package was not "opened" yet, regularly in order to find packages which can be moved to a belly wagon at that moment. In this case the belly wagon for the flight is opened (by HR EQ A, A1) in the meanwhile.

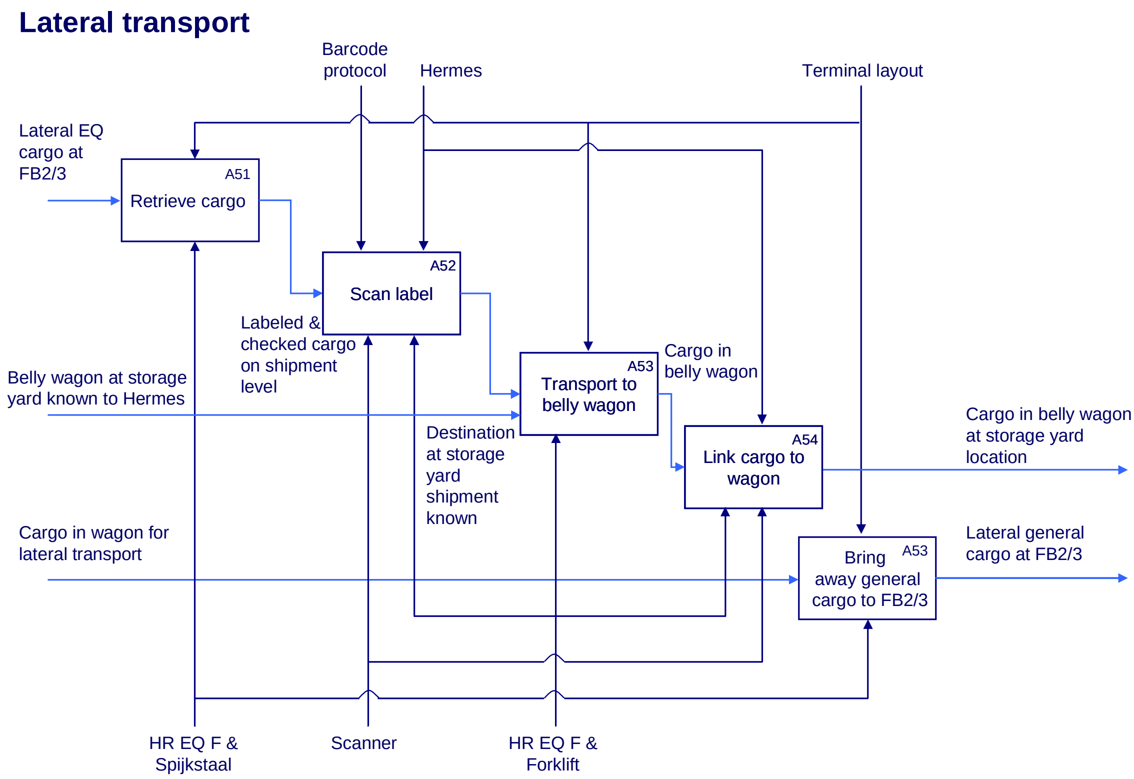


Figure 75: EQ activity A5 in detail: Lateral transport

A6. Reposition empty wagons

After the unloading of the belly wagons (or ULD's), an empty wagon will remain. This wagon has to be repositioned to make room for new cargo arriving at the break down area. These empty wagons are in general used to fill up the empty spots at the storage yard for belly wagons. These empty spots are caused by the departure of belly wagons to the planes. In the long run the arriving wagons from the planes will be equal to the number of wagons to the plane; otherwise there will grow a pile of belly wagons somewhere. This does not have to imply that the amount of cargo on arriving and departing flights will be the same.

The repositioning of the empty belly wagons from the breakdown will be performed by the by the FLT's drivers at the break down (HR type F). In case more wagons are departing than arriving, the weighing employee, which will bring away the full belly wagons to transportation, will bring extra empty wagons from outside.

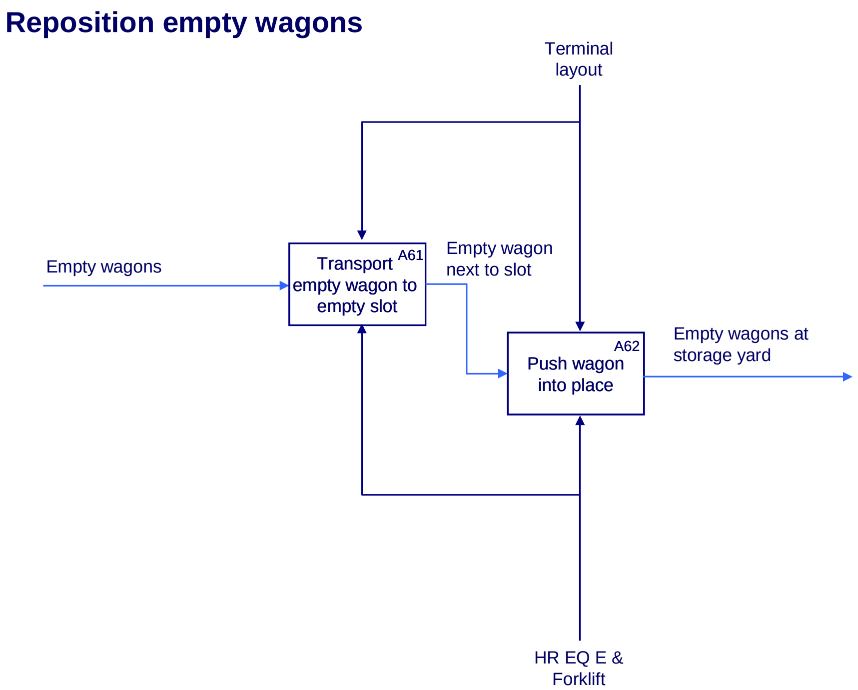


Figure 76: EQ activity A6 in detail: Repositioning empty belly wagons

A7. Collect & weigh train

The train with departing belly wagons will be collected (A71) as soon as all the booked cargo is located in the belly wagons at the storage yard or a specific time before the flight departure (90 minutes). The employee will check whether there are belly wagons with cargo at the BOB location for the collected flights as well.

The employees will try to make a long train with a maximum of six belly wagons. At EQ the employees will also take the sequence of detaching of the wagons at the gates into account, just as they do at the mail department.

The location based software will warn the employee at the weighbridge that the pick-up time is coming close by changing the colour of the wagon in the overview screen (appendix J).

The wagons will be weighed at the weigh bridge. To determine the weight of the cargo the weight of the belly wagons should be deducted from the total weight.

Most of the time the weighing at EQ is performed by two employees which are working together, one will reposition the train to make sure the right wagons is above the weighbridge. The other will read the weight and will register the measurements.

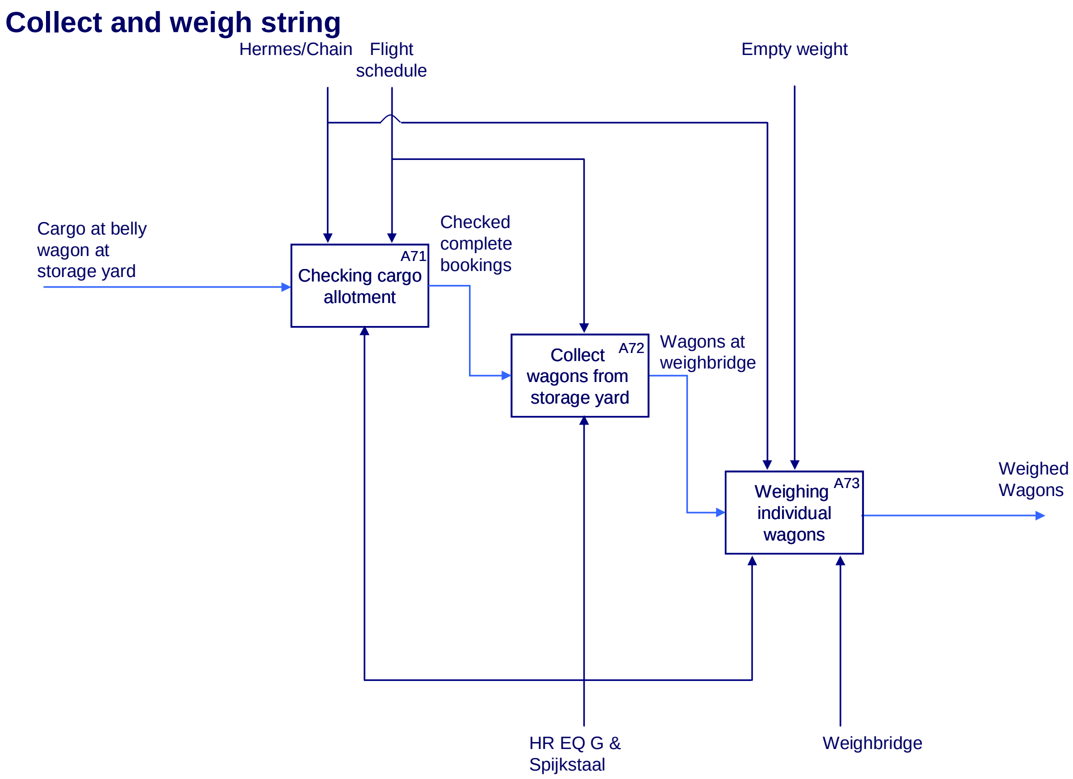


Figure 77: EQ activity A7 in detail Collect and weigh train of departing cargo

A8. Distribution to customer

When a customer will arrive at the landside of the terminal to pick up arrived import cargo, the employee at the "Voorloods" will collect the cargo from the storage for import cargo and hand over the cargo of the total shipment to the customer (A81). This action will be performed by the same employee which is responsible for the acceptance of export cargo at the landside, HR type B.

At the "Voorloods" a FLT truck will often be used to load the cargo on the truck of the customer. The customer and the employee will check the state of the packages and determine whether or not the shipment is complete (A82).

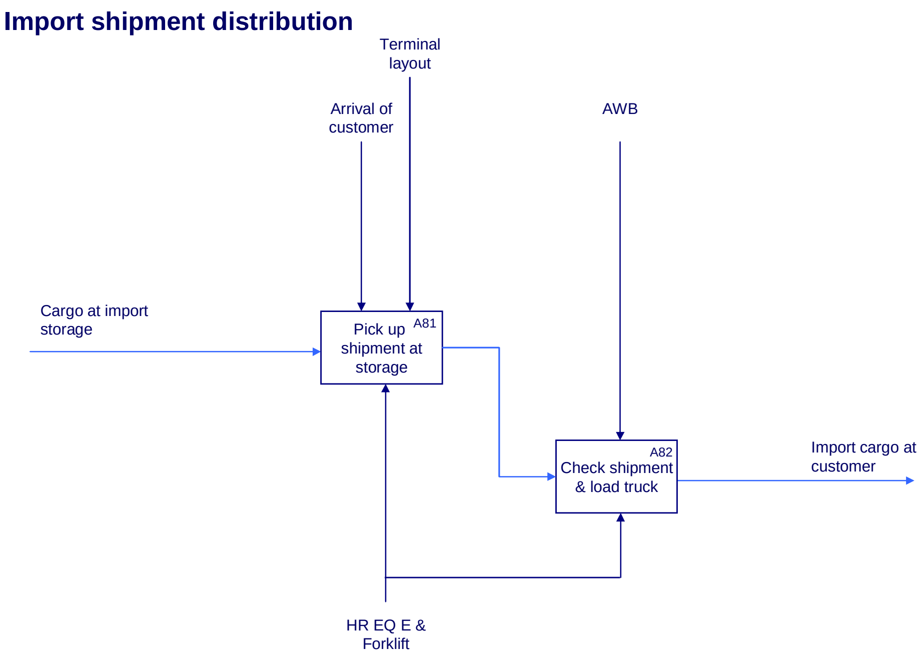


Figure 78: EQ activity A8 in detail: Import shipment distribution

A9. Bring to transportation & bring in empties

After the wagons are weighed (A7) the same employee will drive the train to the security check (A91). Here dogs will search the full wagons for explosive or dangerous goods. The employees and dogs performing the check are not part of the equation department.
The weigh employee will be waiting until the check is performed to continue the trip outside to the transportation department (A83). Now the wagon is at the lane for transportation waiting for the transport to the plane by the transportation department.
The employee, which brings the wagons outside, can take empty wagons in from outside when there are emerging to much empty spots at the storage yard inside (A94).

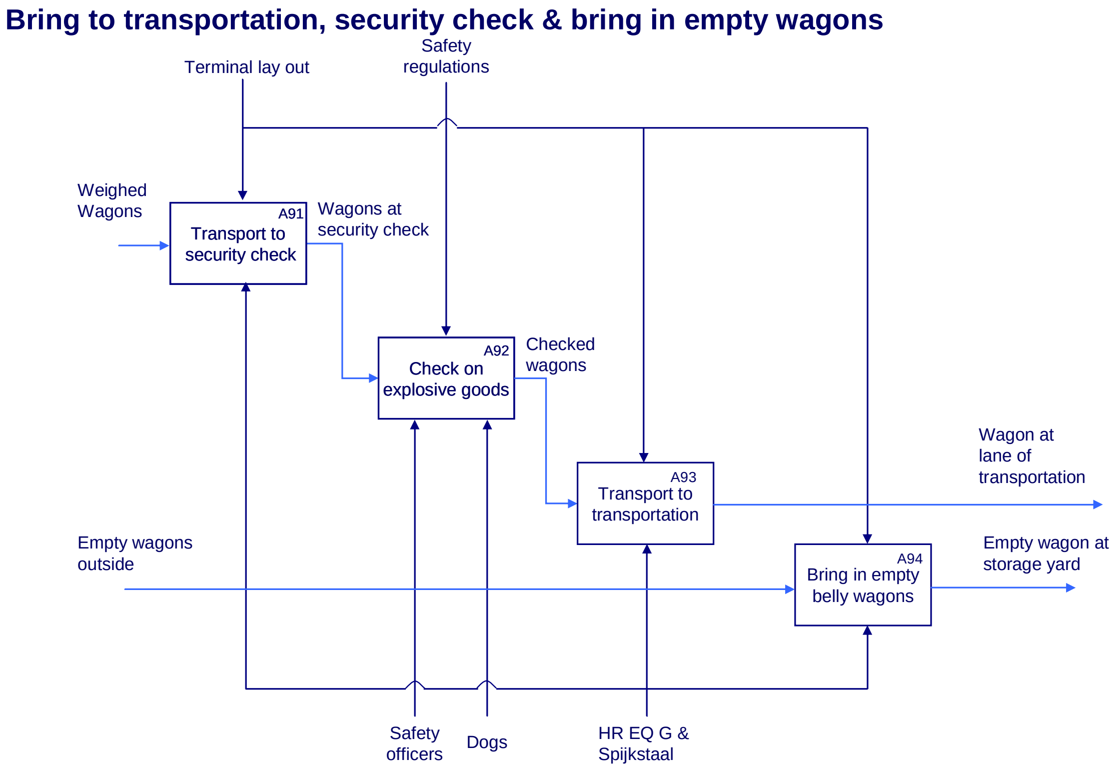


Figure 79: EQ activity A9 in detail: Bring belly wagons to transportation via security

J Overview of belly wagons at EQ storage yard

1	2	3	4	5	6		1	2	3	4	5	6
KL 1121 ARN 19:35	KL 1435 BHX 19:35	KL 1481 GLA 19:35	KL 1139 CPH 19:40	KL 1193 BGO 19:40	KL 1449 ABZ 19:40	1	KL 167 DXB 04:00	KL 167 PEN 04:00	KL 167 SIN 04:00	KL 791 GRU 08:20	KL 669 DFW 08:30	KL 459 KWI 08:40
KL 1141 OSL 05:30	KL 1107 ARN 05:25	KL 1665 BCN 05:20	KL 1629 MXP 05:20	KL 1677 BCN 19:45	KL 1097 MAN 19:45	2	KL 743 LIM 07:50	KL 621 ATL 08:50	NW 034 BOM 08:45	KL 565 NBO 08:45	KL 661 IAH 08:40	KL 459 MCT 08:40
KL 1699 MAD 05:30	KL 1839 VIE 05:30	KL 1953 ZRH 05:35	KL 1351 PRG 05:35	KL 1925 GVA 05:40	KL 1001 LHR 05:45	3	KL 6063 EWR 09:10	KL 591 JNB 09:00	KL 6091 PDX 09:00	KL 543 ADD 09:05	KL 543 KRT 09:05	KL 571 DAR 08:50
KL 1765 FRA 07:15	KL 1007 LHR 07:00	KL 1229 CDG 06:30	KL 1125 CPH 06:25	KL 1471 GLA 06:20	KL 1791 MUC 06:00	4	KL 685 MEX 11:30	KL 713 PBM 11:00	KL 735 CUR 10:20	KL 605 SFO 09:40	KL 871 DEL 08:40	KL 571 JRO 08:50
KL 1739 LUX 07:25	KL 1671 BCN 07:30	KL 1279 EDI 07:10	KL 1363 WAW 07:45	KL 1443 ABZ 07:45	KL 1109 ARN 07:50	5	KL 6033 SEA 11:35	KL 6057 MEM 12:35	KL 6097 BDL 11:55	KL 651 IAD 11:45	KL 587 LOS 11:50	KL 451 AUH 12:00
KL 1723 BRU 07:55	KL 1653 VCE 07:55	KL 1613 IST 07:55	KL 1575 ATH 07:55	KL 1403 MRS 07:55	KL 1143 OSL 07:55	6	KL 577 ABV 12:20	KL 589 ACC 12:10	KL 427 DXB 12:10	KL 641 JFK 12:00	KL 601 LAX 11:55	KL 451 BAH 12:00
KL 903 SVO 08:00	KL 1303 TLS 08:00	KL 1779 HAM 08:05	KL 1793 MUC 08:05	KL 1187 BGO 08:10	KL 1389 OTP 08:10	7	KL 577 KAN 12:20	KL 691 YYZ 12:25	KL 803 MNL 12:40	KL 6037 BOS 13:40	KL 617 DTW 13:50	KL 671 YUL 13:50
KL 1127 CPH 08:30	KL 1957 ZRH 08:20	KL 1199 SVG 08:20	KL 1927 GVA 08:15	KL 1695 LIS 08:15	KL 1623 MXP 08:10	8	KL 681 YVR 14:10	KL 6055 MSP 14:00	KL 611 ORD 14:00	KL 887 HKG 13:50	KL 867 KIX 13:50	KL 861 NRT 13:50
KL 1241 CDG 17:15	KL 1027 LHR 17:35	KL 1369 WAW 18:30	KL 1775 FRA 19:15	KL 1033 LHR 18:50	KL 1171 HEL 18:55	9			KL 643 JFK 16:50	KL 895 PVG 16:50	KL 409 ALA 17:05	KL 897 PEK 17:05
KL 1151 OSL 19:05	KL 907 SVO 19:05	KL 1849 VIE 19:00	KL 1937 GVA 18:55	KL 1835 TXL 18:55	KL 1609 FCO 18:55	10	KL 429 DXB 19:15	KL 891 CTU 19:15	KL 877 TPE 19:15	KL 877 BKK 19:15	KL 553 CAI 19:15	KL 865 ICN 17:10
KL 1319 BOD 19:05	KL 1635 MXP 19:05	KL 1581 ATH 19:05	KL 1163 GOT 19:15	KL 1205 SVG 19:15	KL 1361 OTP 19:15	11	KL 809 CGK 19:30	KL 809 KUL 19:30	KL 837 SIN 20:00	KL 753 BON 22:05	KL 753 GYE 22:05	KL 753 UIO 22:05
KL 1801 MUC 19:30	KL 1789 HAM 19:30	KL 1697 LIS 19:30	KL 1707 MAD 19:25	KL 1617 IST 19:20	KL 1969 ZRH 19:15	12						

K Flowcharts

K.1 Mail operation

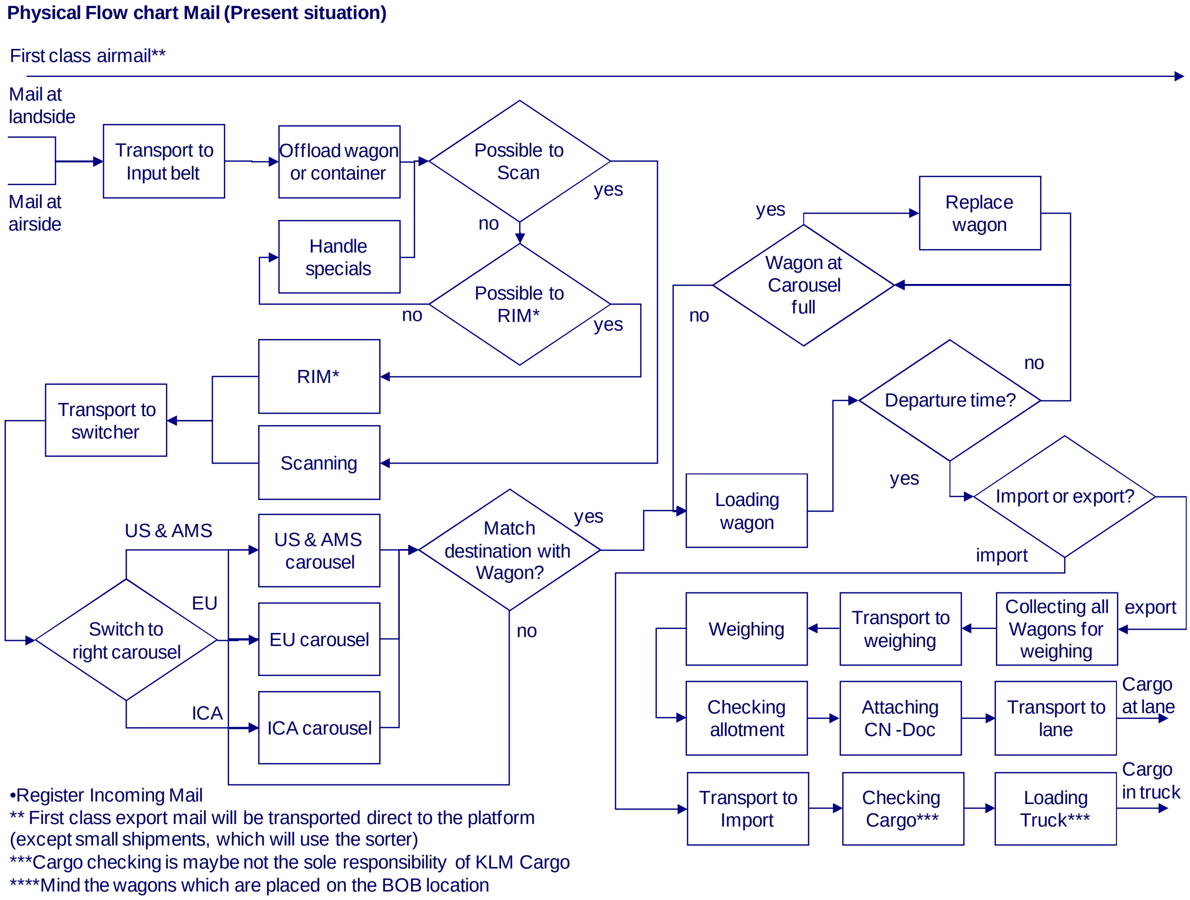


Figure 80: Flowchart of mail operation

K.2 Equation operation

Physical Flow chart EQ (Present situation)

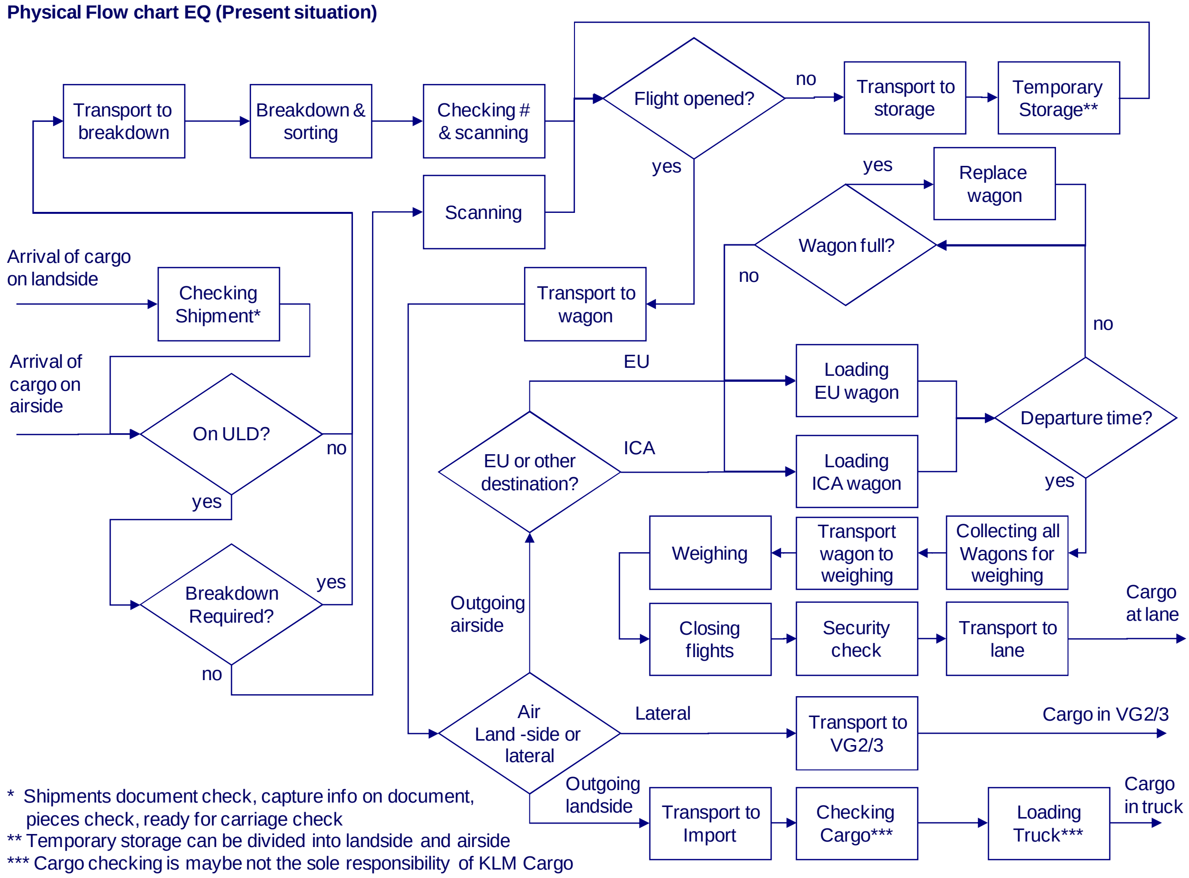


Figure 81: Flowchart of EQ operation

K.3 Flowchart of integrated operations

Physical Flow chart after integration of Mail & EQ (Future situation)

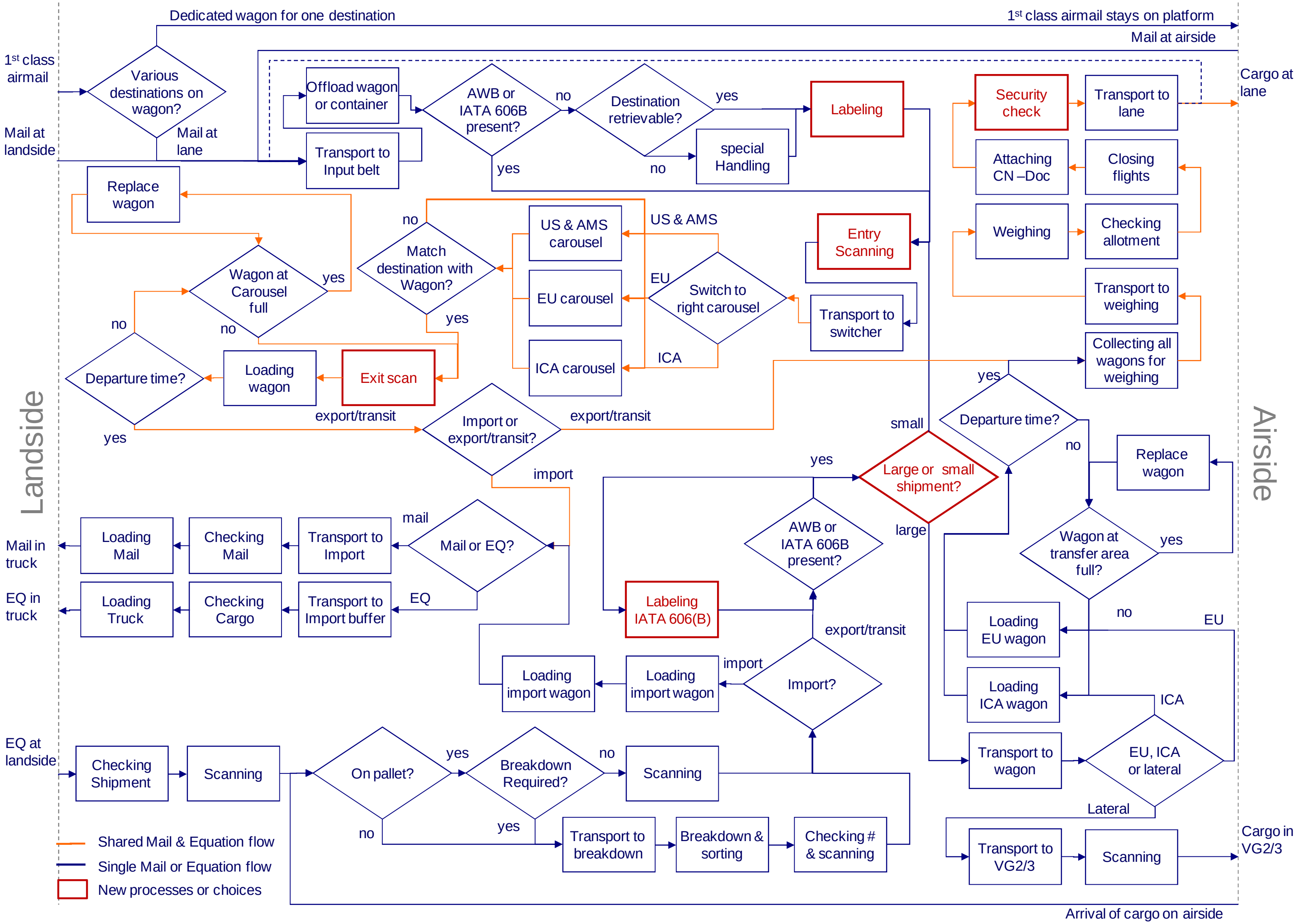


Figure 82: Flowchart of the future integrated operation

L Transformation of the conceptual models to the simulation

In this appendix the logic of Arena and the transition from the IDEF-0 and flowcharts to the simulation model will be described using an example from the Arena model of FB1, shown in Figure 83.

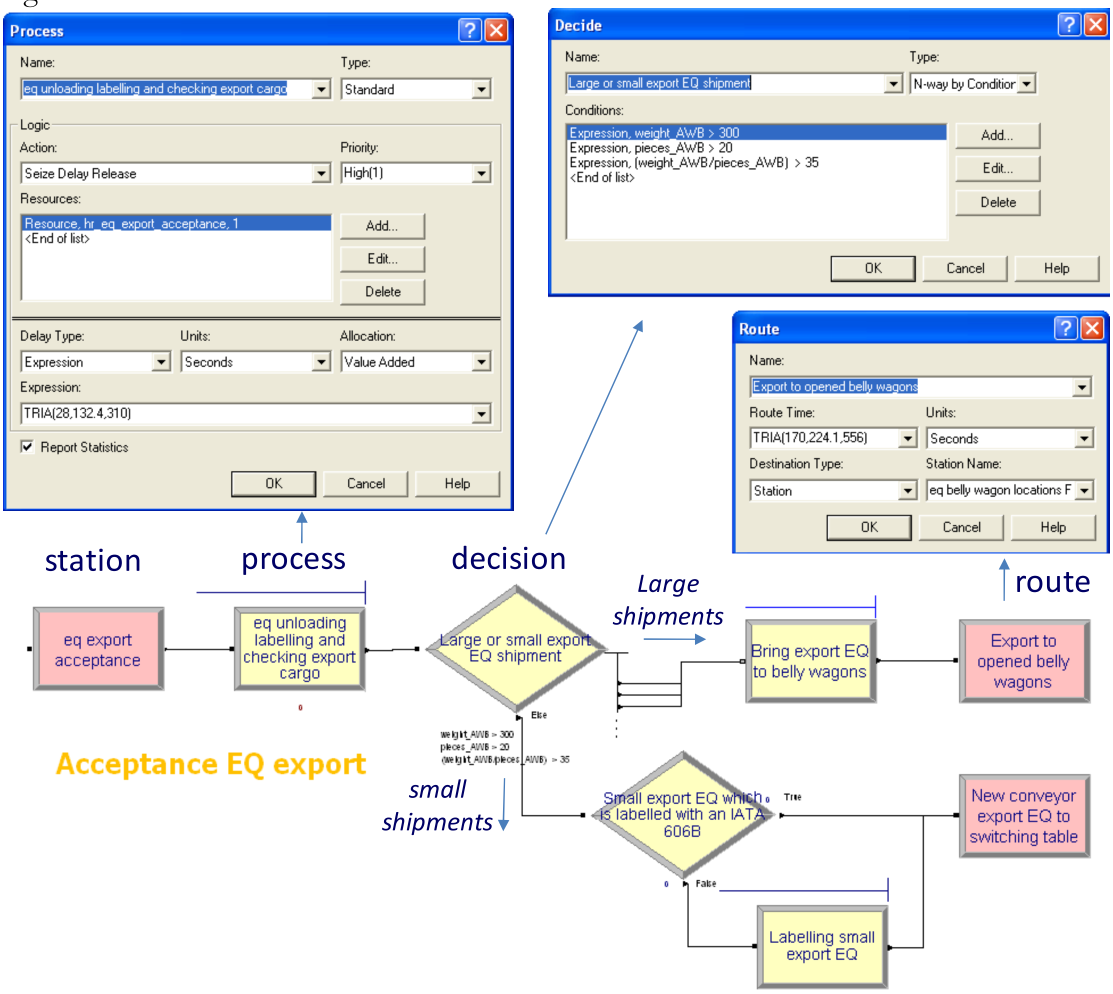


Figure 83: Example of Arena simulation

In Figure 83 a possible model of the export acceptance at EQ is displayed as example. The entities representing mail or EQ will come in from the left at the "station" module and will flow over the connectors between the modules to the right side of the figure. After arrival at the station, the cargo will enter the process of the "unloading, labeling and the ready for carriage check" performed by the export acceptance employee. Afterwards it will be decided whether the shipment is "small" or "large". Some small shipment might need to be labeled with an IATA 606(B) label; other small shipments will be placed on the new conveyor belt directly. The large shipment will be brought to the belly wagon at the storage yard.
When the flowcharts and IDEF-0 diagrams are compared to the Arena building blocks of Figure 83 two similarities are observed.

- The yellow square blocks are representing processes in the Arena model, just like the square blocks are representing processes in the IDEF-0 and flowcharts.
- The diamond module in Arena is a choice module, in the flowchart decisions are also modelled with a block in the form of a diamond.

The comparison between the conceptual models and the Arena model shows the conceptual models can be used as a basis for the simulation model, nevertheless a more detailed explanation of the Arena building blocks will be required to explain how the decision criterions and required resources can be inserted in the Arena model.

Building blocks in Arena

The resources and equipment identified in the IDEF-0 diagrams will have to be linked to the corresponding processes in Arena as well to make the transition from the conceptual models, this is explained below. Furthermore, the way decision criterions can be inserted in the Arena modules will be described. Finally the working of the modules used to move the cargo through the simulation is described: the station and route modules.

Process-modules
In the process module in Arena it is possible to insert the required resources and the process times for a specific process. In Figure 83 the interface to insert the required details of a process is showed. Via the interface it is possible to inserted process time distributions and claim a specific resource to perform the activity, in this interface one resource "hr_eq_export_acceptance" is claimed. Some processes might require more than one resource type (employee functions in reality) or might need several workers of one resources type; this can also be inserted via this interface.
At the same time one resource type can be responsible for more than one process. It is possible to give one process a higher priority in this module. In this way processes which are crucial to make deadlines can be given a higher priority than the processes which can be easily postponed in reality.

Decide-modules
In the decide-module a choice is made based on the inserted decision criterions. The criterions are inserted via the interface showed in Figure 83. In the example it is showed how the division between the flow of large and small EQ shipments is made. When a cargo entity coming in at the decide module will fulfill the conditions of one of the three inserted lines it will be send to one of the three corresponding exits at the right of the decide module. When the entity does not fulfill one of the conditions, the shipments is send to the exit at the bottom of the decide module.
In the same way the small shipments can be divided between IATA606(B) labeled AWBs and non-labeled AWBs in the next decide module. In this module the division is made based on a probability, which is calculated in sub-paragraph 6.6.3.

Station and Route-modules
The station and route modules are used to coordinate the flow of cargo through the simulation model of FB1. In the route modules the name of the next station for the cargo arriving at the route module can be inserted. The time required to travel to this next station can also be inserted. The use of route modules with a decide module make it possible to route specific shares of cargo flows through the simulation model.

With this example the logic of the Arena simulation is explained. In the described modules it is possible to link specific resources and process times to processes. In this way the identified processes and resources from the IDEF-0 diagrams can be translated to the Arena model. The flowcharts are used primarily to map the flows of cargo and the sequence of processes now and in the future situation. The IDEF-0 diagrams identified the required resources for processes in FB1. In Arena the link between the process and resources is made as well and together with the inserted process times the program is able to calculate the utilization of the scheduled resources.

M Production data

Sources

Two sources for data were used, because the operations of airmail and EQ are registered in different software packages. The airmail data was retrieved from Trips and the EQ data is based on Cargoal, but was extracted out of Firda.
For EQ the received data was all in one file, for the production data of mail from Trips several files had to be combined to result in an useful overview per mailbag. The relations between the used files can be derived from the Trips manual. Figure 84 displays the relations between the different files in Trips.

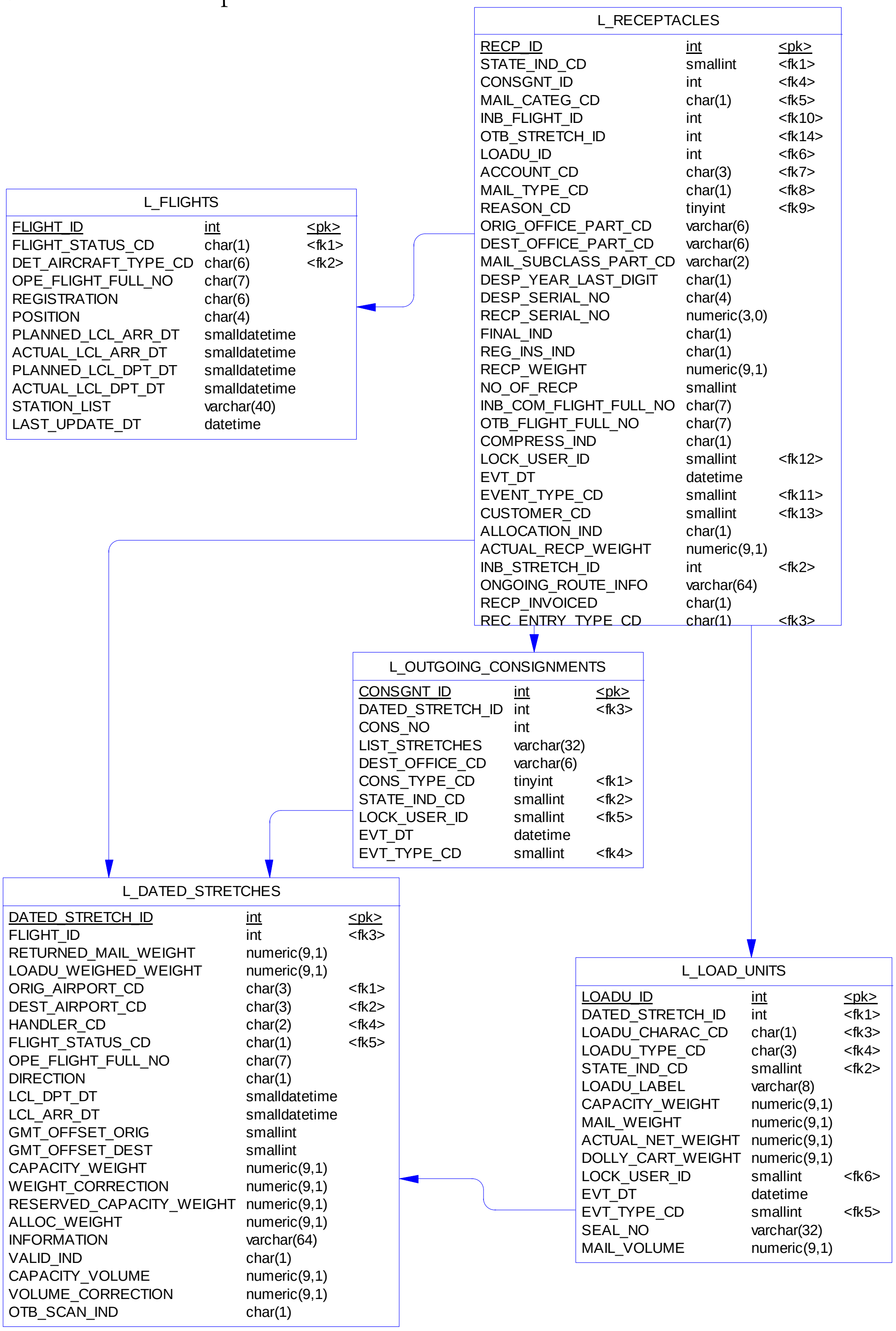


Figure 84: Relation between data files Trips (Universal postal union, 2005, p.17)

M.1 Coding schemes

Table 37: The different coding schemes for products, used carousel, cargo flow and the different carriers transporting EQ and mail

Product type	department	code
M21	EQ	1
General cargo	EQ	2
Priority	Mail	3
SAL	Mail	4

Carousel	department	code
EUR carousel	Mail	1
USA carousel	Mail	2
ICA carousel	Mail	3

Cargo flow	department	code
export	EQ & mail	1
transit	EQ & mail	2
import	EQ & mail	3
dwars-in	EQ	4
dwars-uit	EQ	5

The grey areas in the ULD coding scheme are displaying the three codes used for loose cargo.

M.2 Characteristics of cargo entities

Entity_id is an unique number added during the data transformation and is also used as input characteristic in order to simplify the retrieval of original data in the input file.
Although mail has nothing to do with an AWB, the mail entities will have attributes referring to AWBs. This makes it possible to add up the for example volume characteristics of mail and EQ after the integration of the flows. Instead of AWB you should read Receptacle for the mail entities.
The eq_flight_index and mail_flight index is an unique number dedicated to a certain flight, which makes it easier to link cargo with a flight.
The carousel attribute is sending the collo to the right carousel. The attribute nr_AWBs_on_TULD is used to group export AWBs on an ULD after the generation. For export EQ no information is available on the load unit it arrived with. With an assumption those export AWBs coming in on an ULD are selected. The number of AWBs that should be grouped together is indicated by the value of this attribute.

Assumptions

Weight per mailbag

The volume of airmail shipments is not registered, therefore the density of the different mail types are used to estimate the volume per mailbag. The density in combination with the weight per receptacle, which is known, can be used to approximate the volume of a shipment.

- Letter mail 135 kg/m3 (135 applied for SAL)
- EMS or boxes 115 kg/m3 (115 applied on other mail)

Weight per EQ collo

The average weight of a package is used for EQ AWBs when broken down to collo level in the simulation. Averaging the weight per collo reduces the effect of incidental heavy shipments. The incidental heavy collo, which should make the AWB a "large" shipment, will not be identified in the simulation. A whole shipment is considered large in case the average weight of the packages of a shipment is above the large shipment criterion

Export TULDs

The outgoing export ULDs which carries only one AWB with a volume of 8 m3 or larger are assumed to be T-ULDs.

- This takes out almost all AKEs, AKHs, which is quite plausible because these smaller types are often used when cargo is build up on an ULD at EQ.
- Export AWBs going out on the same ULD to the same destination are batched together when the date and time of arrival is identical.

City codes

KLM uses the airport codes in their operations to sort the mail and EQ. The postal companies are in general also using the airport codes to label the mail bags, but in some cases the city codes are out on the label. Trips will register city as well as airport codes, but this causes some confusion during the test runs, because some bags could not be send to the right carousel. No carousel information is linked with city codes. All city codes were replaced by an airport code.

Flow division airmail and EQ

The division between the different flows of airmail is showed in a pie chart (Figure 85). For airmail the division is relatively simple and will be based on the number of bags. These numbers differ from previous percentages per flow (Table 3), because the export bags that will be brought to the plane by TNT are taken out in this overview.
For EQ the division is based on the number of AWBs. Pie charts for the future situation will be composed based on number of pieces, volumes and weight as well (sub-paragraph 6.6.2).

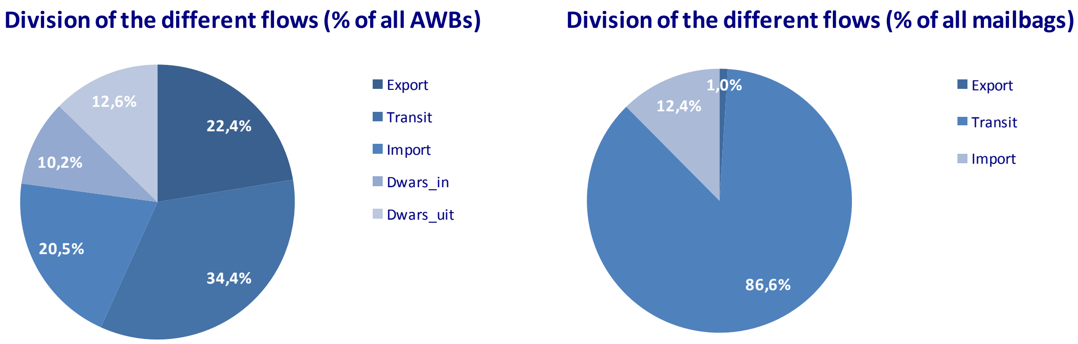


Figure 85: Flow division for both EQ (left) and airmail (right)

Entities characteristics

The following items were removed from the input file:

- The AWBs build up at the implant of KLM at DHL, which are in the Cargoal data, but will never enter FB1. In total 807 AWBs were taken out of the input for the simulation
- The compressed mail data, which represents the airmail coming in from TNT and will not enter FB1.

Table 38: Characteristics of mail receptacle and AWB entities

Entity	EQ shipment
Attribute	entity_id
Attribute	product_type
Attribute	flow_code
Attribute	AWB
Attribute	pieces_AWB
Attribute	weight_AWB
Attribute	volume_AWB
Attribute	origin
Attribute	destination
Attribute	incoming_carrier_code
Attribute	incoming_flightnr
Attribute	incomingATA_month
Attribute	incomingATA_day
Attribute	incomingATA_hour
Attribute	incomingATA_minute
Attribute	outgoing_carrier_code
Attribute	outgoing_flightnr
Attribute	outgoingATA_month
Attribute	outgoingATA_day
Attribute	outgoingATA_hour
Attribute	outgoingATA_minute
Attribute	incomingULD_type
Attribute	incomingULD_id
Attribute	outgoingULD_type
Attribute	outgoingULD_id
Attribute	eq_flight_index
Attribute	carousel
Attribute	nr_AWBs_on_TULD

Entity	Mail receptacle
Attribute	entity_id
Attribute	product_type
Attribute	flow_code
Attribute	AWB
Attribute	pieces_AWB
Attribute	weight_AWB
Attribute	volume_AWB
Attribute	origin
Attribute	destination
Attribute	incoming_carrier_code
Attribute	incoming_flightnr
Attribute	incomingATA_month
Attribute	incomingATA_day
Attribute	incomingATA_hour
Attribute	incomingATA_minute
Attribute	outgoing_carrier_code
Attribute	outgoing_flightnr
Attribute	outgoingATA_month
Attribute	outgoingATA_day
Attribute	outgoingATA_hour
Attribute	outgoingATA_minute
Attribute	mail_flight_index
Attribute	carousel
Attribute	scan_method

M.3 Arrival and departure planning per Mail flow

In this appendix the arrival patterns are derived from the input data. The arrival pattern is not adjusted for the transportation time to FB1. In the simulation the transportation time is added after flight arrival and before flight departure.

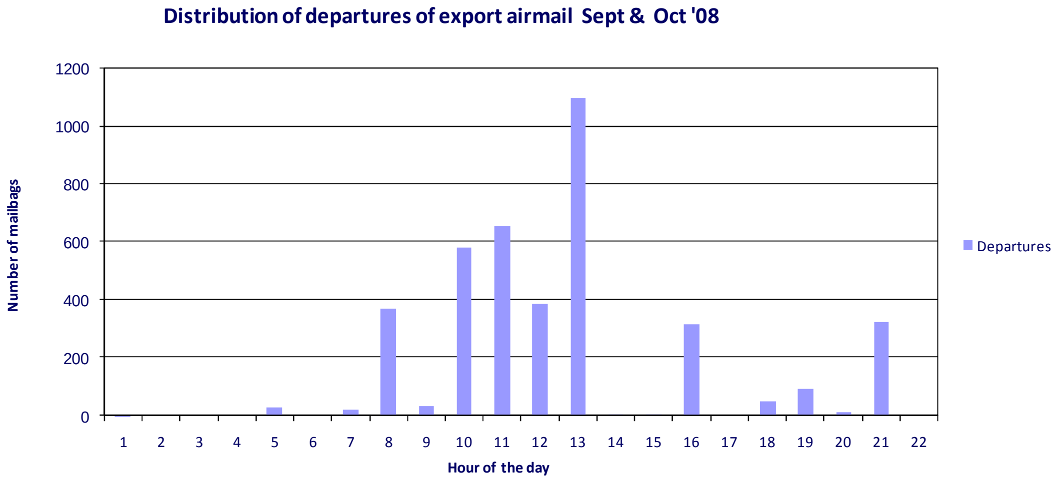


Figure 86: Histogram of the departure pattern of export mail over the day

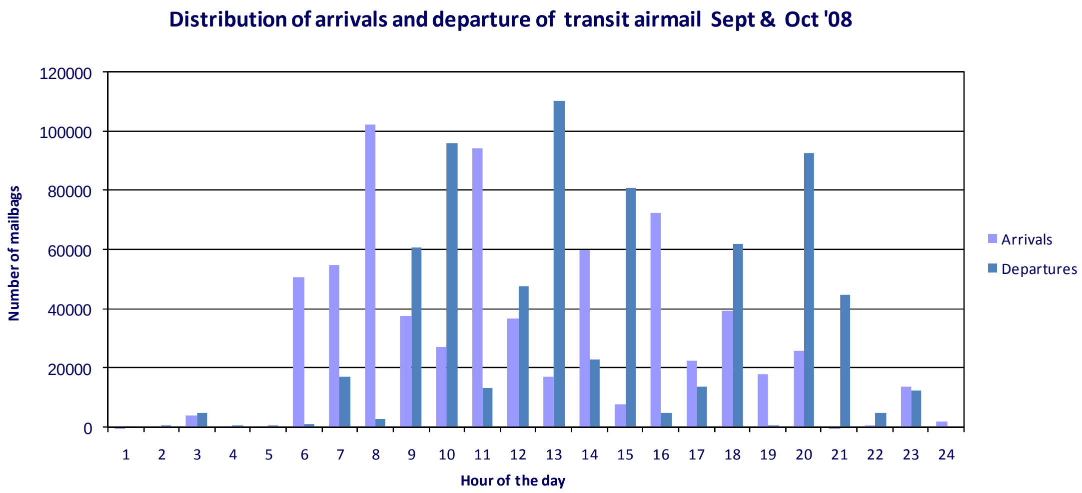


Figure 87: Histogram of the arrival and departure pattern of transit mail over the day

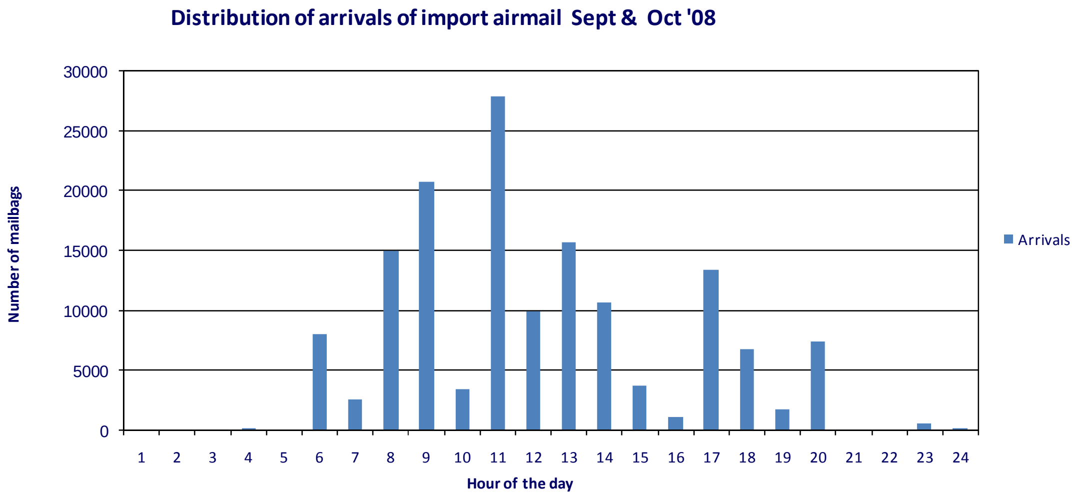


Figure 88: Histogram of the arrival pattern of import mail over the day

M.4 Arrival and departure planning per EQ cargo flow

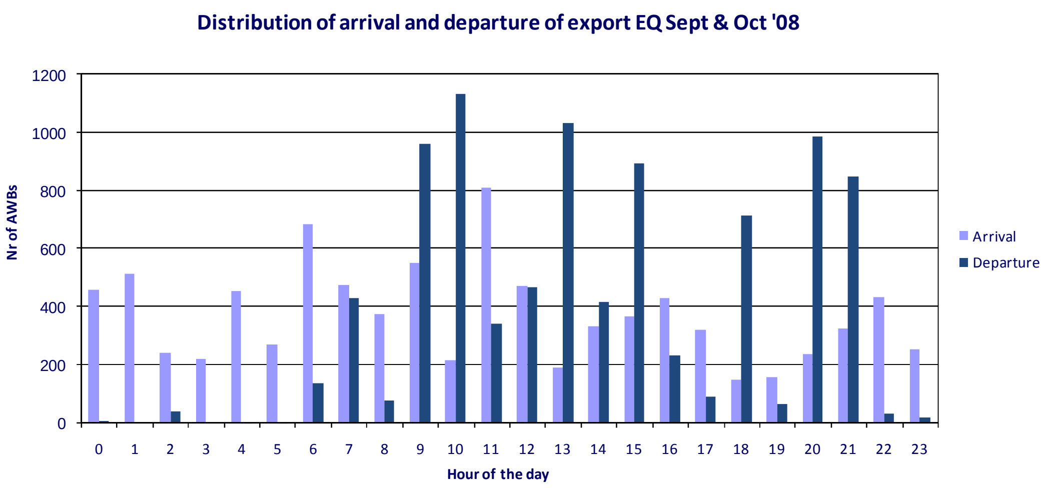


Figure 89: Histogram of the arrival and departure pattern of export EQ over the day

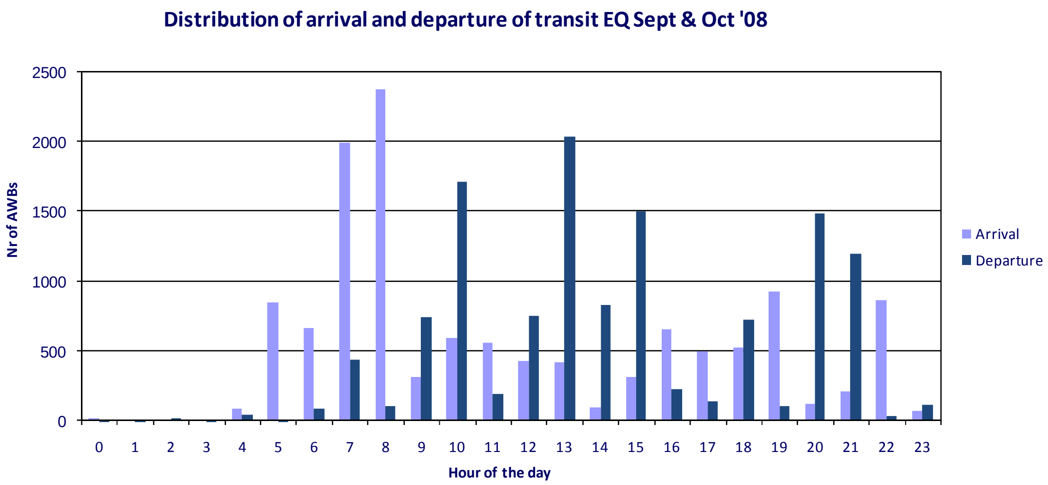


Figure 90: Histogram of the arrival and departure pattern of transit EQ over the day

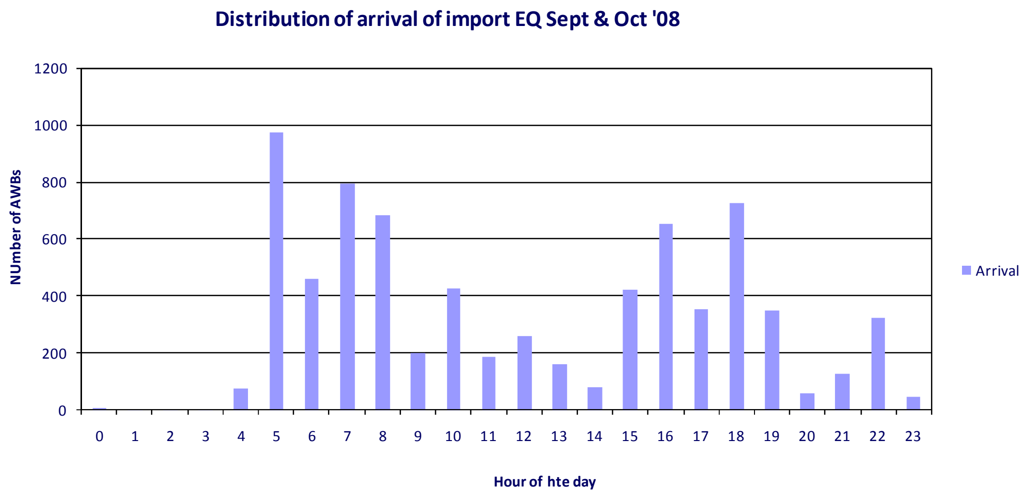


Figure 91: Histogram of the arrival pattern of import EQ over the day

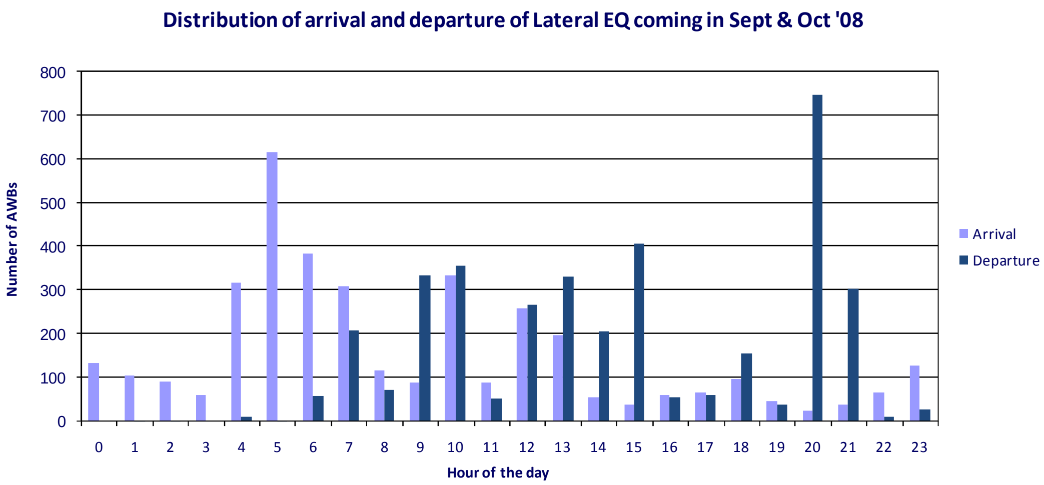


Figure 92: Histogram of the arrival and departure pattern of lateral incoming EQ over the day

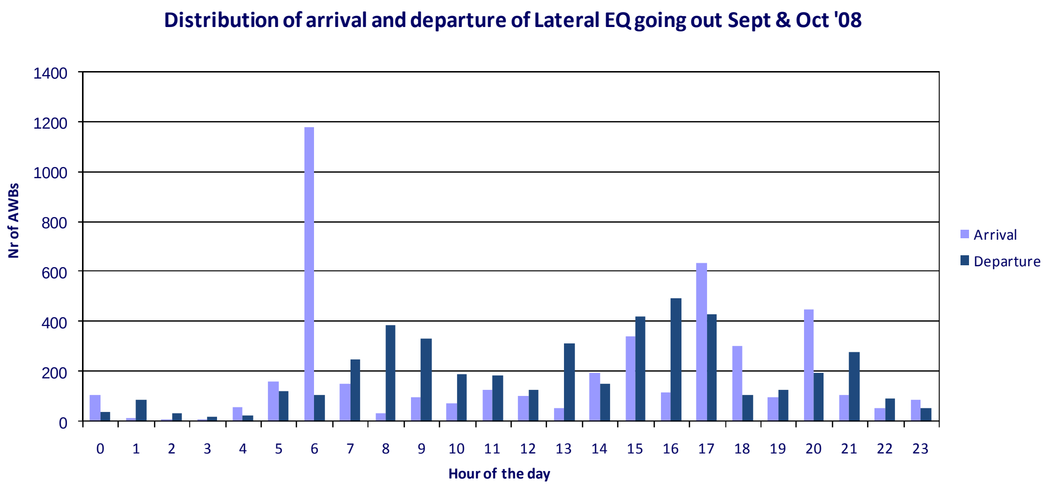


Figure 93: Histogram of the arrival and departure pattern of lateral outgoing EQ over the day

N Supplement on used Flight schedules

N.1 Estimating the difference between actual and scheduled flight times for mail flights

The **actual** arrival and departure times are not available for the mail department, but are essential for a realistic arrival of mail at FB1 and for a realistic departure of mail from Schiphol, as is explained above. Therefore, the **actual** times at the mail department are estimated by adding a correction factor to the available **scheduled** time. The correction is made by adding up the estimated time difference between the scheduled and actual times and the transportation time between FB1 and the plane. For every mail flight this time difference is randomly taken from a probability distribution based on the difference between the actual and scheduled times at the EQ department.
The resulting probability distribution is different for the arriving and departing flights. Departing flights will in general not depart before the scheduled departure time, whether arriving flights can either be earlier of later than scheduled. The analysis of the difference is displayed in appendix N.

N.2 Probability distribution of the difference between STA-ATA and STD-ATD

The estimation of the probability density function for the time difference between STA and ATA and between STD and ATD is based on data available for all EQ flights. A large number of data points are available. Some time differences were very large or negative, which indicates possible outliers. In order to take the outliers out the data point of the top and bottom 5%-percentile of the time difference are taken out.

The remaining flights were analyzed with the Arena input analyzer. This analysis results in a normal distributed difference between ATA and STA. The difference is normally distributed with a mean of – 5.91[7] minutes and a variance of 15 minutes.

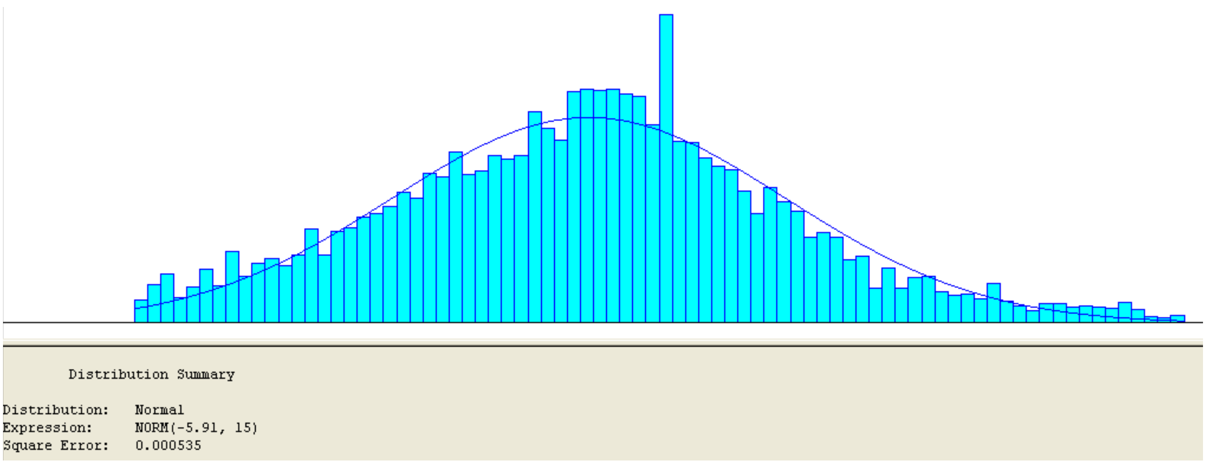


Figure 94: Arena input analyzer results for the difference between ATA and STA

The remaining data points for the outgoing flights were analyzed in Microsoft Excel and used to compose a triangular distribution for the flight departure. This distribution is easy to explain and has a finite range, which was more convenient for implementation in the simulation model.

[7] A negative mean implies the ATA of the flights at Schiphol is on average earlier than the STA

dif. STD-ATD	time (minutes)	Probability
Min	-6.00	0
Mode	0	0.025
Max	74.00	0

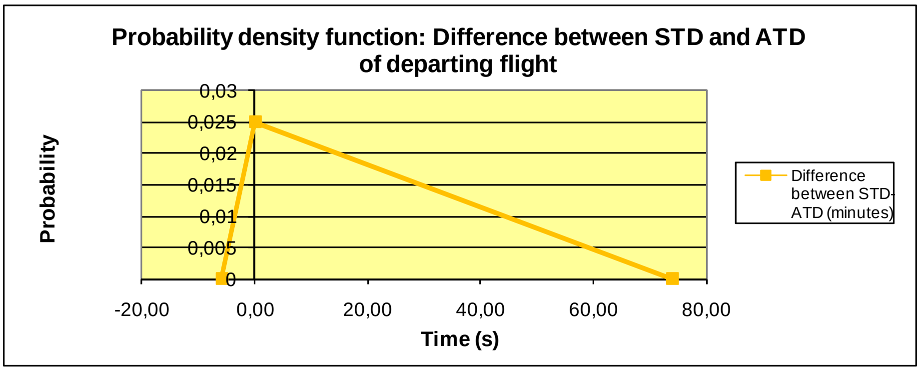


Figure 95: Probability density function of the difference between STD and ATD

The analysis results in a normal distributed difference between STA and ATA and a triangular distributed difference between STD and ATD. The normal distribution for arriving mail flights is added to the transportation time from the plane to FB1 and the triangular distribution of the departing flights is added to the transportation time from FB1 to the plane. In this way a negative time difference can be inserted in the flow of cargo, inserting a negative route time in Arena is not possible. Therefore the minimum route time for the transportation time corrected for the scheduled and actual difference is null seconds. For example the route time to FB1 for mail arriving from an European destination = MX((TRIA(18, 30, 50) + Norm(-5.91, 15)),0.0001).

N.3 Characteristics of flight entities

In Table 39 the format of the mail flight input file is shown as an example. For EQ the file is extended with the ATD for departing flights with EQ and the ATA for arriving flights is replacing the STA for EQ flights.

Table 39: Characteristics arriving and departing flight with mail entities

Departing flight with mail	Attribute
Attribute	flight_outgoing_carrier_code
Attribute	flight_outgoing_flightnr
Attribute	STD_month
Attribute	STD_day
Attribute	STD_hour
Attribute	STD_minute
Attribute	mail_flight_index
Attribute	departing_flight_destination
Attribute	departing_flight_destination2
Attribute	departing_flight_destination3

Arriving flight with mail	Atrribute
Attribute	incoming_carrier_code
Attribute	Incoming_flightnr
Attribute	incomingSTA_month
Attribute	incomingSTA_day
Attribute	IncomingSTA_hour
Attribute	IncomingSTA_minute

Overlap in outgoing flights

The outgoing mail routes are registered individually per mailbag (receptacle). Sometimes these routes will include next trajectories; therefore one outgoing flight can be modeled multiple times. In this case the flight is modeled once with only the first destination and once or more times with the first destination and ongoing destinations. In this way all destinations served by the KLM are modeled and the full network possibilities are modeled. The overlap in outgoing flights will not influence the performance indicators used in this simulation study, because:

- The actual cargo loaded on a specific plane is not a subject of this study and therefore it will not matter if flights pass the simulation model more than once. Cargo can only be pick-up once and it is made sure that the arrival and departure times of the overlapping flights are identical (even when estimating the actual times).

- in the base case the overlap in the outgoing mail flights only involves the mail department. The overlap in flights will not result in more work for employees at the mail department. At the mail department the flights will not be opened one by one and therefore the number of outgoing flights is not a driver for the workload of an employee. In the integrated situation no flight are opened at EQ, only wagons are opened per destination of the cargo, therefore the extra flights will not influence the workload of the EQ operation in the integrated situation.

N.4 Arrival and departure pattern of flights with Mail

The overlap between the departing flights with airmail has been taken out for the composition of these histograms.

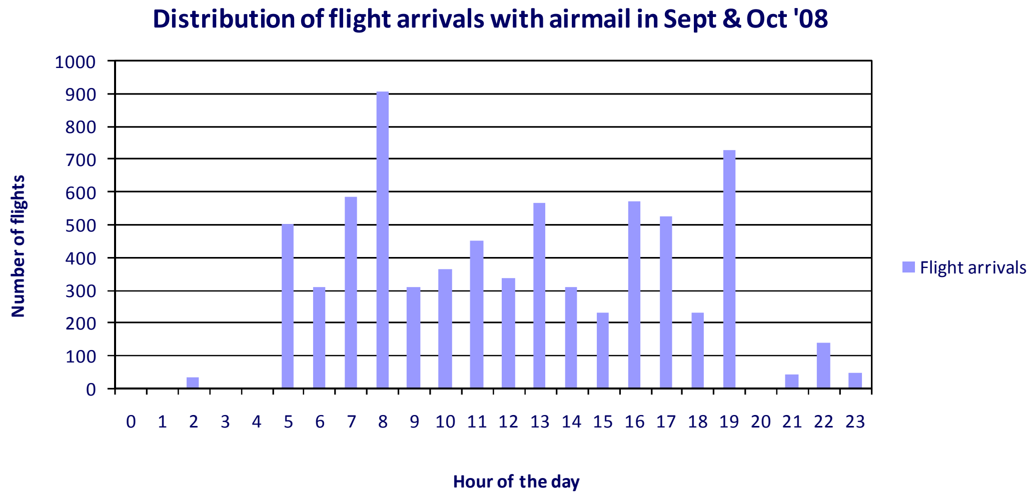


Figure 96: Histogram of the arrival pattern of flights with mail over the day

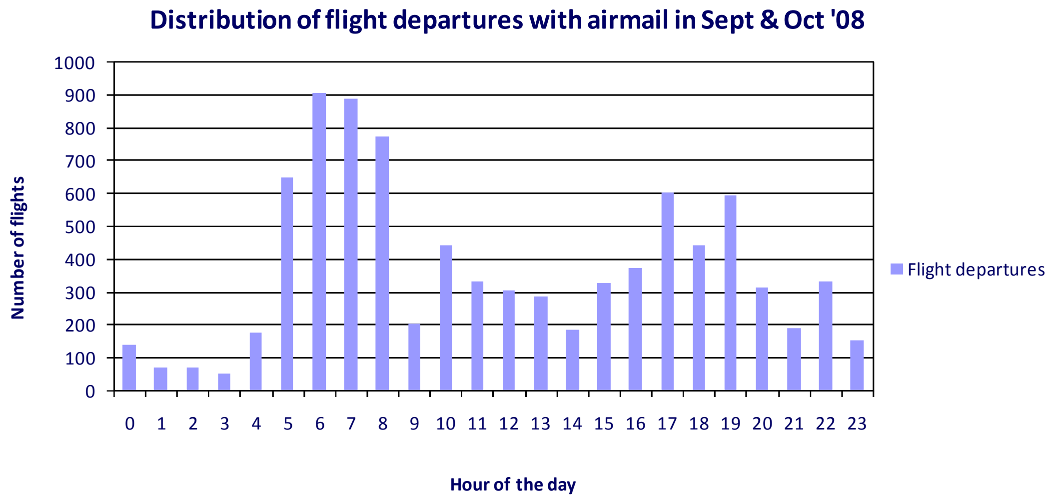


Figure 97: Histogram of the departure pattern of flights with mail over the day

N.5 Arrival and departure pattern of flights with EQ

The histograms are based on the scheduled arrival and departure times of flight carrying EQ.

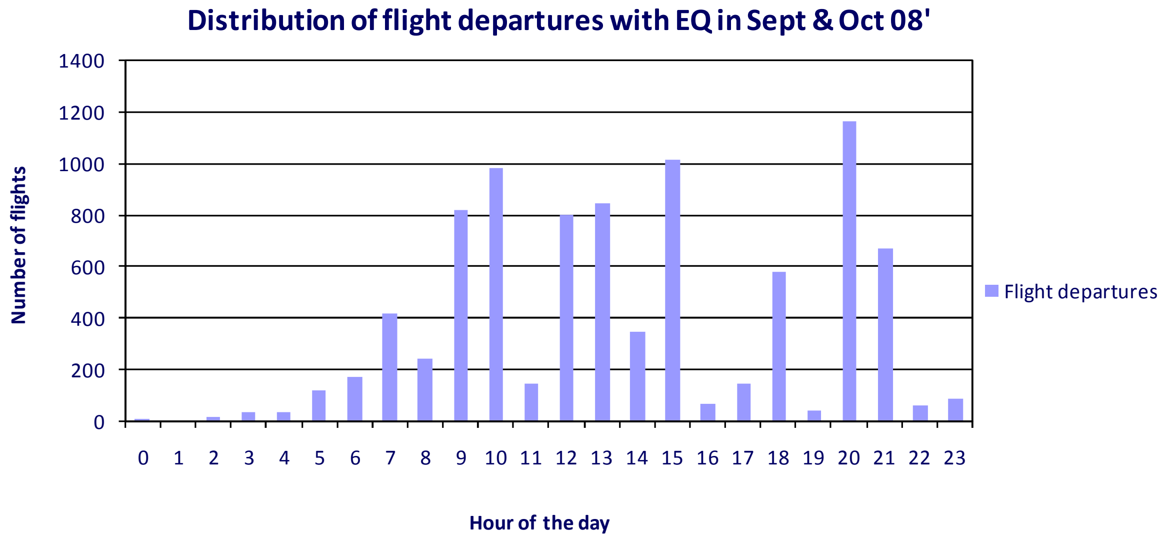


Figure 98: Histogram of the arrival pattern of flights with EQ over the day

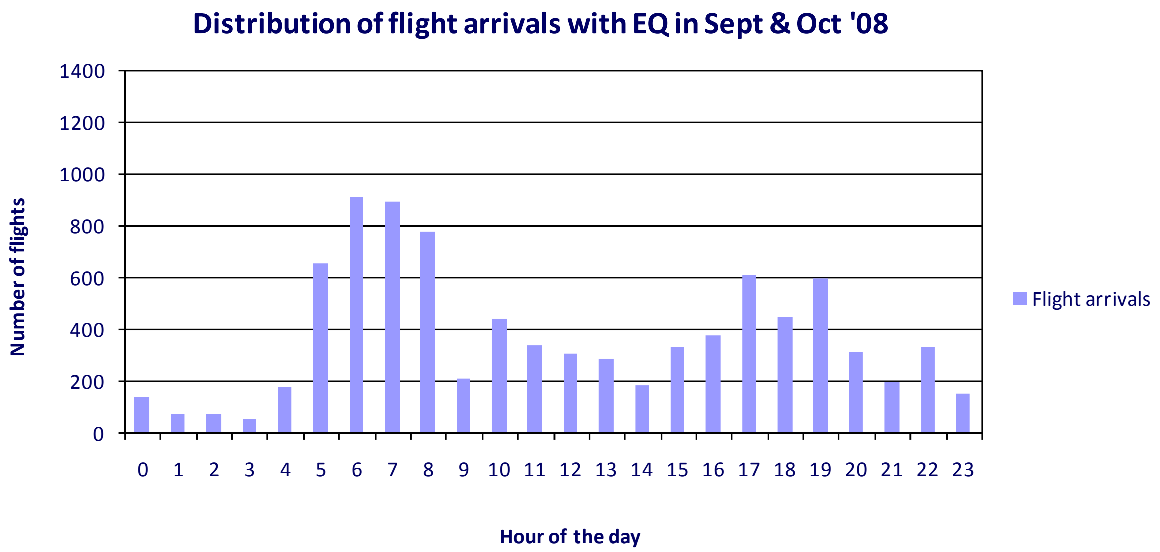


Figure 99: Histogram of the departure pattern of flights with EQ over the day

O Supplement process times estimation

Time measurements were performed for all processes in the operation identified during the conceptualization. The time measurements were all taken by one measurer and the moment to start and stop the stopwatch were applied consequently.
For all process the drivers for occurrence of the process were identified beforehand and validated while measuring times in FB1. Some duration of processes were expected to be correlated with the value of an independent driver. In case a correlation was expected, the values of the independent variable were also registered. For example it was expected that weighing one belly wagon will take less time than weighing five.
When walking around measuring process times raised good opportunities to ask questions about the processes to the employees. The period of collection of data in FB1 was very useful in order to improve the understanding of the operations.

Number of time measurements per process
Due to the large number of different processes, the large duration of some processes and the low frequency of certain processes, it was hard to collect a large number of measurements for each process. In some cases only a couple measurements were obtained, which will have consequences for the estimation of the distribution.

Reaction to measuring of process times
There is a possibility that employees will perform their task in a different way than they are used to, because someone is watching or in this case measuring process times. This effect can be compared to the difference between revealed or stated preference surveys. It was tried to reduce this effect by emphasizing that the measurements would be used to determine their personal performance and that they should do their work just as they normally would do.
For some processes it was possible to measure from a large distance. In this case the employee knew measurements were taken somewhere in FB1, but did not know when the measurements did involve him.
Although the shortcomings of the measurements are apparent and should be interpreted with some caution, there are advantages of the measuring method:

- All measurement were performed by one and the same person, which will ensure consistency
- The measured activities were within eyesight of the person measuring, which does not require the transfer of data from employees to the measurer. Transferring data incorporates the risk of losing information.
- Due to visibility on the performed activities it was possible to take out irregularities immediately. For example when an employee was breaking off his action to drink coffee the measuring was stopped.
- For the processes which are influenced by the integration a large number of measurements were taken. For the processes that will not be influenced by the integration, the resulting bias is present in both situations and will have a relative limited influence on the comparison before and after the integration.

O.1 Time measurements mail operation

Time measurements unloading

Count		Activity	#fte	# of bags	Time excl stops (s)	Total invested time (s)	Time per bag (s)
1	1.2	Unload & scan	1	189	680	680	3,6
4	1.2	Unload & scan	1	62	344	344	5,5
5	1.2	Unload & scan	1	91	213	213	2,3
12	1.2	Unload & scan	1	31	134	134	4,3
2	1.2	Unload & scan	2	52	170	340	6,5
3	1.2	Unload & scan	2	26	120	240	9,2
6	1.2	Unload & scan	2	32	140	280	8,8
7	1.2	Unload & scan	2	299	898	1796	6,0
9	1.2	Unload & scan	2	57	185	370	6,5
10	1.2	Unload & scan	2	67	160	320	4,8
11	1.2	Unload & scan	2	233	653	1306	5,6
13	1.2	Unload & scan	2	49	175	350	7,1
8	1.2	Unload & scan	3	68	170	510	7,5
						average	**6,0**
						minimum	**2,3**
						mode	**6,4**
						maximum	**9,2**

Count		Activity	Time (s)
1	1.3	Move train during unloading	10
1	1.3	Move train during unloading	25
1	1.3	Move train during unloading	45
2	1.3	Move train during unloading	27
3	1.3	Move train during unloading	20
7	1.3	Move train during unloading	20
8	1.3	Move train during unloading	15
11	1.3	Move train during unloading	15
11	1.3	Move train during unloading	17
		average	21,6
		minimum	10,00
		mode	10,00
		maximum	45,00

Count		Activity	#fte	Time (s)
1	1.4	Bring away wagon	1	115
2	1.4	Bring away wagon	1	90
3	1.4	Bring away wagon	1	60
4	1.4	Bring away wagon	1	150
5	1.4	Bring away wagon	1	53
			average	**87,7**
			minimum	**53,0**
			mode	**60,0**
			maximum	**150,0**

Time measurements scanning

Count		Activity	#fte	# of bags	Time (s)	Time per bag (s)
11	2.1	RIM bags	1	1	15	15
12	2.1	RIM bags	1	5	98	19,6
					average	**17,3**

Count		Activity	#fte	Time (s)
1	2.2	Read scanner in office	1	140
2	2.2	Read scanner in office	1	90
3	2.2	Read scanner in office	1	120
			average	**116,7**

Count		Activity	#fte	Time (s)
1	2.3	Bring away wagon	1	115
2	2.3	Bring away wagon	1	90
3	2.3	Bring away wagon	1	60
4	2.3	Bring away wagon	1	150
5	2.3	Bring away wagon	1	53
			average	**87,7**
			minimum	**53,0**
			mode	**60,0**
			maximum	**150,0**

Time measurements sorting

Count		Activity	# FTE	# bags	Time (s)	Time per bag (s)
1	3.1	Sort mailbags	1	16	97	6,1
2	3.1	Sort mailbags	1	35	96	2,7
3	3.1	Sort mailbags	1	3	12	4,0
4	3.1	Sort mailbags	1	3	11	3,7
5	3.1	Sort mailbags	1	5	30	6,0
6	3.1	Sort mailbags	1	12	44	3,7
7	3.1	Sort mailbags	1	2	11	5,5
8	3.1	Sort mailbags	1	4	18	4,5
9	3.1	Sort mailbags	1	2	11	5,5
10	3.1	Sort mailbags	1	12	39	3,3
11	3.1	Sort mailbags	1	72	136	1,9
12	3.1	Sort mailbags	1	11	45	4,1
13	3.1	Sort mailbags	1	21	55	2,6
14	3.1	Sort mailbags	1	5	19	3,8
15	3.1	Sort mailbags	1	17	33	1,9
16	3.1	Sort mailbags	1	21	54	2,6
					average	**3,9**
					minimum	**1,9**
					mode	**3,6**
					maximum	**6,1**

Time measurements carousel

Count		Activity	# bags	Time per bag (s)
2	4.1	Match bag with wagon	1	2
3	4.1	Match bag with wagon	1	4
4	4.1	Match bag with wagon	1	2
5	4.1	Match bag with wagon	1	2
6	4.1	Match bag with wagon	1	2
7	4.1	Match bag with wagon	1	2
8	4.1	Match bag with wagon	8	2,25
9	4.1	Match bag with wagon	1	2
10	4.1	Match bag with wagon	2	3,5
11	4.1	Match bag with wagon	1	3
13	4.1	Match bag with wagon	1	1
16	4.1	Match bag with wagon	2	2,5
17	4.1	Match bag with wagon	1	5
18	4.1	Match bag with wagon	1	4
19	4.1	Match bag with wagon	1	2
20	4.1	Match bag with wagon	1	3
			average	**2,6**
			minimum	**1,0**
			mode	**1,9**
			maximum	**5,0**

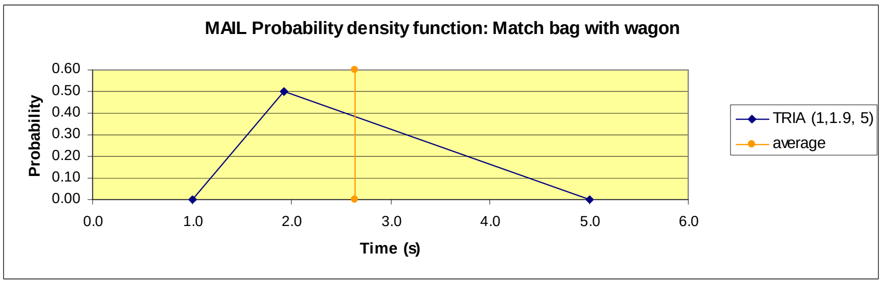


Figure 100: Example of the triangular distribution based on the process time measurements

Count		Activity	# bags	Time per bag (s)
3	4.2	Unload belt	1	3
4	4.2	Unload belt	1	4
5	4.2	Unload belt	1	7
6	4.2	Unload belt	1	6
7	4.2	Unload belt	1	7
8	4.2	Unload belt	1	4
9	4.2	Unload belt	1	12
10	4.2	Unload belt	2	6
11	4.2	Unload belt	1	10
12	4.2	Unload belt	1	6
13	4.2	Unload belt	1	3
14	4.2	Unload belt	4	7,5
17	4.2	Unload belt	1	5
18	4.2	Unload belt	1	11
19	4.2	Unload belt	1	7
			average	**6,6**
			minimum	**3,0**
			mode	**4,7**
			maximum	**12,0**

Time measurements weighing

Count		Activity	# fte	# of wagons	Time (s)
4	5.1	Collecting string	1	1	70
6	5.1	Collecting string	1	2	85
7	5.1	Collecting string	1	1	60
				average	**71.7**
				minimum	**60.0**
				mode	**70.0**
				maximum	**85.0**

Count		Activity	# fte	# of wagons	Time (s)
1	5.2	Weighing wagons (incl. canvas)	1	5	254
3	5.2	Weighing wagons (incl. canvas)	1	3	168
4	5.2	Weighing wagons (incl. canvas)	1	2	165
5	5.2	Weighing wagons (incl. canvas)	1	1	25
6	5.2	Weighing wagons (incl. canvas)	1	2	126
7	5.2	Weighing wagons (incl. canvas)	1	1	80
8	5.2	Weighing wagons (incl. canvas)	1	1	73
				average	**127.3**
				minimum	**25.0**
				mode	**102.9**
				maximum	**254.0**

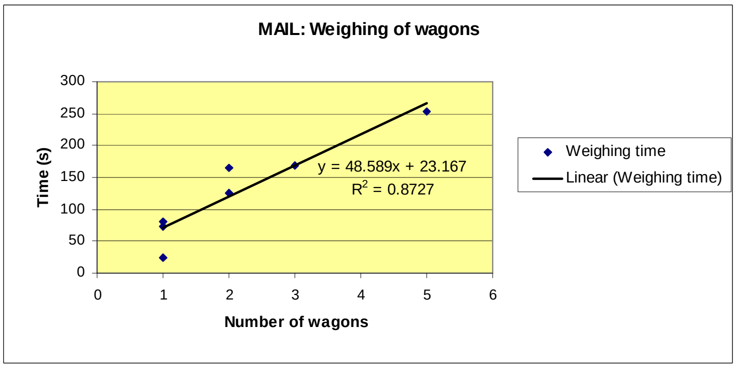


Figure 101: Example of linear regression analysis on the time measurements

Count		Activity	# fte	# of wagons	Time (s)
4	5.3	Retrieve documents	1	2	245
5	5.3	Retrieve documents	1	1	120
6	5.3	Retrieve documents	0	2	0
				average	**121.7**

Count		Activity	# fte	Time (s)
7	5.4	Bring to transportation lane	1	48
6	5.4	Bring to transportation lane	1	50
5	5.4	Bring to transportation lane	1	78
3	5.4	Bring to transportation lane	1	89
4	5.4	Bring to transportation lane	1	145
2	5.4	Bring to transportation lane	1	160
			average	**95.0**
			minimum	**48.0**
			mode	**77.0**
			maximum	**160.0**

Count		Activity	# fte	# of wagons	Time (s)
4	5.5	Replace wagons at the belt	1	1	63
6	5.5	Replace wagons at the belt	1	1	44
7	5.5	Replace wagons at the belt	1	1	180
8	5.5	Replace wagons at the belt	1	2	118
9	5.5	Replace wagons at the belt	1	1	86
				average	**98.2**
				minimum	**44.0**
				mode	**70.6**
				maximum	**180.0**

O.2 Time measurements EQ operation

Time measurements "checker"

Count		Activity	Time (s)
1	1.1	Print stickers/prepare breakdown	75
2	1.1	Print stickers/prepare breakdown	170
4	1.1	Print stickers/prepare breakdown	118.5
7	1.1	Print stickers/prepare breakdown	327
		average	**173**
		minimum	**75**
		mode	**116**
		maximum	**327**

Count		Activity	# load devices	# colli	Time (s)	Time per load device (s)	Time per colli (s)
1	1.2	Count and check AWB's	1		25	25	-
2	1.2	Count and check AWB's	9		377	41.9	-
3	1.2	Count and check AWB's	5		138	27.6	-
4	1.2	Count and check AWB's	9	109	180	20.0	1.65
5	1.2	Count and check AWB's	3	11	40	13.3	3.64
6	1.2	Count and check AWB's	10	208	701	70.1	3.37
7	1.2	Count and check AWB's	5	106	600	120.0	5.66
8	1.2	Count and check AWB's	3		140	46.7	-
9	1.2	Count and check AWB's	6	227	830	138.3	3.66
					average	**55.9**	**3.6**
					minimum	**13.3**	**1.7**
					mode	**16.0**	**3.5**
					maximum	**138.3**	**5.7**

Time measurements "wegrijder"

Count		Activity	Destination	Time (s)
25	2.1	Bring away load devices	alley	102
			constant	**102**

Count		Activity	Destination	Time (s)
15	2.1	Bring away load devices	BOB	110
			constant	**110**

Count		Activity	Destination	Time (s)
1	2.1	Bring away load devices	import	140
6	2.1	Bring away load devices	import	100
7	2.1	Bring away load devices	import	181
22	2.1	Bring away load devices	import	180
23	2.1	Bring away load devices	import	130
29	2.1	Bring away load devices	import	148
33	2.1	Bring away load devices	import	167
36	2.1	Bring away load devices	import	150
47	2.1	Bring away load devices	import	150
9	2.1	Bring away load devices	import	96
			average	**144.2**
			minimum	**96.0**
			mode	**155.6**
			maximum	**181.0**

Count		Activity	Destination	Time (s)
2	2.1	Bring away load devices	lateral	29
3	2.1	Bring away load devices	lateral	58
27	2.1	Bring away load devices	lateral	58
34	2.1	Bring away load devices	lateral	34
35	2.1	Bring away load devices	lateral	56
			average	**47.0**
			minimum	**29.0**
			mode	**54.0**
			maximum	**58.0**

Count		Activity	Destination	Time (s)
38	2.1	Bring away load devices	refridgerator	610
			constant	**610**

Count		Activity	Destination	Time (s)
11	2.1	Bring away load devices	same belly wagon	76
12	2.1	Bring away load devices	same belly wagon	92
13	2.1	Bring away load devices	same belly wagon	73
39	2.1	Bring away load devices	same belly wagon	45
43	2.1	Bring away load devices	same belly wagon	170
			average	**91.2**
			minimum	**45.0**
			mode	**58.6**
			maximum	**170.0**

Count		Activity	Destination	Time (s)
18	2.1	Bring away load devices	storage	80
19	2.1	Bring away load devices	storage	60
26	2.1	Bring away load devices	storage	49
41	2.1	Bring away load devices	storage	104
			average	**73.3**
			minimum	**49.0**
			mode	**66.8**
			maximum	**104.0**

Count		Activity	# colli to sort	# flights	Destination	Time (s)
8	2.1	Bring away load devices	3	3	wagon	174
10	2.1	Bring away load devices	4	4	wagon	310
14	2.1	Bring away load devices		1	wagon	98
17	2.1	Bring away load devices	1	1	wagon	222
20	2.1	Bring away load devices	1	1	wagon	101
21	2.1	Bring away load devices	2	1	wagon	72
28	2.1	Bring away load devices	8	1	wagon	148
30	2.1	Bring away load devices	2	1	wagon	84
40	2.1	Bring away load devices		1	wagon	120
42	2.1	Bring away load devices	2	1	wagon	230
44	2.1	Bring away load devices		1	wagon	180
46	2.1	Bring away load devices	7	1	wagon	130
48	2.1	Bring away load devices	5	1	wagon	110
49	2.1	Bring away load devices	5	1	wagon	104
4	2.1	Bring away load devices		1	wagon	116
5	2.1	Bring away load devices		1	wagon	54
31	2.1	Bring away load devices	2	2	wagon	167
32	2.1	Bring away load devices	2	2	wagon	156
45	2.1	Bring away load devices	4	4	wagon	600
				1	**average**	**140.8**
					minimum	**54.0**
					mode	**58.4**
					maximum	**310.0**

Count		Activity	Destination	Time (s)
24	2.1	Bring away load devices	weighing	57
			constant	**57**

Time measurements breakdown

Count		Activity	# colli	# FTE	# wagons	Time (s)	Total time invested (s)
1	3.1	Break down wagon/pallet	19	3	0	373	1119
2	3.1	Break down wagon/pallet	51	3	1	300	900
3	3.1	Break down wagon/pallet	6	1	0	126	126
4	3.1	Break down wagon/pallet	14	3	0	81	243
5	3.1	Break down wagon/pallet	33	3	1	350	1050
6	3.1	Break down wagon/pallet	64	2	1	276	552
7	3.1	Break down wagon/pallet	21	1	0	220	220
8	3.1	Break down wagon/pallet	42	3	2	530	1590
10	3.1	Break down wagon/pallet	11	2	0	198	396
11	3.1	Break down wagon/pallet	8	3	0	75	225
12	3.1	Break down wagon/pallet	55	3	3	775	2325
13	3.1	Break down wagon/pallet	165	3	5	1094	3282
14	3.1	Break down wagon/pallet	49	1	0	245	245
15	3.1	Break down wagon/pallet	160	3	3	156	468
16	3.1	Break down wagon/pallet	80	3	3	960	2880
17	3.1	Break down wagon/pallet	3	2	0	156	312
18	3.1	Break down wagon/pallet	227	4	4	1740	6960
19	3.1	Break down wagon/pallet	35	2	1	328	656
20	3.1	Break down wagon/pallet	189	4	4	1013	4052
21	3.1	Break down wagon/pallet	16	2	0	292	584

Time measurements "Dwars"

Count		Activity	Wagons to VG2/3	Wagons to VG1	# Coupling FB1	Time (s)
1	4.1	Retrieve cargo from/bring cargo to VG2/3	3	0	2	530
2	4.1	Retrieve cargo from/bring cargo to VG2/3	2	0	1	383
3	4.1	Retrieve cargo from/bring cargo to VG2/3	3	0	1	575
4	4.1	Retrieve cargo from/bring cargo to VG2/3	0	1	0	543
5	4.1	Retrieve cargo from/bring cargo to VG2/3	2	0	1	290
6	4.1	Retrieve cargo from/bring cargo to VG2/3	3	0	1	400
					average	**453.5**
					minimum	**290.0**
					mode	**495.5**
					maximum	**575.0**

Time measurements weighing

Count		Activity	Length train	Time (s)
1	6.1	Collecting train	3	185
2	6.1	Collecting train	5	390
3	6.1	Collecting train	5	245
4	6.1	Collecting train	6	320
5	6.1	Collecting train	6	240
6	6.1	Collecting train	3	146
7	6.1	Collecting train	1	56
8	6.1	Collecting train	1	80
9	6.1	Collecting train	2	173
10	6.1	Collecting train	2	88
11	6.1	Collecting train	3	220
12	6.1	Collecting train	5	185
13	6.1	Collecting train	2	243
16	6.1	Collecting train	1	20
17	6.1	Collecting train	2	160
			average	**183,4**
			minimum	**20,0**
			mode	**185,0**
			maximum	**390,0**

Count		Activity	Length train	Time (s)
1	6.2	Weighing wagons	3	240
2	6.2	Weighing wagons	5	210
3	6.2	Weighing wagons	5	160
4	6.2	Weighing wagons	6	200
5	6.2	Weighing wagons	6	320
6	6.2	Weighing wagons	3	156
7	6.2	Weighing wagons	1	50
8	6.2	Weighing wagons	1	28
9	6.2	Weighing wagons	2	100
10	6.2	Weighing wagons	2	92
11	6.2	Weighing wagons	3	105
12	6.2	Weighing wagons	5	225
13	6.2	Weighing wagons	2	225
15	6.2	Weighing wagons	5	510
17	6.2	Weighing wagons	6	500
			average	**208,1**
			minimum	**28,0**
			mode	**225,0**
			maximum	**510,0**

Count		Activity	Time (s)
1	6.3	Security check with dogs	assumed to be equal to weighing

Count		Activity	Time (s)
12	6.4	Bring to transportation lane	630
13	6.4	Bring to transportation lane	419
14	6.4	Bring to transportation lane	217
15	6.4	Bring to transportation lane	400
16	6.4	Bring to transportation lane	170
		average	**367,2**
		minimum	**170,0**
		mode	**301,6**
		maximum	**630,0**

Count		Activity	Time per wagon (s)
14	6.5	Place new wagons from BD	13,3
		average	**13,3**

Count		Activity	Time per wagon (s)
15	6.6	Place new wagons from outside	40,0
16	6.6	Place new wagons from outside	48,3
		average	**44,2**

Time measurements “Weeg opening”

Count		Activity	Time per wagon (s)
17	7.1	Open wagon & prepare envelops	24,4
		average	**24,4**

Count		Activity	Time per wagon (s)
14	7.2	Place envelops	65,6
17	7.2	Place envelops	57,8
		average	**61,7**

Time measurements "Voorloods"

Count		Activity	Time (s)
1	8.1	Unloading/Loading & check of export/import	193
2	8.1	Unloading/Loading & check of export/import	120
3	8.1	Unloading/Loading & check of export/import	133
4	8.1	Unloading/Loading & check of export/import	310
7	8.1	Unloading/Loading & check of export/import	28
		average	**156,8**
		minimum	**28,0**
		mode	**132,4**
		maximum	**310,0**

Count		Activity	Time (s)
1	8.2	Bring away export cargo	170
2	8.2	Bring away export cargo	556
3	8.2	Bring away export cargo	283
4	8.2	Bring away export cargo	290
5	8.2	Bring away export cargo	258
6	8.2	Bring away export cargo	400
7	8.2	Bring away export cargo	260
		average	**316,7**
		minimum	**170,0**
		mode	**224,1**
		maximum	**556,0**

Count		Activity	Time (s)
2	8.3	Retrieve import products for customers	150
3	8.3	Retrieve import products for customers	75
4	8.3	Retrieve import products for customers	240
5	8.3	Retrieve import products for customers	160
6	8.3	Retrieve import products for customers	170
7	8.3	Retrieve import products for customers	90
9	8.3	Retrieve import products for customers	170
10	8.3	Retrieve import products for customers	80
12	8.3	Retrieve import products for customers	210
13	8.3	Retrieve import products for customers	170
14	8.3	Retrieve import products for customers	110
15	8.3	Retrieve import products for customers	130
		average	**146,3**
		minimum	**75,0**
		mode	**123,8**
		maximum	**240,0**

Count		Activity	Time (s)
8	8.4	Check departing cargo and release to customer	30
11	8.4	Check departing cargo and release to customer	40
12	8.4	Check departing cargo and release to customer	30
13	8.4	Check departing cargo and release to customer	55
14	8.4	Check departing cargo and release to customer	50
15	8.4	Check departing cargo and release to customer	60
		average	**44,2**
		minimum	**30,0**
		mode	**42,5**
		maximum	**60,0**

Count		Activity	# ULD's + type	Time (s)	Time per ULD
4	8.5	Retrieve dolly's	4 dolly's	474	118,5
7	8.5	Retrieve dolly's	1 dolly	100	100
16	8.5	Retrieve dolly's	1 dolly	65	65
				Average	**94,5**

Count		Activity	# ULD's + type	Time (s)	Time per ULD
7	8.6	Load dollies	1 AAP	80	80
4	8.6	Load dollies	3 AKE& 1 AAP	628	157
				Average	**118,5**

Count		Activity	# ULD's	Time (s)
7	8.7	Transport TULDs between Voorloods and airside	1	260
			Average	**260**

Count		Activity	# ULD's	Time (s)	Time per ULD (s)
1	8.8	(Un)loading truck	6	536	89,3
4	8.8	(Un)loading truck	1	170	170,0
5	8.8	(Un)loading truck	1	133	133,0
6	8.8	(Un)loading truck	4	750	187,5
7	8.8	(Un)loading truck	1	234	234,0
8	8.8	(Un)loading truck	1	101	101,0
9	8.8	(Un)loading truck	1	129	129,0
				average	**149,1**
				minimum	**89,3**
				mode	**124,0**
				maximum	**234,0**

O.3 Time measurements transportation department

The distribution of transportation times will differ for the different gates at Schiphol. In general the intercontinental flights will be loaded at gates E and F. The intercontinental destinations are located along the ICA and USA carousel, therefore there is a relation between the carousel and the gates used by the plane. This relation is used to estimate the distributions of the required time to transport the cargo to and from the plane.

Measurements

The time measurements are derived from a survey performed by the employees of the transportation department during their shift in January 2009. The time between the actual arrival time at the gate of the plane and the arrival of the cargo at FB1 is registered. The loading and unloading of the cargo out of and loading into the plane are included in these measurements.

Taking out outliers for transportation time distributions

The performed analysis resembles the technique to estimate the process times for mail and EQ. A triangular distribution was composed based on the measurements as well. Nevertheless for the process time of transportation the top 5%-percentile and the bottom 5%-percentile was left out of the analysis, in order to leave out possible outliers. The measurements for transportation were performed by various employees and they did not leave out exceptions when measuring as was done measuring the process times.

Table 40: Time measurements of cargo transportation from D-gates to FB1 (EUR)

Correction for begin shift	Transport time (min)	Corrected time (min)	origin	Carousel
0:00	0:12	0:12	OTP	1
0:00	0:15	0:15	ZRH	1
0:00	0:18	0:18	KBP	1
0:00	0:20	0:20	BCN	1
0:00	0:20	0:20	DUB	1
0:00	0:21	0:21	MXP	1
0:00	0:23	0:23	LIS	1
0:00	0:25	0:25	LIS	1
0:00	0:25	0:25	MAD	1
0:00	0:25	0:25	KBP	1
0:00	0:25	0:25	LHR	1
0:00	0:25	0:25	SVO	1
0:00	0:25	0:25	CPH	1
0:00	0:30	0:30	WAW	1
0:00	0:30	0:30	DUB	1
0:00	0:30	0:30	MXP	1
0:00	0:30	0:30	CDG	1
0:00	0:30	0:30	BCN	1
0:00	0:30	0:30	MXP	1
0:00	0:30	0:30	ARN	1
0:00	0:31	0:31	WAW	1
0:00	0:32	0:32	HEL	1
0:00	0:33	0:33	MAD	1
0:00	0:33	0:33	ZRH	1
0:00	0:34	0:34	ARN	1
0:00	0:35	0:35	CDG	1
0:00	0:38	0:38	VIE	1
0:00	0:39	0:39	CPH	1
0:00	0:40	0:40	CDG	1
0:00	0:40	0:40	FCO	1
0:00	0:40	0:40	PRG	1
0:00	0:42	0:42	MXP	1
0:00	0:43	0:43	IST	1
0:00	0:45	0:45	FRA	1
0:00	0:46	0:46	CPH	1
0:00	0:47	0:47	GVA	1
0:00	0:50	0:50	FRA	1
0:00	0:50	0:50	KBP	1
0:00	0:53	0:53	SVG	1
0:00	2:10	2:10	VIE	1
	Minimum	**0:18**		
	Maximum	**0:50**		
	Average	**0:32**		

Table 41: Time measurements of cargo transportation from E & F-gates to FB1 (ICA & USA)

Correction for begin shift	Transport time (min)	Corrected time (min)	origin	Carousel
1:14	1:26	0:12	CGK	3
0:00	0:17	0:17	YVR	2
0:00	0:33	0:33	DAR	3
0:00	0:33	0:33	ORD	2
0:00	0:35	0:35	CAI	3
0:00	0:39	0:39	SFO	2
0:51	1:31	0:40	EWR	2
1:00	1:40	0:40	GYE	2
0:00	0:42	0:42	MNL	3
0:00	0:45	0:45	LAX	2
0:00	0:48	0:48	ICN	3
0:21	1:11	0:50	AUH	3
0:22	1:17	0:55	TPE	3
0:34	1:29	0:55	NBO	3
0:37	1:32	0:55	SIN	3
0:00	0:57	0:57	JFK	2
0:00	0:58	0:58	ALA	3
0:00	1:06	1:06	DXB	3
0:00	1:06	1:06	DOH	3
0:00	1:13	1:13	HKG	3
0:00	1:20	1:20	JFK	2
	Minimum	**0:17**		
	Maximum	**1:13**		
	Average	**0:47**		

Transportation time distribution

The time measurements are used to estimate a triangular distribution of the process times. The estimation is executed similar to the estimation of the other process time distribution, as explained in 4.5.3. The only difference is the fact that the top and bottom 5%-percentile are considered outliers.

Table 42: Distribution of transportation times to gate D and to gate E & F

Carousel 1	Transport time	Probability
Min	18	0
Mode	30	0.0625
Max	50	0

Carousel 2&3	Transport time	Probability
Min	17	0
Mode	53	0.036
Max	73	0

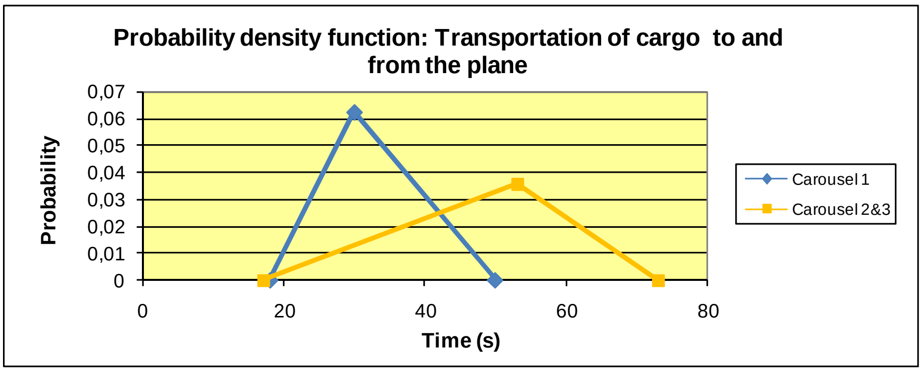


Figure 102: Triangular distribution of the transportation times between the gate and FB1

P Resources in the simulation

P.1 Resources used in the simulation model

Table 43: Mail employee functions modelled as resources

Resources mail	Capacity	Initial capacity
hr_mail_unload	Work schedule mail via alter modules	0
hr_mail_scanning	Work schedule mail via alter modules	0
hr_mail_switching	Work schedule mail via alter modules	0
hr_mail_carousel_EUR	Work schedule mail via alter modules	0
hr_mail_carousel_ICA	Work schedule mail via alter modules	0
hr_mail_carousel_USA	Work schedule mail via alter modules	0
hr_mail_weighing_EUR	Work schedule mail via alter modules	0
hr_mail_weighing_intercontinental	Work schedule mail via alter modules	0

Table 44: EQ employee functions modelled as resources

Resources eq	Capacity	Initial capacity
hr_eq_checker	Work schedule EQ via alter modules	0
hr_eq_bring_away	Work schedule EQ via alter modules	0
hr_eq_break_down	Work schedule EQ via alter modules	0
hr_eq_weigh_opening	Work schedule EQ via alter modules	0
hr_eq_weighbridge	Work schedule EQ via alter modules	0
hr_eq_export_acceptance	Work schedule EQ via alter modules	0
hr_eq_night	Work schedule EQ via alter modules	0
hr_eq_lateral_sorter	Work schedule EQ via alter modules	0
hr_eq_lateral_driver	Work schedule EQ via alter modules	0

Table 45: Equipment modelled as resources in the simulation

Equipment eq & mail	Capacity	Initial capacity
equipment_eq_weighbridge	Fixed Capacity	1
equipment_mail_weighbridge	Fixed Capacity	2
hr_mail_transport	Fixed Capacity	Infinite

The work schedules used in the Arena simulation are based on the new basis for the work schedules of the mail and equation department. Some slight adjustments were made in order to simplify the simulation or to give due weight to the flexibility of the deployment of resources.

P.2 Work schedules mail

Morning shift

As said the basis for the work schedules in the simulation were the new work schedules of KLM Cargo. For the morning shift at the mail department this is the following schedule:

Table 46: New morning shift schedule for mail by KLM Cargo

MORNING SHIFT	SU	MO	TU	WE	TH	FR	SA	Simulated?
Import / incoming control (Registration)	4	4	4	4	4	4	4	yes
Import / incoming control (Sorting)	1,5	1,5	1,5	1,5	1,5	1,5	1,5	yes
Europe	5	5	5	5	5	5	5	yes
Intercontinental	2	2	2	2	2	2	2	yes
Americas	3	3	3	3	3	3	3	yes
Import	1	1	1	1	1	1	1	yes
Export	1	1	1	1	1	1	1	yes
Trucks (loading / unloading)	0	0	0	0	0	0	0	no
Quality / Irregularities	1,5	1,5	1,5	1,5	1,5	1,5	1,5	no
Platform coordinator	1	1	1	1	1	1	1	no
Total	**20**	**20**	**20**	**20**	**20**	**20**	**20**	
Total simulated functions	**16,5**	**16,5**	**16,5**	**16,5**	**16,5**	**16,5**	**16,5**	

This schedule was simplified, because some processes will not be simulated. This is the case for the functions "Import", "Export", "Trucks", "Quality" and "Platform coordinator". The "incoming control" is divided in employees responsible for scanning and employees responsible for the unloading and movement of belly wagons around the input location.

In the evening shift there is no employee scheduled for the function "import" in the basis schedule, but there will be import mailbags taken off the carousel. The number of employees scheduled for the functions "import" and "carousel USA" are combined in the simulation to facilitate the import process in the evening as well. The import wagons are positioned along the USA carousel, therefore the combination with these functions is the best option.

The number of employees scheduled for the "sorting" (or switching in simulation model) function is rounded up towards 2 from 1.5. In the simulation it is not possible to work with half resources therefore it is rounded up towards 2. When the sorting function becomes critical in the process this assumption has to be evaluated.

The weighing of departing belly wagons is also split off from the KLM Cargo schedule for each carousel. For the EUR carousel two persons are made responsible for weighing. One person will be responsible for both the ICA as the USA carousel, this employee is compensated with the number of employees along the USA carousel. This results in the following schedule:

Table 47: Number of mail employees scheduled in the morning shift per function

Function morning	row number	sun	mon	tue	wed	thu	fri	sat
hr_mail_unload	1	2	2	2	2	2	2	2
hr_mail_scanning	2	2	2	2	2	2	2	2
hr_mail_switching	3	2	2	2	2	2	2	2
hr_mail_carousel_EUR	4	3	3	3	3	3	3	3
hr_mail_carousel_ICA	5	2	2	2	2	2	2	2
hr_mail_carousel_USA	6	3	3	3	3	3	3	3
hr_mail_weighing_EUR	7	2	2	2	2	2	2	2
hr_mail_weighing_intercontinental	8	1	1	1	1	1	1	1
	Total	**17**	**17**	**17**	**17**	**17**	**17**	**17**

Evening shift

The bases for the work schedules in the simulation are the new work schedules of KLM Cargo. For the evening shift at the mail department this is the following schedule:

Table 48: New evening shift schedule for mail by KLM Cargo

EVENING SHIFT	SU	MO	TU	WE	TH	FR	SA	Simulated?
Import / incoming control (Registration)	2	2	2	2	2	2	2	yes
Import / incoming control (Sorting)	1	1	1	1	1	1	1	yes
Europe	2	2	2	2	2	2	2	yes
Intercontinental	1	1	1	1	1	1	1	yes
Americas	1,5	1,5	1,5	1,5	1,5	1,5	1,5	yes
Import	0	0	0	0	0	0	0	yes
Export	0	0	0	0	0	0	0	yes
Trucks (loading / unloading)	1	1	1	1	1	1	1	no
Quality / Irregularities	1	1	1	1	1	1	1	no
Platform coordinator	0,5	0,5	0,5	0,5	0,5	0,5	0,5	no
Total	**10**	**10**	**10**	**10**	**10**	**10**	**10**	
Total simulated functions	**7,5**	**7,5**	**7,5**	**7,5**	**7,5**	**7,5**	**7,5**	

In the evening schedule for mail handling the number of employees along the USA carousel is rounded up towards 2 from 1.5 for the same reason as mentioned for the morning shift, the simulation cannot work with half resources. When the workload of the employees along the USA carousel becomes critical in the process this assumption has to be evaluated as well.

For the weighing process only one employee is scheduled for the EUR carousel, instead of two, because otherwise the employees along the belt were reduced to one, which seems very low.

Table 49: Number of mail employees scheduled in the evening shift per function

Function evening	row number	sun	mon	tue	wed	thu	fri	sat
hr_mail_unload	1	1	1	1	1	1	1	1
hr_mail_scanning	2	1	1	1	1	1	1	1
hr_mail_switching	3	1	1	1	1	1	1	1
hr_mail_carousel_EUR	4	2	2	2	2	2	2	2
hr_mail_carousel_ICA	5	1	1	1	1	1	1	1
hr_mail_carousel_USA	6	1	1	1	1	1	1	1
hr_mail_weighing_EUR	7	1	1	1	1	1	1	1
hr_mail_weighing_intercontinental	8	1	1	1	1	1	1	1
	Total	**9**	**9**	**9**	**9**	**9**	**9**	**9**

P.3 Work schedules Equation

The KLM Cargo schedule for the EQ department is simplified as well. The functions "Per afgifte", "Koerier" and "Platform coordinator" are not modeled in the simulation. The functions that are used could almost be taken over one by one. Only some functions were split up into two separate functions in the simulation.

One of the weighing employees in the base schedule was removed at the weighbridge and was made responsible for replacing belly wagons at the storage yard and providing the wagons with the right envelops and labels. The two employees responsible for the lateral cargo transportation and sorting were placed into two special functions, sorting the lateral cargo and transportation of the cargo between FB1 and FB2/3.

Morning shift

The following new work schedule is used by KLM Cargo:

Table 50: New morning shift schedule for EQ by KLM Cargo

MORNING SHIFT	ZO	MA	DI	WO	DO	VRIJ	ZA	Simulated?
CHECKER	2	1	2	2	2	2	2	yes
WEGRIJDER	2	1	2	2	2	2	2	yes
STAPELEN	3	2	3	4	4	4	4	yes
DWARS/UITZOEK	2	2	2	2	2	2	2	yes
WEEG	3	2	3	3	3	3	3	yes
VOORLOODS	2	2	2	2	2	2	2	yes
PER AFGIFTEN	2	2	2	2	2	2	2	no
KOERIER	2	2	2	2	2	2	2	no
PLATFORM COORDINATOR	1	1	1	1	1	1	1	no
TOTAL	**19**	**15**	**19**	**20**	**20**	**20**	**20**	no
Total simulated functions	**14**	**10**	**14**	**15**	**15**	**15**	**15**	

Splitting up the "dwars/uitzoek" and "weeg" results in the following schedule for the relevant functions:

Table 51: Number of EQ employees scheduled in the morning shift per function

Function morning	row number	sun	mon	tu	wed	thu	fri	sat
hr_eq_checker	1	2	1	2	2	2	2	2
hr_eq_bring_away	2	2	1	2	2	2	2	2
hr_eq_break_down	3	3	2	3	4	4	4	4
hr_eq_lateral driver	4	1	1	1	1	1	1	1
hr_eq_lateral bring away	5	1	1	1	1	1	1	1
hr_eq_weigh_opening	6	1	1	1	1	1	1	1
hr_eq_weighbridge	7	2	1	2	2	2	2	2
hr_eq_export_acceptance	8	2	2	2	2	2	2	2
	Total	**14**	**10**	**14**	**15**	**15**	**15**	**15**

Evening shift

The same changes are made to the evening shift schedule as for the morning schedule. KLM Cargo's schedule looks the following:

Table 52: New evening shift schedule for EQ by KLM Cargo

EVENING SHIFT	ZO	MA	DI	WO	DO	VRIJ	ZA	Simulated?
CHECKER	1	1	2	2	2	2	2	yes
WEGRIJDER	2	2	2	2	2	2	2	yes
STAPELEN	2	2	4	4	4	4	4	yes
DWARS/UITZOEK	2	2	2	2	2	2	2	yes
WEEG	2	2	2	2	2	2	2	yes
VOORLOODS	2	2	2	2	2	2	2	yes
PER AFGIFTEN	2	2	2	2	2	2	2	no
KOERIER	2	2	2	2	2	2	2	no
PLATFORM COORDINATOR	1	1	1	1	1	1	1	no
TOTAL	**16**	**16**	**19**	**19**	**19**	**19**	**19**	no
Total simulated functions	**11**	**11**	**14**	**14**	**14**	**14**	**14**	

This results in the following schedule used in the simulation:

Table 53: Number of EQ employees scheduled in the evening shift per function

Function evening	row number	sun	mon	tu	wed	thu	fri	sat
hr_eq_checker	1	1	1	2	2	2	2	2
hr_eq_bring_away	2	2	2	2	2	2	2	2
hr_eq_break_down	3	2	2	4	4	4	4	4
hr_eq_lateral driver	4	1	1	1	1	1	1	1
hr_eq_lateral bring away	5	1	1	1	1	1	1	1
hr_eq_weigh_opening	6	1	1	1	1	1	1	1
hr_eq_weighbridge	7	1	1	1	1	1	1	1
hr_eq_export_acceptance	8	2	2	2	2	2	2	2
	Total	**11**	**11**	**14**	**14**	**14**	**14**	**14**

P.4 Night shift and breaks

Other characteristics of the schedule of the employees in FB1 are listed below:

- The employees at FB1 work in two shifts, one morning shift from 6:00 to 14:30 and one evening shift from 14:30 to 23:00.
- In the simulation model the employees at the weighbridge at mail and EQ are not taking a big break of an hour simultaneously. This represents the responsibilities and the planning of these employees in reality, because they will prepare the cargo for departing flights leaving during their break in advance, they will make sure deadlines are met even during their break period
- It is assumed that the moments and duration of breaks are identical for both departments. The moments and duration of the breaks was observed during the time measuring in FB1, the operational management thinks the measured breaks are longer than the official allowed breaks. The breaks observed in FB1 are used to simulate the operations.
- The night shift at the EQ department has been removed at the end of 2008. The cargo arriving at night will be brought to FB2&3. Here a night shift is working anyhow and they can breakdown the cargo and make sure the EQ will make the flights at night. The EQ which will not fly at night will be brought to the EQ operation in the morning as lateral incoming cargo. In the integrated structure the handling of EQ cargo at night is done at FB2_3, nevertheless the model works with a nightshift in FB1. In the simulation model 5 employees executing the most crucial tasks, resembling the situation in September and October 2008. In Table 54 the scheduled number of employees at night for EQ is displayed.

Table 54: Work schedule night shift at EQ

Function night	all days
hr_eq_checker	1
hr_eq_bring_away	1
hr_eq_break_down	1
hr_eq_weigh_opening	0
hr_eq_weighbridge	1
hr_eq_export_acceptance	2
hr_eq_lateral bring away	0
hr_eq_lateral driver	0

Q Simulation model description

Q.1 ULD transition structure of the simulation model

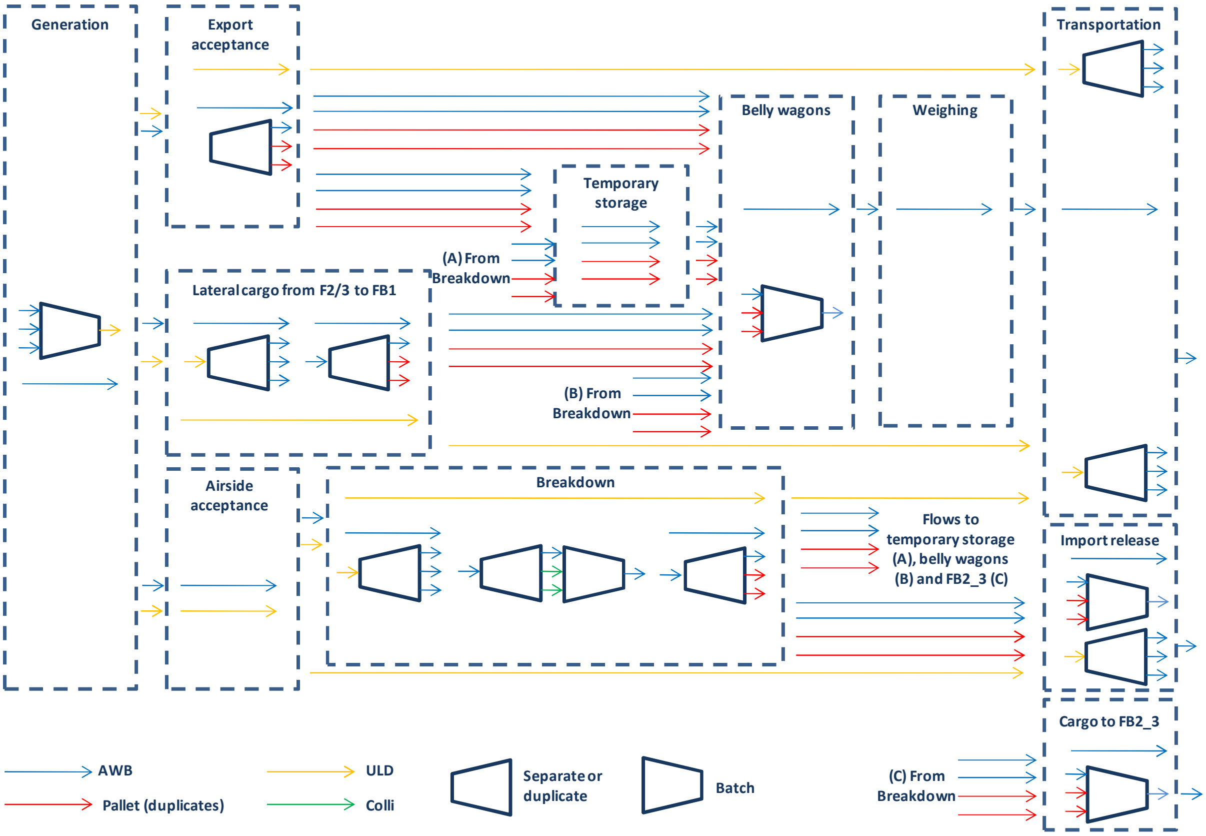


Figure 103: Transition structure between the different load carriers

Q.2 Deadlines prior to the scheduled flight departure of cargo

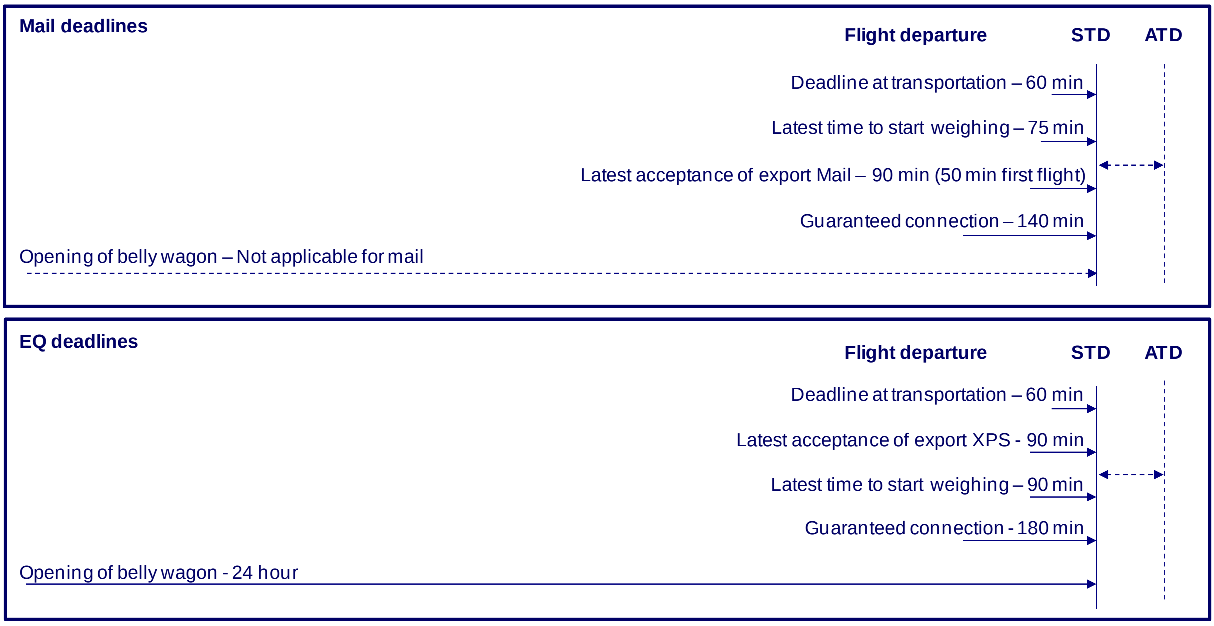


Figure 104: Deadlines prior to the flight departure for mail and EQ

Q.3 Change of the link between cargo and a specific flight

Currently, the link between EQ and arriving flight is based on the arrival time at Schiphol (Figure 105, orange arrows). The cargo is linked with the departing flight on flight index for EQ (Figure 105, red arrow); this is the flight of the booking of the cargo.

In the future the departure of the EQ leaving FB1 will be made on the basis of destination codes (Figure 105, blue arrows). This will work according to the FIFO-principle, as soon as the cargo is waiting along the carousel it can be put on the first flight to its destination, this does not have to be a specific flight.

Entity	Plane_arrival
Attribute	flight_incoming_carrier_code
Attribute	flight_incoming_flightnr
Attribute	flight_incomingATA_month
Attribute	flight_incomingATA_day
Attribute	flight_incomingATA_hour
Attribute	flight_incomingATA_minute

Entity	EQ shipment
Attribute	entity_id
Attribute	product_type
Attribute	flow_code
Attribute	AWB
Attribute	pieces_AWB
Attribute	weight_AWB
Attribute	volume_AWB
Attribute	origin
Attribute	destination
Attribute	incoming_carrier_code
Attribute	incoming_flightnr
Attribute	incomingATA_month
Attribute	incomingATA_day
Attribute	incomingATA_hour
Attribute	incomingATA_minute
Attribute	outgoing_carrier_code
Attribute	outgoing_flightnr
Attribute	outgoingATD_month
Attribute	outgoingATD_day
Attribute	outgoingATD_hour
Attribute	outgoingATD_minute
Attribute	incomingULD_type
Attribute	incomingULD_id
Attribute	outgoingULD_type
Attribute	outgoingULD_id
Attribute	eq_flight_index
Attribute	carousel
Attribute	nr_AWBs_on_TULD
Attribute	STD_month
Attribute	STD_day
Attribute	STD_hour
Attribute	STD_minute

Departing flight with eq	Attribute
Attribute	flight_outgoing_carrier_code
Attribute	flight_outgoing_flightnr
Attribute	STD_month
Attribute	STD_day
Attribute	STD_hour
Attribute	STD_minute
Attribute	eq_flight_index
Attribute	departing_flight_destination
Attribute	departing_flight_destination2
Attribute	departing_flight_destination3
Attribute	flight_outgoingATD_month
Attribute	flight_outgoingATD_day
Attribute	flight_outgoingATD_hour
Attribute	flight_outgoingATD_minute

Integration:
FiFo-principle, based on destination

Figure 105: Links between cargo and flight currently and after the integration

Q.4 Results model verification

Mailbags

					Time registration at departments											
RECP_ID (AWB)	mail_flight_index	final_flight_index	carousel	whole round	actual_arrival	input loactions	switching_table	carousel	wagon_along_carousel	collected	weighbridge	transportation	plane	of_removal	location_removal	missed_booking
15667804	0	0	2	0	1	750.02	750.04	750.05	750.06	0	0	0	0	0	0	0
15667805	0	0	2	0	1	750.36	750.37	750.38	750.45	0	0	0	0	0	0	0
15670892	1318	1319	1	0	1	750.36	750.37	750.39	750.41	752.42	752.43	752.51	753.09	0	0	0
15670893	1558	1326	1	0	1	750.02	750.04	750.06	750.12	752.75	752.77	752.86	753.39	0	0	0
15670894	1629	1364	1	0	1	750.02	750.04	750.06	750.08	755.67	755.68	755.76	756.49	0	0	0
15670895	1614	1436	3	0	1	750.02	750.04	750.06	750.07	763.75	763.77	763.84	764.58	0	0	0
15673001	1561	1561	2	0	1	774.02	774.03	774.04	774.05	782.08	782.1	782.18	783.06	0	0	0
15673002	1561	1561	2	0	1	774.02	774.04	774.04	774.05	782.08	782.1	782.18	783.06	0	0	0
15673003	1561	1561	2	0	1	774.02	774.03	774.04	774.06	782.08	782.1	782.18	783.06	0	0	0
15673004	1566	1566	2	0	1	774.02	774.04	774.05	774.07	782.42	782.5	782.59	783.61	0	0	0

Please note: the actual arrival time was not linked correctly during the verification phase; this was changed before the experiments

Outgoing mail flights

flight_index	Volume storage yard	Weight storage yard	Nr_of pieces storage yard	Nr_of_AWBs storage yard	time_generation_dep_flight	flight_departure	departing_flight_destination	departing_flight_destination2	departing_flight_destination3
1561	0.297	40.1	3	3	759.33	783.33	271	0	0
1319	0.0043	0.5	1	1	729.67	753.67	196	130	0
1326	0.0026	0.3	1	1	730	754	66	184	0
1364	0.0009	0.1	1	1	732.92	756.92	221	0	0
1436	0.007	0.8	1	1	741	765	144	248	0
1566	0.0274	3.7	1	1	759.67	783.67	272	0	0

EQ AWBs

			Time registration at departments												
entity_id	eq_flight_index	final_flight_index	actual_arrival	incoming_lateral_FB2_3	temp_storage	Break down	bellywagon	collected	weighbridge	transportation	plane	arrival_at_FB2_3	import_available_for pickup	of_removal	location_removal
3728	2962	2962	1160.58	0	0	0	0	0	0	1160.75	1161.79	0	0	0	0
3729	2962	2962	1160.58	0	0	0	0	0	0	1160.73	1161.77	0	0	0	0
3730	2962	2962	1160.58	0	0	0	0	0	0	1160.73	1161.77	0	0	0	0
5129	254	286	787.15	0	0	788.02	788.08	799.88	799.96	800.13	800.68	0	0	788.08	3
5130	254	286	787.15	0	0	788.02	788.18	799.88	799.96	800.13	800.68	0	0	788.18	3
5687	944	944	862.13	0	0	862.58	862.66	878.25	878.57	878.73	879.17	0	0	0	0
10089	114	114	756.1	756.1	0	0	756.18	763.65	763.7	763.89	764.94	0	0	0	0
10711	120	120	756.73	0	0	0	756.88	764.23	764.31	764.4	765.16	0	0	0	0
13864	89	89	756.52	0	0	757.17	757.37	760.5	760.53	760.7	761.1	0	0	0	0
15788	2049	0	861	0	0	861.81	0	0	0	0	0	861.96	0	0	0
16152	322	0	756.25	0	0	756.82	0	0	0	0	0	756.96	0	0	0

Outgoing EQ flights

flight_index	open or close	T_opening	T_closing	Volume storage yard	Weight storage yard	Nr_of pieces storage yard	Nr_of_AWBs storage yard	Nr of wagon required storage yard	Volume total	Weight total	Nr_of pieces total	Nr_of_AWBs total	time_generation_dep_flight	flight_departure	departing_flight_destination
286	2	777.38	799.88	0.5	148.6	52	2	1	0.5	148.6	52	2	777.38	801.38	2
120	2	741.73	764.23	0.65	815	51	1	1	0.65	815	51	1	741.73	765.73	17
89	2	738	760.5	1.34	267	50	1	1	1.34	267	50	1	738	762	169
2962	2	1141.72	1164.22	0	0	0	0	1	20.22	2498	5	3	1141.72	1165.72	85
114	2	741.15	763.65	0.1	13	1	1	1	0.1	13	1	1	741.15	765.15	169
944	2	855.75	878.25	0.01	3.5	1	1	1	0.01	3.5	1	1	855.75	879.75	226

Q.5 Comparing KLMs Performance indicators with the model output

For mail and EQ the performance indicators are registered per week in management reports. Although these values seems material which can be use dot validate the performance of the model, it has to be concluded that that these KPI's used by KLM Cargo are not comparable to the simulation outcomes. The following aspects are the causes of the difference between the two:

- The EQ cargo that did not made the first flight will probably be rebooked. The rebooking changed the initial data in Cargoal and this enlarged the time KM Cargo had to handle the cargo. All shipments in the Cargoal database should make the flights, because it is derived from the real flight information. Cargoal will not register the initial reservation.
- The mailbags that will be send back from the plane will go into the process again. The already registered mailbags will be processed again and the data in Trips will be overwritten by the new times. This implies that the data in Trips has a better performance than the performance is in reality.
- As has been noticed during the construction of the model and the input files, there are some cargo flows which are registered in Trips and Cargoal but do not enter FB1 at any time (DHL ULDs and export mail of TNT). These flows skip FB1 on their way to the plane, but will contribute to the performance indicators of KLM, while these are derived from Trips and Cargoal as well. In the model input these flows are taken out of the simulation of FB1 as is reflecting reality. Nevertheless the performance of only the cargo that passes FB1 might be better or worse than the values of the performance indicators of KLM Cargo

R Minutes interview and meetings

R.1 Interview J.J.G. Maarschalk

Date: 22/9/2008
Attendance: J.J.G. Maarschalk (Senior sales manager) and G. van Amstel

Criteria for carrier choice
1. On what criteria will customers base their carrier choice?
- quality (network, handling, do what you promise)
- image (feeling, Dutch have a hands-on mentality , French can do it tomorrow)
- price
- knowledge/professional (SC knowledge, market developments)
- partners in the industry (month-to- month advertisement)
- frequency (daily)
- network
- type of cargo (freighter only (Dangerous goods), odd sizes)

2. What are services are desired by customers?
- After sales/customer service (enquiries, information on connections, suggesting alternatives)
- Frequent conference calls

3. How will customer demand change for the future? (e.g. T&T)
- T & T will become a requirement
- Electronic billing
- Cardid – between sending postal office to receiving postal company, and copy to carrier
- After scanning Restid to the postal office which send the mail
- Local operational employees using for customer service

Customer loyalty
4. How big is customer loyalty for mail?
- The loyalty is decreasing, the offered network, the required time to transport the mail and the costs are becoming more decisive in the choice of the carrier.

5. Is performance important or will loyalty be based on the relation between the sales managers?
- Both, but it is certainly important to perform well in busy periods due to seasonal effects. This results in loyalty for the quiet periods as well.

6. Did the increased costs for air transport result in a decrease in cargo for KLM Cargo?
- No, because the demand for airmail is present anyhow. Seasonal effects are causing fluctuation in the transport demand.

Customer satisfaction
7. Are customers happy with the current performance of KLM Cargo?
- Some are never satisfied
- Tons of airmail are the best estimator of customers satisfaction

8. Who is the mayor competitor of KLM Cargo

- KLM Cargo competes on transit flows. Other well organised handling processes are the competition for KLM Cargo (Frankfurt, Kopenhagen, Wenen (east), upcoming Madrid).

9. Is speed important in the mail handling? When mail will more often miss its flight this will cause customers to go away?
- From some products it will, but reliability is more important. CET (critical entry time)
- CDG process too slow, often they do not make the LAT.
- Customers use the Air mail connections to determine which flight to use for their daily mail. If KLM Cargo offers the connection this will implicit include the speed of the handling process.

Customer communication

10. What performance indicators are communicated with the customers?
- TP, transit performance (performance report)
- Allocation performance (works in two ways)

11. Are all customers paid a yearly visit?
- No not all, it depends on size. Top 25 are visited at least once. Local visits and phone calls. Ad hoc calls from sales, only with a message

Integration

12. Do you expect the mail operations will benefit from the integration?
- Quality should at least be maintained, maybe improved.
- Maybe more feasible flows with mail in combination

13. What would you like to see changed during the integration?
- The dialogue between sales, customer service and operation is important. In general operation must think in solutions.

R.2 Interview N.D.I Aipassa

Date: 3/10/2008
Attendance: N.D.I. Aipassa (Manager Operations of airmail and transportation) and G. van Amstel

General

1. What do you think will be the main bottleneck in the integrated situation for the operations?
- In my opinion there are three pillars in the operation: Manpower, Tools, and Capacity, for all three pillars I think the integration has positive effects due to synergy.
- Nevertheless I think that the safety regulations will become an issue. At this moment the mail operations are closed off, as it should be according to regulations for mail.

2. What do you think will be the main bottleneck in the decision making process?
- I think the integration of the IT will be the bottleneck. Important issue is that Hermes is guiding the operation, instead of the operations are guiding the software, as is the case for Trips.

Space

3. Combining EQ and mail will result in a larger number of destinations, but the space at the present mail operation is limited, how should this be solved in your opinion?

- FIFO-principle will limit the required number of belly wagons for EQ products. When cargo is booked on a specific flight you will need space to store packages which have to wait. Will customers be willing to accept none-booked EQ products?
- With the privatization in the mail industry, the mail and package sorting is performed at the same centres at airports. This will be the case in most developed countries, but some countries still have a strict distinction between the national postal office and the express packages. This will influence the way in which cargo can be shipped from Schiphol and how cargo will arrive at Schiphol. Sometimes the cargo cannot be combined on one wagon.

4. Will a storage rack be a good solution for the shortage of space? (You cannot use the full height of the building, human reach is limiting condition)
- Storage should be avoided; storage is a characteristic of the old situation where cargo is booked on a flight instead of based on destination.
- Indeed humans cannot reach very high, certainly not with heavy packages.

5. Now the EQ flow is working with FLT, while the mail operation is performed manually. How will this be performed in the new situation?
- 85% of the mail is transit flow of mail, this will all arrive in belly wagons or on dollies. This will also imply that it is possible to handle the packages manually, because they are taken out of the plane that way.

6. Will it be important to split priority mail, SAL and EQ for constrained flights?
- At this moment the flows are already separated. SAL mail will be sorted when there are relatively less other mail products to sort, for example in the evening.
- For small loads of SAL mail no exception is made of course.

Labelling

7. What is the share of bags that is not provided with a UPU-label? Is the data available per destination? (Is this the share that has to be rimmed?)
- 15% will not have a proper label; this exists out of a flow form African countries and SAL mail.

Weighing

8. If both products are transported on the same belly wagon. Will this raise difficulties for the weighing process?
- No not immediately. You know exactly what is on the belly wagon because of the exit (outbound) scan.
- Mind scanning at the carousel, the employee has to be next to the wagon which he has opened and put all bags in, after that he can
- At Sodexi there are slopes dedicated for a destination, in that way scanning can be postponed to the moment the bags are put on the wagon from the slope, in that way the bags for one destination are scanned all at once.

9. In what program will the weighing be performed?
- For mail in Trips and for EQ in Cargo 2000. An interface in Hermes in front of these two systems is proposed. But it will all depend on the software choices.

10. Will the weighing people have to work in two programs?
- Not yet decided

11. Especially when some packages are missing?
- Hard to say at this stage of the development?

PI's/Efficiency

12. What are the most important performance indicators for the mail operation?
- Number of failed connections.

13. In what way is this monitored at the moment? How could this be improved?
- It will improve somewhat due to the exit-scan, but the principle will not change fundamentally.

14. What would be desirable in the new situation for the customers?
- not an operational issue

15. What do you think will be the effect of the integration on the performance of the mail operation?
- Hard to say at this stage, but it will not become faster.

16. Will it be beneficial for the performance (and maybe load factor) to separate S.A.L. from the other mail products? Maybe only for the constrained flights?
- This is already the case for large SAL shipments.

17. What effect will the exit scan along the carousels have on the performance of the mail operations?
- Can only become slower, which should be avoided, but it is hard to predict the delay at this stage, the final configuration is not decided upon.

Employees

18. Are employees looking forward to the integration?
- Change is never getting a warm welcome in the lower regions of the organization. They are not happy with the integration, but there is no other choice than to accept the changes.

19. What are the boundary conditions with respect to working conditions?
- UPU says mail should weigh between 25-30 kilograms. In general the bags will be lower.

20. Will the degree to which the operations are accessible for part-time employees be important?
- It would be beneficial when the operation is easy to understand and temporary workers can be easily instructed to do the work. Nevertheless the key activities in the operation will never become the responsibility of part time employees.

R.3 Minutes meeting H.J.F. Deben

Date: 4/11/2008
Attendance: H.J.F. Deben (process planner airmail) and G. van Amstel

Mixed loading

Depends on whether or not the receiving party can handle mixed cargo
Depends on the fact if the flight is "constrained", this can have five causes:
- restriction (reason: short turnaround time at airports)
- pay load critical (reason: often distance to destination (long distance EU))

- cargo vs. mail (more cargo could cause mail to be pushed off)
- Containerized, when containerized for EQ or mail, no mixed loading is possible.
- Fokker 70 or Fokker 100, which have no belly capacity

You do not want to load mixed and one wagon with EQ cannot go on the flight, because you have the possibility that an EQ shipment is not completely in the wagon.

Frequency
Mail destinations are departing every day

Flexibility of employees
Advice Hans: to keep the geographical difference present between the different carousels

Loading on board of the plane
Plane has different compartments. Often this is dedicated to cargo (EQ) or mail and this is put in the plane separately. When live, EQ and Mail is driven to the plane, but the mail did not fit in after all, the mail should be taken out, when this happens whit mixed wagons the ground services will not sort out the mail and EQ, but will send everything back.
In principle cargo is placed with cargo and mail with mail. This could give trouble when brought mixed to the plane. What will be KLM's policy?
Think about unexpected events, what will happen in that case when mixed wagons were brought to the plane? Ground services will probably send all wagons back.

Closing of flights/Planning/Weighing
When the two different products are loaded on the same wagon, it is difficult to close off the wagon for one type of product, because for this product the allotment is reached, while there is still room left for the second product. In this case the flight is closed before one of the two products has reached the allotment. When will the "mail" wagon be closed and when will the "EQ" wagon be closed

Booking
When EQ is loaded FIFO on a flight, it might be necessary to determine if there is enough room for storage at the receiving station

ARBO:
Wagons parallel to belt direction, this will be the safest for the workers unloading the carousel. This is with respect to the easiest way to transfer the bags and with respect to the safety when someone will bump into the belly wagons along the belt.

Transportation
EQ uses chain to communicate with transportation. Mail does not and has a platform coordinator present at the platform which will communicate on the location and the destination(s) of the wagon of one train just brought to a lane at transportation.

Possible solution:
Locate a collection wagon at every carousel used for several small destinations at the conveyor belt. This wagon will be monitored by an employee, which will sort out the wagon to small wagons build up at different area at the mail department. This would imply that the empty containers are not stored inside anymore and TNT export has to be stored outside or near the input locations as well.

S Visit to Sodexi at Charles de Gaulle airport, Paris

S.1 Minutes visit

Date: 28/1/2009
Location: Charles de Gaulle airport, Paris

Integration design

- Destinations have a unique location at a conveyor system exit, this is static
- Transit cargo is transported to the opened container at the shoot directly after input (FIFO)
- 600 arrivals & departures per day serving +/ 240 destinations
- Separate department for valuables, human remains and animals, just like at Schiphol
- Lateral transport between G1XL and Sodexi is exceptional
- A90 min V90min, including transport to the gates of min. 30 minutes
- Some locations are equipped with weigh locations for the opened containers
- Weight of the ULDs is determined by the weight of the AWB * # of AWBs
- 80% transit
- Odd sizes are brought to the container directly by a special employee
- Ration of bulk is less than in Amsterdam, in general ULDs are used
- Max weight of collo via the belt is 50 kilograms

Conditions

- All colli are labelled for EQ
- Mail without barcode is labelled only with destination
- No bookings are made, FIFO is applied in all aspects of the handling process

Software packages

- Gioppi, transportation planning
- Gedephy, warehouse system
- Pelican is Air France's counterpart of Cargoal

Implementation and start-up

- Integration of mail and equation was realized three years ago. This caused problems the first three months
- Customers were prepared for the expected start-up problems at the start of the integration
- Problems did occur relating to the employees and the changes of their responsibilities
- When you change your process do it all at once. Sodexi advices to make rigorous changes all at once, instead of adapting incrementally

Effects of the integration

- Improvements of the coordination of tracking and tracing of the cargo
- Increased performance of the transportation department (especially at CDG due to the large distance between Sodexi and the gates)
- Higher load factor due to mixed loading
- Early notification of errors (e.g. missing collo at arrival at CDG)

Export acceptance

- The labels are attached by the customer themselves at the export acceptance

- No employees in normal cases
- Heavy export will be transported directly to the opened container
- Customer will put the export cargo on the input belt
- External company is responsible for x-ray
- Export cargo is going in the process by a belt. Every export packages is scanned simultaneously
- Customer can weigh his packages at Sodexi when required

Mail
- Export mail is not handled by Sodexi, this is responsibility of La Poste. This is similar to the Dutch situation.
- Mailbags are not labelled by Sodexi, because it is too time consuming

Transportation
- GPS system for tracking and tracing of trucks
- Communication with truck driver under way
- Flexible and able to make last minute changes
- Program optimizes the load factor of the trucks by combing the load of different flights

Customers
- Customer are made aware of the benefits of labelling and full documentation
- No booking of cargo, but when customer is important Sodexi will anticipate on desires of the customer when the customer contacts Sodexi.

Process
- No weighbridge in normal procedure, because weight is known
- Splitting up an AWB is not a problem, large size collo can be shipped to opened container immediately, other collo of AWB can use the belt system
- Special labelling locations for EQ packages
- Belt system contains +/ 10 shoots. Around one shoot there are eight locations to place a ULD
- Sodexi is operation 24 hours a day, 7 days a week
- Last shoot is used for mail and destinations with low weight/volume

Import
Import cargo is brought to the import release racks by special employee

Input locations
Two scan moments, first scan is an entry scan, second scan confirms the location on the belt

S.2 Photos Sodexi

Figure 106: Packages on the automated sorter belt of Sodexi

Figure 107: View on the slides of the shoot with ULDs around it

Figure 108: Roller cages at the end of the last shoot of the sorter system

T Specification of the differences between the simulation models

In this appendix the changes between the four simulation models are specified. The changes in the simulation model are based on the required changes identified in the integration proposal in paragraph 6.3.2.

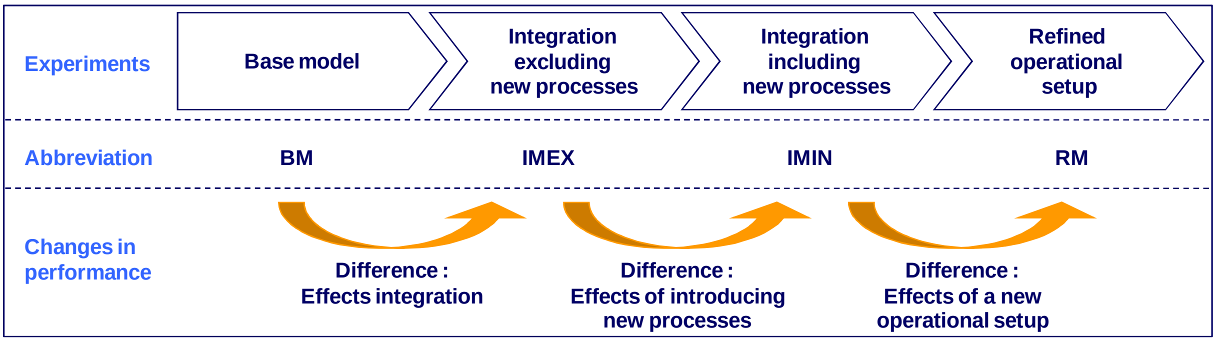


Figure 109: Sequence of simulation experiments

Differences in Arena simulation between BM and IMEX

The differences between the BM and IMEX model contain most the most fundamental changes of the integration project.

- The packages of small export shipments are loaded on a conveyor belt, which will transport them to the sorting station of the mail department.
- The period between the collection of cargo at the mail department and the flight departure is changed from 75 minutes to 90 minutes.
- The new transportation times of the extended conveyor belt system are inserted (as mentioned in paragraph 4.5.3)
- The small EQ shipments are divided into collo. These shipments are gathered per shipment before allowed on the belly wagon along the carousel. This resembles the aim of KLM Cargo is to avoid part shipments. The planner is responsible for the collection of all collo. The data from the exit scan can help the planners in the future.
- The FIFO-principle is introduced at the EQ department. This implies that the cargo at the storage yard is searched on destination, instead of a corresponding flight code.
- Belly wagons are only opened and positioned at the EQ storage yard, when cargo will arrive for the specific destination.
- The transport from the mail department to the transportation department will included the security check.
- All flights used by mail and EQ in the base case are made accessible for both products in IMEX.
- The time required for the transportation from the mail department to the transportation department is increased and assumed to be equal to the current time for this process at EQ department.
- The USA carousel is extended, which implies the time required to make a round is extended by 50% to 6 minutes. The distribution of the required time from the arrival at the carousel to the right wagon at the USA carousel becomes a uniform distribution with a minimum of 0 and a maximum of 6 minutes.
- Removal of the temporary storage.

Assumptions

- Mail and EQ will be brought in separately when arrived by plane.

- Lateral cargo is sorted out and brought to one of the input locations by the lateral sorter and this will take same time as the trip to the belly wagons at the storage yard in the base case.

Differences in Arena simulation between IMEX and IMIN

To transform the IMEX model to the IMIN model all new processes have to be added to the simulation in Arena. This incorporates the following changes to IMEX:

- The labelling of all **small** lateral incoming, transit and export collo with IATA 606(B) labels in case the collo is not labelled with an IATA606(B) yet by the forwarders, FB2/3 or the outstations. The labelling process is assumed to take 10 second minimally and 1 minute maximally. The process time increases proportionally form 10 seconds (1 collo) to 60 seconds (35 collo, the maximum of one small EQ shipment).
- The labelling of all mailbags which are RIM-ed manually currently. The process time of the labelling process is modelled by adding 10 seconds to the old process time distribution of RIM-ing.
- Bringing in the scanner to upload the data will not be required anymore because the scanners will send the captured data to Trips wireless; therefore the uploading process is removed.
- Add entry scan at the input locations for EQ cargo, mail is already scanned in the base case. The process time of the entry scan for EQ is assumed to be equal to the
- Adding the exit scan when collo (mail and small EQ) will leave the carousel This new process resembles the current unload and scan process at the mail input locations and therefore these process times are used to model the exit scan.

Differences between BM and RM

The configuration of RM will be based on the simulation results of the modelling of the first three models. These results have showed the refinement of the current situation might be worthwhile to investigate, instead of the refinement of the integrated situation. This requires a modification of the sequence of experiments, because the RM will be comparable to the BM. Figure 110 illustrates the resulting comparison which is the subject of paragraph 7.9.

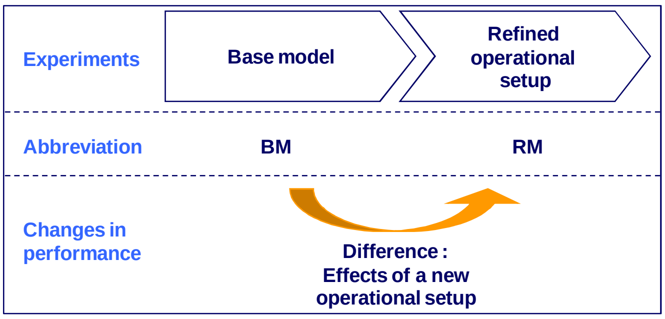


Figure 110: Modified sequence of experiments with respect to the refined model

The specific differences between the BM and RM are:

- All flights used by mail and EQ in the base case are made accessible for both products in RM.
- The period between the collection of cargo at the mail department and the flight departure is changed from 75 minutes to 90 minutes.
- The FIFO-principle is introduced at the EQ department. This implies that the cargo at the storage yard is searched on destination, instead of a corresponding flight code.
- Removal of the temporary storage.

U Pie charts EQ shipment size

U.1 Data used to make the division in the different shipment sizes

Table 55: Data used to determine the division of shipment sizes

Flow	Shipment size	Via belt?	AWBs (#)	AWBs (% of total)	Weight (kg)	Weight (% of total)
Export (loose) Small shipment	small	yes	6458	17.82%	151668	**3.63%**
Export (loose) Large shipment	large	no	1435	3.96%	542686	12.99%
Export (ULD)	large	no	209	0.58%	270277	6.47%
Transit (Loose) Small shipmet	small	yes	10824	29.87%	282866	**6.77%**
Transit (Loose) Large shipment	large	no	1592	4.39%	234637	5.61%
Transit (ULD)	large	no	34	0.09%	38105	0.91%
Import	-	no	7417	20.47%	1802633	43.14%
Lateral (Loose) Small shipment	small	yes	2525	6.97%	109377	**2.62%**
Lateral (Loose) Large shipment	large	no	1159	3.20%	357659	8.56%
Lateral in (ULD)	large	no	3	0.01%	5994	0.14%
Lateral out	-	no	4579	12.64%	383003	9.17%
Total			**36235**	**100.0%**	**4178905**	**100.0%**

U.2 Division of shipment size of export EQ

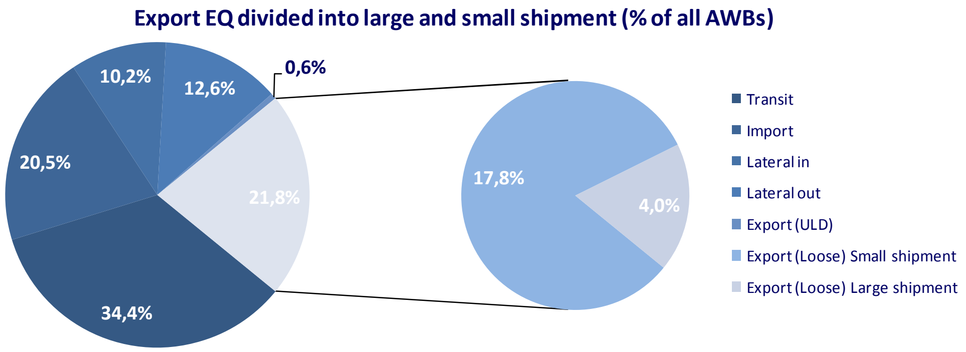


Figure 111: Sub-division of export EQ in shipment size based on number of AWBs

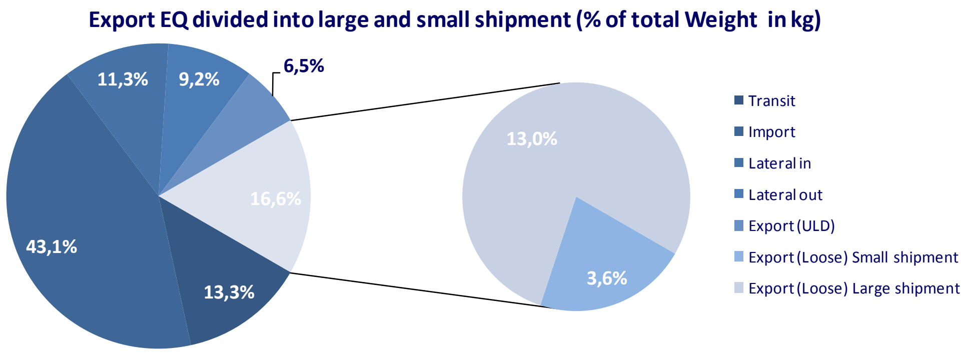


Figure 112: Sub-division of export EQ in shipment size based on weight

U.3 Division of shipment size for transit EQ

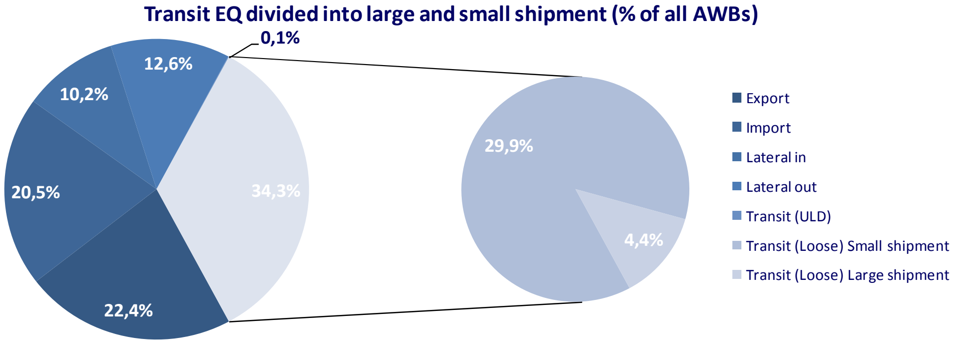


Figure 113: Sub-division of transit EQ in shipment size based on number of AWBs

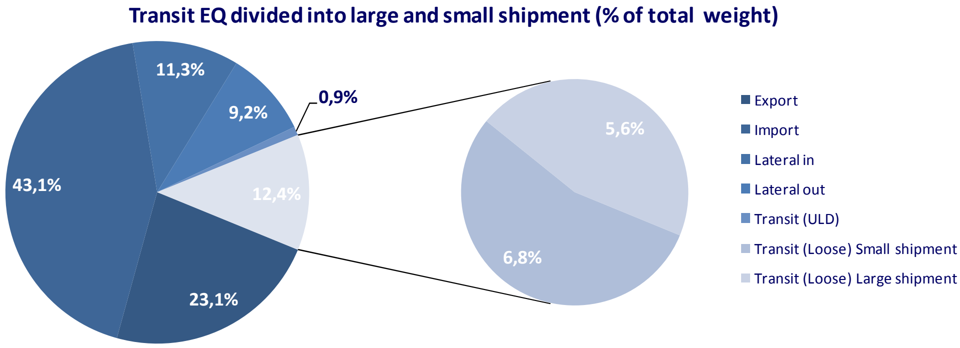


Figure 114: Sub-division of transit EQ in shipment size based on weight

U.4 Division of shipment size for lateral incoming cargo

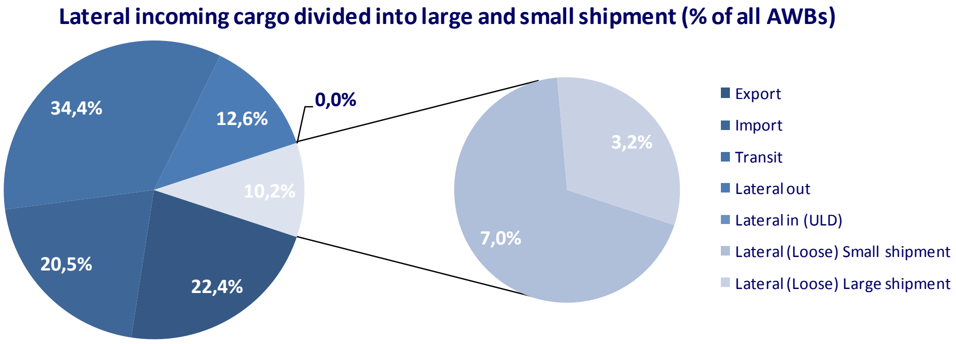


Figure 115: Sub-division of lateral incoming EQ in shipment size based on number of AWBs

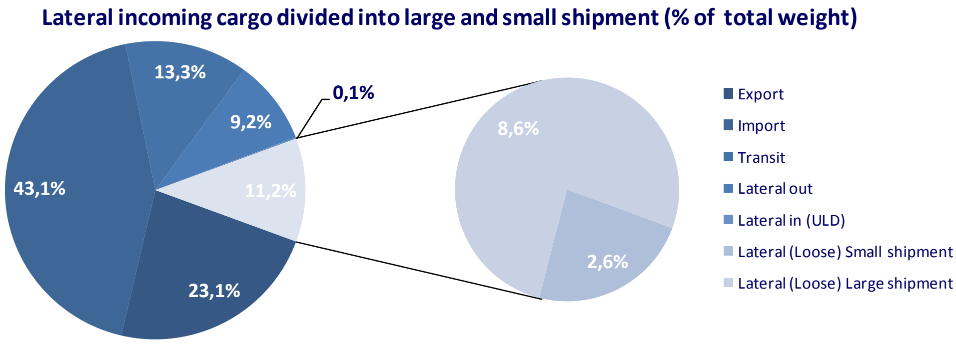


Figure 116: Sub-division of lateral incoming EQ in shipment size based on weight

V Location FB1 at Schiphol airport

V.1 Location of FB1 at the Schiphol airport premises

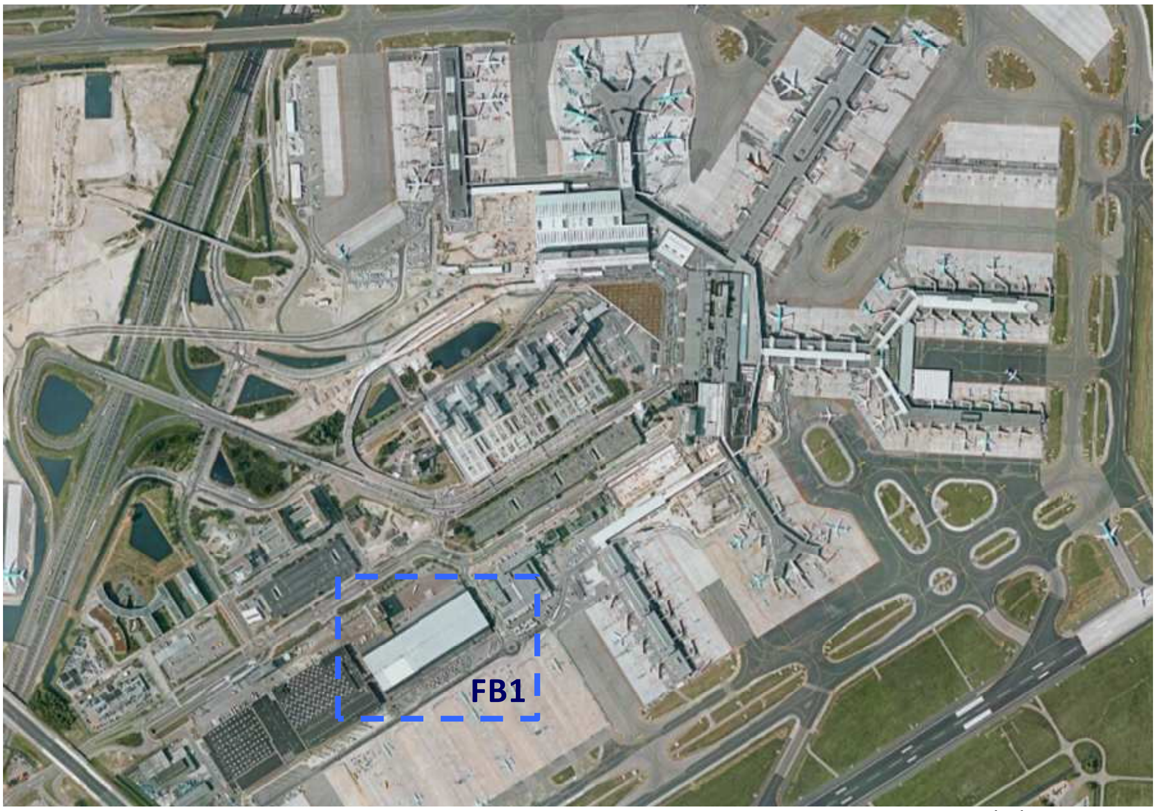


Figure 117: Top view of Schiphol airport with FB1 in the dashed blue square (Google earth, 1/3/2009)

V.2 Gates at Schiphol

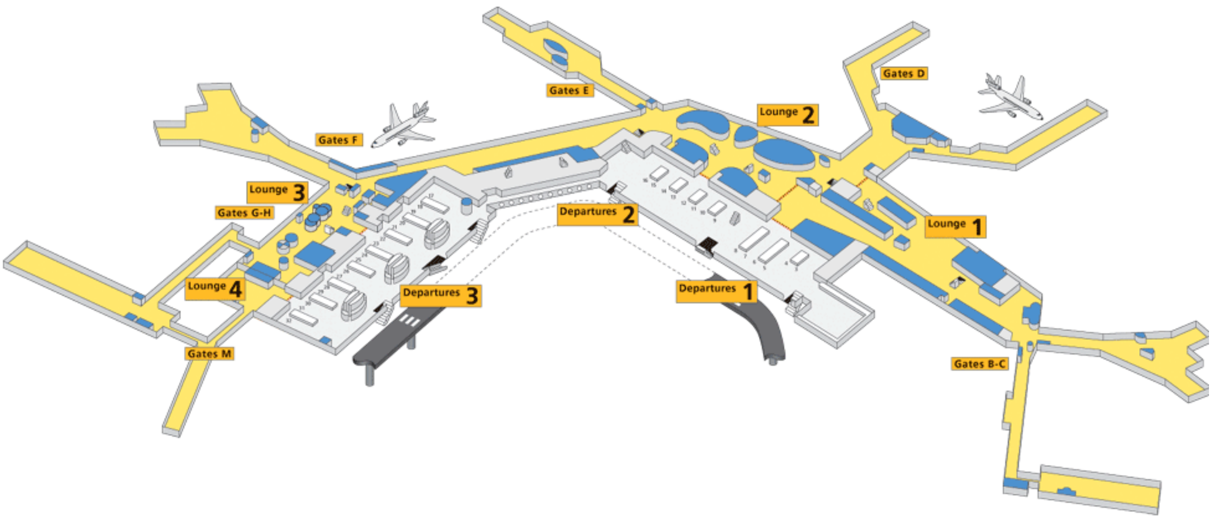


Figure 118: Overview of the gates used for departures at Schiphol airport (www.schiphol.nl, 1/3/2009)

W Current wagon allocation along the carousels

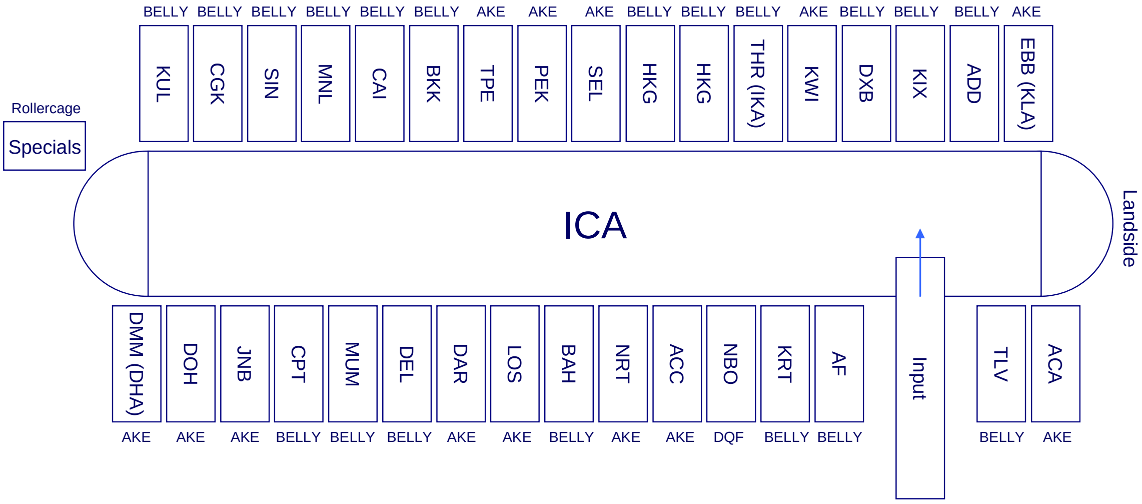


Figure 119: Airport codes of the belly wagon destinations at ICA carousel

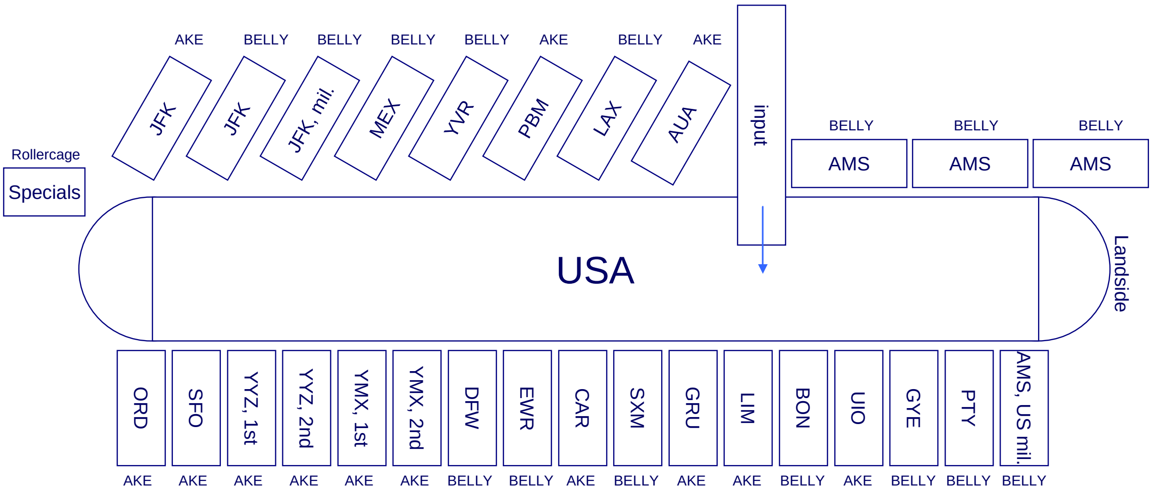


Figure 120: Airport codes of the belly wagon destinations at USA carousel

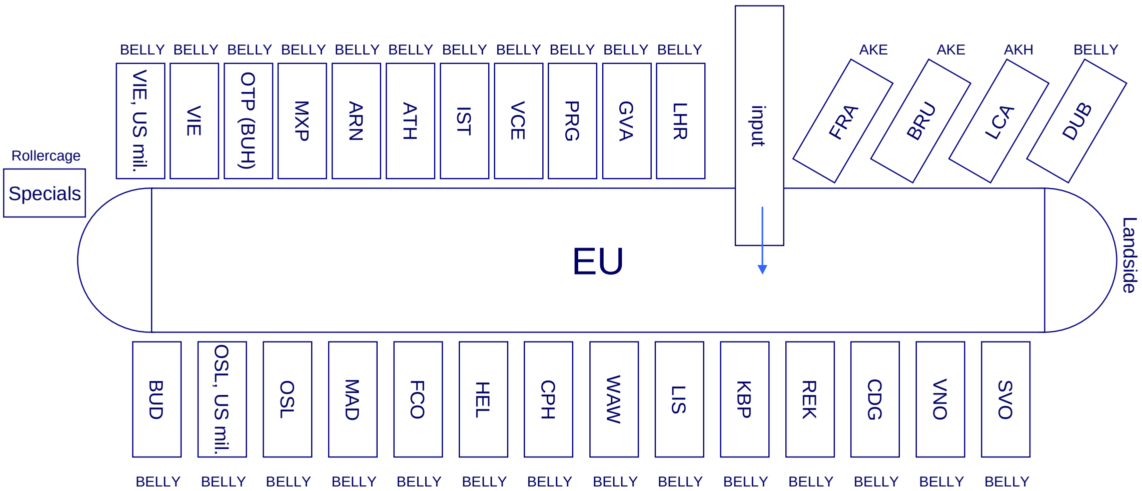


Figure 121: Airport codes of the belly wagon destinations at EU carousel

X Results sensitivity analyses

The displayed results of the base case of the sensitivity analyses were simulated with an old work schedule and therefore differ slightly from the final results discussed in chapter 5 & 7 for which most recent work schedules are used.

X.1 Results sensitivity analyses base model

Table 56: Results of the sensitivity analysis; increased transport time by 15% and growth of mail (+12,5% and EQ (25%) quantities

Performance indicators	BM	Change to BM	Transport (+15%)	Change to BM	Growth (EQ:+25%,MAIL: +12,5%)
Resource usage mail	**Average**	**Change**	**Average**	**Change**	**Average**
hr_mail_unload	**0.71**	0%	**0.71**	9%	**0.77**
hr_mail_scanning	**0.70**	0%	**0.70**	11%	**0.78**
hr_mail_switching	**0.29**	0%	**0.29**	13%	**0.33**
hr_mail_carousel_EUR	**0.19**	0%	**0.19**	13%	**0.22**
hr_mail_carousel_ICA	**0.21**	0%	**0.21**	12%	**0.24**
hr_mail_carousel_USA	**0.16**	0%	**0.16**	11%	**0.18**
hr_mail_weighing_EUR	**0.41**	-1%	**0.41**	5%	**0.43**
hr_mail_weighing_intercontinental	**0.49**	0%	**0.49**	8%	**0.53**
equipment_mail_weighbridge	**0.13**	0%	**0.13**	4%	**0.14**
Resource usage eq	**Average**	**Change**	**Average**	**Change**	**Average**
hr_eq_checker	**0.23**	0%	**0.22**	4%	**0.23**
hr_eq_bring_away	**0.28**	0%	**0.28**	23%	**0.35**
hr_eq_break_down	**0.36**	0%	**0.36**	13%	**0.41**
hr_eq_weigh_opening	**0.31**	0%	**0.31**	4%	**0.32**
hr_eq_weighbridge	**0.45**	0%	**0.45**	0%	**0.45**
hr_eq_export_acceptance	**0.41**	0%	**0.40**	22%	**0.49**
hr_eq_lateral_sorter	**0.37**	0%	**0.36**	8%	**0.39**
hr_eq_lateral_driver	**0.26**	1%	**0.27**	2%	**0.27**
equipment_eq_weighbridge	**0.21**	0%	**0.21**	-1%	**0.21**
Handling times mail dep	**Average**	**Change**	**Average**	**Change**	**Average**
Time between arrival input location - ready in belly wagon	**0.39**	-1%	**0.39**	31%	**0.51**
Export - Time between arrival input location - ready in belly wagon	***0.20***	-8%	***0.18***	37%	***0.27***
Transit - Time between arrival input location - ready in belly wagon	***0.41***	-1%	***0.40***	30%	***0.53***
Import - Time between arrival input location - ready in belly wagon	***0.31***	-2%	***0.30***	40%	***0.43***
Time between ready in belly wagon - collection	**7.31**	1%	**7.34**	1%	**7.35**
Time between collection - ready at transport	**0.16**	0%	**0.16**	0%	**0.16**
Average turnaround time mail; arrival FB1 -ready at transport	**8.04**	2%	**8.18**	2%	**8.20**
Average turnaround time mail STA-ATD plane	**10.03**	3%	**10.28**	2%	**10.21**
Handling times eq dep	**Average**	**Change**	**Average**	**Change**	**Average**
Time between export acceptance EQ - ready in belly wagon at EQ	**0.33**	-1%	**0.32**	46%	**0.48**
Time between arrival breakdown - ready in belly wagon at EQ	**2.76**	-1%	**2.75**	4%	**2.87**
Time between arrival breakdown - ready in belly wagon at EQ	**0.43**	1%	**0.44**	29%	**0.56**
Time between arrival breakdown - ready at import EQ	**0.38**	1%	**0.39**	22%	**0.47**
Time between ready in belly wagon - collection	**8.63**	0%	**8.59**	-1%	**8.57**
Export	***7.54***	0%	***7.55***	-2%	***7.42***
Transit	***9.53***	-1%	***9.45***	0%	***9.52***
Lateral	***8.41***	0%	***8.41***	0%	***8.41***
Time between collection - ready at transport	**0.29**	-2%	**0.28**	1%	**0.29**
Average turnaround time eq FB1	**15.10**	-5%	**14.36**	-4%	**14.49**
Average turnaround time eq FB1 ATA-ATD plane	**16.58**	0%	**16.633**	0%	**16.65**
Handling times eq SMALL	**Average**	**Change**	**Average**	**Change**	**Average**
Time between export acceptance EQ - belly wagon at Mail department	**n.a.**	n.a.	**n.a.**	n.a.	**n.a.**
Time between arrival breakdown - ready in belly wagon at Mail department	**n.a.**	n.a.	**n.a.**	n.a.	**n.a.**
Average turnaround time eq FB1	**n.a.**	n.a.	**n.a.**	n.a.	**n.a.**
Average turnaround time eq ATA-ATD plane	**n.a.**	n.a.	**n.a.**	n.a.	**n.a.**
Number of mailbags flown on earlier flight	**Average**	**Change**	**Average**	**Change**	**Average**
Number of export mailbags collected to fly on earlier flight	**123**	1%	**125**	5%	**129**
Number of transit mailbags collected to fly on earlier flight	**16847**	-5%	**16000**	7%	**18097**
Sum of mailbags flown on earlier flight	**16970**	-5%	**16125**	7%	**18226**
Number of re-bookings for EQ flown on earlier flight	**Average**	**Change**	**Average**	**Change**	**Average**
Number of rebookings of SMALL export EQ collected to fly on earlier flight	**n.a.**	n.a.	**n.a.**	n.a.	**n.a.**
Number of rebookings of SMALL transit EQ collected to fly on earlier flight	**n.a.**	n.a.	**n.a.**	n.a.	**n.a.**
Number of rebookings of EQ collected to fly on earlier flight	**n.a.**	n.a.	**n.a.**	n.a.	**n.a.**
Export	**n.a.**	n.a.	**n.a.**	n.a.	**n.a.**
Transit	**n.a.**	n.a.	**n.a.**	n.a.	**n.a.**
Lateral in	**n.a.**	n.a.	**n.a.**	n.a.	**n.a.**
Sum of rebookings for EQ flown on earlier flight					
Missed flights mail	**Average**	**Change**	**Average**	**Change**	**Average**
Number of mailbags which will miss flight at collection	**1608**	14%	**1828**	-86%	**223**
Number of mailbags which will miss flight at transportation	**4030**	91%	**7695**	66%	**6683**
Sum of mailbags which will miss made flight	**5638**	69%	**9522**	22%	**6906**
Missed bookings EQ	**Average**	**Change**	**Average**	**Change**	**Average**
Number of EQ AWBs that will miss their booked flight due to flight closing	**89**	1%	**90**	19%	**106**
Number of EQ AWBs that will miss their booked flight at transportation	**46**	324%	**193**	11%	**51**
Number of EQ AWBs that will miss their booked flight at mail at collection	n.a.	n.a.	**n.a.**	n.a.	**n.a.**
Number of EQ AWBs that will miss their booked flight at mail at transportation	n.a.	n.a.	**n.a.**	n.a.	**n.a.**
Sum of missed EQ bookings	**134**	111%	**283**	16%	**156**
Space requirments mail	**Average**	**Change**	**Average**	**Change**	**Average**
Maximum number of locations required at mail in simulation	**81**	-1%	**80**	0%	**80**
Space requirments EQ	**Average**	**Change**	**Average**	**Change**	**Average**
Maximum number of locations required at eq in simulation	**189**	-1%	**187**	3%	**194**

X.2 Results sensitivity analysis of the integration situation

Table 57: Results of the sensitivity analysis with 10% exceptions in small EQ shipments after integration

Performance indicators	IMIN	Change	Exceptions (10%)
Resource usage mail	**Average**	**Change**	**Average**
hr_mail_unload	**0.71**	0%	**0.71**
hr_mail_scanning	**0.69**	0%	**0.69**
hr_mail_switching	**0.34**	-1%	**0.34**
hr_mail_carousel_EUR	**0.37**	-2%	**0.37**
hr_mail_carousel_ICA	**0.40**	-1%	**0.39**
hr_mail_carousel_USA	**0.29**	-1%	**0.29**
hr_mail_weighing_EUR	**0.68**	-1%	**0.67**
hr_mail_weighing_intercontinental	**0.83**	-1%	**0.82**
equipment_mail_weighbridge	**0.18**	-1%	**0.17**
Resource usage eq	**Average**	**Change**	**Average**
hr_eq_checker	**0.23**	-1%	**0.23**
hr_eq_bring_away	**0.15**	11%	**0.16**
hr_eq_break_down	**0.38**	0%	**0.38**
hr_eq_weigh_opening	**0.10**	33%	**0.13**
hr_eq_weighbridge	**0.24**	22%	**0.29**
hr_eq_export_acceptance	**0.23**	8%	**0.24**
hr_eq_lateral_sorter	**0.23**	-1%	**0.23**
hr_eq_lateral_driver	**0.27**	0%	**0.27**
equipment_eq_weighbridge	**0.12**	21%	**0.14**
Handling times mail dep	**Average**	**Change**	**Average**
Time between arrival input location - ready in belly wagon	**0.52**	-1%	**0.51**
Export - Time between arrival input location - ready in belly wagon	***0.31***	-5%	***0.30***
Transit - Time between arrival input location - ready in belly wagon	***0.53***	-1%	***0.53***
Import - Time between arrival input location - ready in belly wagon	***0.42***	-1%	***0.41***
Time between ready in belly wagon - collection	**7.09**	0%	**7.09**
Time between collection - ready at transport	**0.29**	-1%	**0.29**
Average turnaround time mail; arrival FB1 -ready at transport	**8.02**	0%	**8.04**
Average turnaround time mail STA-ATD plane	**10.15**	0%	**10.18**
Handling times eq dep	**Average**	**Change**	**Average**
Time between export acceptance EQ - ready in belly wagon at EQ	**0.22**	0%	**0.22**
Time between arrival breakdown - ready in belly wagon at EQ	**n.a.**	n.a.	**n.a.**
Time between arrival breakdown - ready in belly wagon at EQ	**0.38**	-7%	**0.35**
Time between arrival breakdown - ready at import EQ	**0.34**	-1%	**0.34**
Time between ready in belly wagon - collection	**6.88**	3%	**7.12**
Export	***6.79***	-1%	***6.72***
Transit	***8.69***	2%	***8.84***
Lateral	***4.30***	0%	***4.29***
Time between collection - ready at transport	**0.24**	4%	**0.25**
Average turnaround time eq FB1	**9.94**	-5%	**9.45**
Average turnaround time eq FB1 ATA-ATD plane	**11.45**	1%	**11.62**
Handling times eq SMALL	**Average**	**Change**	**Average**
Time between export acceptance EQ - belly wagon at Mail department	**0.36**	5%	**0.38**
Time between arrival breakdown - ready in belly wagon at Mail department	**0.71**	1%	**0.71**
Average turnaround time eq FB1	**9.91**	0%	**9.88**
Average turnaround time eq ATA-ATD plane	**12.12**	0%	**12.09**
Number of mailbags flwon on earlier flight	**Average**	**Change**	**Average**
Number of export mailbags collected to fly on earlier flight	**140**	3%	**145**
Number of transit mailbags collected to fly on earlier flight	**18920**	0%	**18910**
Sum of mailbags flown on earlier flight	**16970**	12%	**19055**
Number of re-bookings for EQ flown on earlier flight	**Average**	**Change**	**Average**
Number of rebookings of SMALL transit EQ collected to fly on earlier flight	**346**	-11%	**310**
Number of rebookings of SMALL export EQ collected to fly on earlier flight	**755**	-10%	**679**
Number of rebookings of EQ collected to fly on earlier flight	**214**	25%	**267**
Export	***62***	*4%*	***65***
Transit	***30***	*76%*	***53***
Lateral in	***122***	*23%*	***150***
Sum of rebookings for EQ flown on earlier flight	**1315**	-5%	**1255**
Missed flights mail	**Average**	**Change**	**Average**
Number of mailbags which will miss flight at collection	**2412**	-2%	**2367**
Number of mailbags which will miss flight at transportation	**2380**	-1%	**2368**
Sum of mailbags which will miss made flight	**4792**	-1%	**4735**
Missed bookings EQ	**Average**	**Change**	**Average**
Number of EQ AWBs that will miss their booked flight due to flight closing	**15**	45%	**22**
Number of EQ AWBs that will miss their booked flight at transportation	**60**	3%	**62**
Number of EQ AWBs that will miss their booked flight at mail at collection	**104**	-12%	**91**
Number of EQ AWBs that will miss their booked flight at mail at transportation	**135**	-13%	**118**
Sum of missed EQ bookings	**315**	-7%	**293**
Space requirments mail	**Average**	**Change**	**Average**
Maximum number of locations required at mail in simulation	**100**	0%	**101**
Space requirments EQ	**Average**	**Change**	**Average**
Maximum number of locations required at eq in simulation	**50**	23%	**62**

Y Results processing appendix

Y.1 Selection criteria of the representative entities in the output files

Table 58: Criteria for the selection of the representative entities in the model output

Performance indicators	Selection criteria
Handling times mail dep	
Time between arrival input location - ready in belly wagon	all mail entities
Export - Time between arrival input location - ready in belly wagon	*all mail entities*
Transit - Time between arrival input location - ready in belly wagon	*all mail entities*
Import - Time between arrival input location - ready in belly wagon	*all mail entities*
Time between ready in belly wagon - collection	Transit and export entities (excl. arrivals in August)
Time between collection - ready at transport	Transit and export entities (excl. arrivals in August)
Average turnaround time mail; arrival FB1 -ready at transport	Transit entities (excl. arrivals in August & missed)
Average turnaround time mail STA-ATD plane	Transit entities (excl. arrivals in August & missed)
Handling times eq dep	
Time between export acceptance EQ - ready in belly wagon at EQ	all export entities non ULD
Time between arrival breakdown - ready in belly wagon at EQ	all transit AWBs non TULD (incl. Temp storage)
Time between arrival breakdown - ready in belly wagon at EQ	all transit AWBs non TULD (excl. Temp storage)
Time between arrival breakdown - ready at import EQ	all import AWBs non TULD
Time between ready in belly wagon - collection	All AWBs (excl. via temp storagenot & arrivals in August)
Export - Time between ready in belly wagon - collection	All AWBs (excl. via temp storagenot & arrivals in August)
Transit - Time between ready in belly wagon - collection	All AWBs (excl. via temp storagenot & arrivals in August)
Lateral - Time between ready in belly wagon - collection	All AWBs (excl. via temp storagenot & arrivals in August)
Time between collection - ready at transport	All AWBs (time at belly wagon > 0)
Average turnaround time eq FB1	Transit entities via EQ operation (excl. arrivals at August & missed)
Average turnaround time eq FB1 ATA-ATD plane	Transit entities via EQ operation (excl. arrivals at August & missed)
Handling times eq SMALL	
Time between export acceptance EQ - belly wagon at Mail department	all small export AWBs (hour 6 t/m 21)
Time between arrival breakdown - ready in belly wagon at Mail department	all small transit AWBs (hour 6 t/m 21)
Averageturnaround time eq FB1	all small transit AWBs (excl. arrivals in August, missed)
Average turnaround time eq ATA-ATD plane	all small transit AWBs (excl. arrivals in August, missed)
Number of mailbags flown on earlier flight	
Number of export mailbags collected to fly on earlier flight	export entities excluding arrivals at August
Number of transit mailbags collected to fly on earlier flight	transit entities excluding arrivals at August
Number of re-bookings for EQ flown on earlier flight	
Number of rebookings of SMALL EQ collected to fly on earlier flight	Export entities (excl. arrivals in August)
Number of rebookings of SMALL EQ collected to fly on earlier flight	Transit entities (excl. arrivals in August)
Number of rebookings of EQ collected to fly on earlier flight	All entities (excl. arrivals in August (time collected < (ATD-1.5))
Export	All entities (excl. arrivals in August (time collected < (ATD-1.5))
Transit	All entities (excl. arrivals in August (time collected < (ATD-1.5))
Lateral in	All entities (excl. arrivals in August (time collected < (ATD-1.5))
Missed flights mail	
Number of mailbags which will miss flight at collection	entities (excl. arrivals in August)
Number of mailbags which will miss flight at transportation	entities (excl. arrivals in August)
Sum of mailbags which will miss made flight	
Missed bookings EQ	
Number of EQ AWBs that will miss their booked flight due to flight closing	entities (excl. arrivals in August)
Number of EQ AWBs that will miss their booked flight at transportation	entities (excl. arrivals in August)
Number of EQ AWBs that will miss their booked flight at mail at collection	entities (excl. arrivals in August)
Number of EQ AWBs that will miss their booked flight at mail at transportation	entities (excl. arrivals in August)
Space requirments mail	
Maximum number of locations required at mail in simulation	-
Space requirments EQ	
Maximum number of locations required at eq in simulation	-

Y.2 Average scores per performance indicator per model

Table 59: Simulation results for the first three models (significant differences are marked grey)

Performance indicators	BM	Change	IMEX	Change	IMIN
Resource usage mail	Average	Change	Average	Change	Average
hr_mail_unload	**0.71**	0%	**0.71**	0%	**0.71**
hr_mail_scanning	**0.70**	0%	**0.70**	-2%	**0.69**
hr_mail_switching	**0.29**	15%	**0.34**	0%	**0.34**
hr_mail_carousel_EUR	**0.19**	17%	**0.22**	67%	**0.37**
hr_mail_carousel_ICA	**0.21**	13%	**0.24**	66%	**0.40**
hr_mail_carousel_USA	**0.16**	15%	**0.18**	59%	**0.29**
hr_mail_weighing_EUR	**0.41**	64%	**0.68**	0%	**0.68**
hr_mail_weighing_intercontinental	**0.49**	68%	**0.83**	0%	**0.83**
equipment_mail_weighbridge	**0.19**	33%	**0.26**	0%	**0.26**
Resource usage eq	Average	Change	Average	Change	Average
hr_eq_checker	**0.27**	0%	**0.27**	2%	**0.28**
hr_eq_bring_away	**0.38**	-48%	**0.19**	0%	**0.19**
hr_eq_break_down	**0.33**	0%	**0.33**	4%	**0.34**
hr_eq_weigh_opening	**0.31**	-68%	**0.10**	0%	**0.10**
hr_eq_weighbridge	**0.51**	-43%	**0.29**	0%	**0.29**
hr_eq_export_acceptance	**0.48**	-47%	**0.25**	5%	**0.27**
hr_eq_lateral_sorter	**0.36**	-42%	**0.21**	12%	**0.23**
hr_eq_lateral_driver	**0.27**	3%	**0.28**	-2%	**0.27**
equipment_eq_weighbridge	**0.19**	-41%	**0.11**	0%	**0.11**
Handling times mail dep	Average	Change	Average	Change	Average
Time between arrival input location - ready in belly wagon	**0.39**	18%	**0.46**	11%	**0.51**
Export - Time between arrival input location - ready in belly wagon	***0.19***	*33%*	***0.25***	*24%*	***0.31***
Transit - Time between arrival input location - ready in belly wagon	***0.40***	*17%*	***0.47***	*11%*	***0.52***
Import - Time between arrival input location - ready in belly wagon	***0.31***	*24%*	***0.38***	*10%*	***0.42***
Time between ready in belly wagon - collection	**7.32**	-4%	**7.02**	1%	**7.10**
Time between collection - ready at transport	**0.16**	78%	**0.29**	0%	**0.29**
Average turnaround time mail; arrival FB1 -ready at transport	**7.99**	-1%	**7.90**	1%	**7.99**
Average turnaround time mail STA-ATD plane	**9.99**	0%	**10.03**	1%	**10.13**
Handling times eq dep	Average	Change	Average	Change	Average
Time between export acceptance EQ - ready in belly wagon at EQ	**0.40**	-36%	**0.25**	1%	**0.26**
Time between arrival breakdown - ready in belly wagon at EQ	**2.87**	n.a.	**n.a.**	n.a.	**n.a.**
Time between arrival breakdown - ready in belly wagon at EQ	**0.60**	-49%	**0.31**	3%	**0.31**
Time between arrival breakdown - ready at import EQ	**0.48**	-37%	**0.30**	2%	**0.31**
Time between ready in belly wagon - collection	**8.61**	-20%	**6.88**	0%	**6.86**
Export - Time between ready in belly wagon - collection	***7.47***	*-9%*	***6.76***	*0%*	***6.76***
Transit - Time between ready in belly wagon - collection	***9.55***	*-9%*	***8.70***	*0%*	***8.68***
Lateral - Time between ready in belly wagon - collection	***8.41***	*-49%*	***4.30***	*0%*	***4.29***
Time between collection - ready at transport	**0.30**	-16%	**0.25**	0%	**0.25**
Average turnaround time eq FB1	**14.42**	-36%	**9.27**	0%	**9.26**
Average turnaround time eq FB1 ATA-ATD plane	**16.57**	-31%	**11.39**	0%	**11.38**
Handling times eq SMALL	Average	Change	Average	Change	Average
Time between export acceptance EQ - belly wagon at Mail department	**n.a.**	n.a.	**0.29**	41%	**0.41**
Time between arrival breakdown - ready in belly wagon at Mail department	**n.a.**	n.a.	**0.39**	33%	**0.52**
Averageturnaround time eq FB1	**n.a.**	n.a.	**9.60**	1%	**9.72**
Average turnaround time eq ATA-ATD plane	**n.a.**	n.a.	**11.81**	1%	**11.93**
Number of mailbags flown on earlier flight	Average	Change	Average	Change	Average
Number of export mailbags collected to fly on earlier flight	**126**	21%	**153**	-6%	**143**
Number of transit mailbags collected to fly on earlier flight	**16727**	15%	**19276**	-2%	**18952**
Sum of mailbags flown on earlier flight	**16853**	15%	**19428**	-2%	**19095**
Number of re-bookings for EQ flown on earlier flight	Average	Change	Average	Change	Average
Number of rebookings of SMALL EQ collected to fly on earlier flight	**n.a.**	n.a.	**347**	-1%	**345**
Number of rebookings of SMALL EQ collected to fly on earlier flight	**n.a.**	n.a.	**785**	-2%	**768**
Number of rebookings of EQ collected to fly on earlier flight	**n.a.**	n.a.	**193**	0%	**193**
Export	***n.a.***	*n.a.*	***5***	*0%*	***5***
Transit	***n.a.***	*n.a.*	***16***	*-1%*	***15***
Lateral in	***n.a.***	*n.a.*	***172***	*0%*	***172***
Sum of rebookings for EQ flown on earlier flight	**n.a.**	n.a.	**1325**	-2%	**1305**
Missed flights mail	Average	Change	Average	Change	Average
Number of mailbags which will miss flight at collection	**1474**	25%	**1848**	19%	**2195**
Number of mailbags which will miss flight at transportation	**3881**	-64%	**1384**	-9%	**1263**
Sum of mailbags which will miss made flight	**5355**	-40%	**3233**	7%	**3458**
Missed bookings EQ	Average	Change	Average	Change	Average
Number of EQ AWBs that will miss their booked flight due to flight closing	**94**	-86%	**13**	0%	**13**
Number of EQ AWBs that will miss their booked flight at transportation	**47**	28%	**60**	-1%	**59**
Number of EQ AWBs that will miss their booked flight at mail at collection	n.a.	n.a.	**57**	25%	**71**
Number of EQ AWBs that will miss their booked flight at mail at transportation	n.a.	n.a.	**109**	-7%	**101**
Sum of missed EQ bookings	**141**	70%	**239**	2%	**245**
Space requirments mail	Average	Change	Average	Change	Average
Maximum number of locations required at mail in simulation	**81**	25.7%	**101**	-1%	**100**
Space requirments EQ	Average	Change	Average	Change	Average
Maximum number of locations required at eq in simulation	**187**	-72.9%	**51**	-2%	**50**

With a paired Student t-test a reliability interval is constructed for the differences in the average values of a specific performance indicator in the simulation results of two different models. In Arena the used random numbers remain the same for each replication in all different models. In this way the average scores on performance indicators of the same replication number can be paired to each other for the different simulation models.
In case the reliability interval contains zero, the difference between the compared indicators is not significant, otherwise the difference is significant. SPSS 16.0 was used to perform the paired t-test.

Y.3 Testing model outcomes on normal distribution with kolmogorov-smirnovtest

Table 60 displays the results of the executed kolmogorov-smirnov. The test was executed with SPSS 14.0.0 for windows. Due to te use of a Dutch version of SPSS, the decimal separator is a comma in the tables below.

Table 60: Results for the kolmogorov-smirnovtest for all performance indicators of the base model

Variable	N	Normal Parameters		Asymp. Sig. (2-tailed)	Distribution
		Mean	Std. Deviation		
M1_checker	8	0,273	0,001	0,613	Normal
M1_bring_away	8	0,376	0,002	0,990	Normal
M1_break_down	8	0,332			Constant
M1_weigh_opening	8	0,310	0,000	0,078	Normal
M1_weighbridge	8	0,514	0,003	0,845	Normal
M1_export_acceptance	8	0,481	0,002	0,998	Normal
M1_lateral_sorter	8	0,356	0,003	0,966	Normal
M1_lateral_driver	8	0,269	0,004	0,894	Normal
M1_equipment_eq_weighbridge	8	0,193	0,003	0,997	Normal
M1_unload	8	0,707	0,002	0,735	Normal
M1_scanning	8	0,703	0,001	0,764	Normal
M1_switching	8	0,295	0,000	0,803	Normal
M1_carousel_EUR	8	0,192	0,000	0,718	Normal
M1_carousel_ICA	8	0,212	0,000	0,757	Normal
M1_carousel_USA	8	0,160	0,000	0,940	Normal
M1_weighing_EUR	8	0,412	0,002	0,997	Normal
M1_weighing_intercontinental	8	0,493	0,004	0,712	Normal
M1_mail_weighbridge	8	0,193	0,001	0,926	Normal
M1_export_acceptance_EQ_to_ready_in_belly_wagon_at_EQ	8	0,400	0,009	0,725	Normal
M1_arrival_breakdown_to_ready_in_belly_wagon_at_EQ_incl_temp	8	2,874	0,019	0,734	Normal
M1_arrival_breakdown_to_ready_in_belly_wagon_at_EQ_excl_temp	8	0,597	0,026	0,574	Normal
M1_arrival_breakdown_to_ready_at_import_EQ	8	0,483	0,019	0,898	Normal
M1_ready_in_belly_wagon_to_collection	8	8,613	0,018	0,993	Normal
M1_Export_ready_in_belly_wagon_to_collection	8	7,471	0,013	0,801	Normal
M1_Transit_ready_in_belly_wagon_to_collection	8	9,545	0,029	0,863	Normal
M1_Lateral_ready_in_belly_wagon_to_collection	8	8,412	0,026	0,874	Normal
M1_collection_to_ready_at_transport	8	0,303	0,004	0,996	Normal
M1_turnaround_time_eq_FB1	8	14,419	0,030	0,994	Normal
M1_turnaround_time_eq_FB1_ATA_to_ATD_plane	8	16,572	0,024	0,601	Normal
M1_arrival_input_location_to_ready_in_belly_wagon	8	0,387	0,011	0,961	Normal
M1_Export_arrival_input_location_to_ready_in_belly_wagon	8	0,190	0,008	0,974	Normal
M1_Transit_arrival_input_location_to_ready_in_belly_wagon	8	0,401	0,012	0,980	Normal
M1_Import_arrival_input_location_to_ready_in_belly_wagon	8	0,306	0,007	0,932	Normal
M1_Average_turnaround_time_mail_arrival_FB1_to_ready_at_transpor	8	7,993	0,067	0,721	Normal
M1_Average_turnaround_time_mail_STA_to_ATD_plane	8	9,994	0,068	0,978	Normal
M1_nr_of_export_mailbags_collected_to_fly_on_earlier_flight	8	126	2,507	0,984	Normal
M1_nr_of_transit_mailbags_collected_to_fly_on_earlier_flight	8	16727	151,518	0,944	Normal
M1_nr_of_mailbags_which_will_miss_flight_at_collection	8	1474	66,999	0,681	Normal
M1_nr_of_mailbags_which_will_miss_flight_at_transportation	8	3881	378,783	0,581	Normal
M1_nr_of_EQ_AWBs_that_will_miss_their_booked_flight_due_to_fligh	8	94	1,669	0,934	Normal
M1_nr_of_EQ_AWBs_that_will_miss_their_booked_flight_at_transport	8	47	13,583	0,999	Normal

One variable is constant for all replications, the utilization rate of the breakdown employees, and is therefore not normally distributed. For this variable a comparison of the average scores

between the models will be sufficient to determine a difference, because the variables are constant.
The outcomes of the kolmogorov-smirnovtest. show all other performance indicators can be assumed to be normally distributed. When the “asymmetric significance level”, is higher than 0.05, the outcomes are assumed to be normally distributed (SPSS 14.0 Results coach, 12-5-2009). When the variables are normally distributed it is possible to test the differences between the different model configurations on significance with paired samples t-tests.

Y.4 Results paired samples t-test BM (M1), IMEX (M2) and IMIN (M3)

Due to te use of a Dutch version of SPSS, the decimal separator is a comma in the tables below. The significant differences are marked grey in the tables.

Table 61: Results of the paired t-test of the mail resource utilization rates

		Paired Differences							
					95% Confidence Interval				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	Sig. (2-tailed)
Pair 1	M1_unload - M2_unload	-,0019750	,0039870	,0014096	-,0053082	,0013582	-1,401	7	,204
Pair 2	M2_unload - M3_unload	-,0003125	,0037238	,0013166	-,0034257	,0028007	-,237	7	,819
Pair 3	M1_scanning - M2_scanning	,0001375	,0008766	,0003099	-,0005953	,0008703	,444	7	,671
Pair 4	M2_scanning - M3_scanning	,0157875	,0006600	,0002333	,0152358	,0163392	67,662	7	**,000**
Pair 5	M1_switching - M2_switching	-,0453375	,0002200	,0000778	-,0455214	-,0451536	-582,924	7	**,000**
Pair 6	M2_switching - M3_switching	-,0000125	,0003643	,0001288	-,0003170	,0002920	-,097	7	,925
Pair 7	M1_carousel_EUR - M2_carousel_EUR	-,0322125	,0004704	,0001663	-,0326057	-,0318193	-193,699	7	**,000**
Pair 8	M2_carousel_EUR - M3_carousel_EUR	-,1506625	,0004069	,0001438	-,1510026	-,1503224	-1047,380	7	**,000**
Pair 9	M1_carousel_USA - M2_carousel_USA	-,0237500	,0005806	,0002053	-,0242354	-,0232646	-115,692	7	**,000**
Pair 10	M2_carousel_USA - M3_carousel_USA	-,1085000	,0004811	,0001701	-,1089022	-,1080978	-637,920	7	**,000**
Pair 11	M1_weighing_EUR - M2_weighing_EUR	-,2650125	,0078233	,0027660	-,2715529	-,2584721	-95,812	7	**,000**
Pair 12	M2_weighing_EUR - M3_weighing_EUR	-,0021000	,0064172	,0022688	-,0074649	,0032649	-,926	7	,385
Pair 13	M1_weighing_intercontinental - M2_weighing_intercontinental	-,3333000	,0150767	,0053304	-,3459044	-,3206956	-62,528	7	**,000**
Pair 14	M2_weighing_intercontinental - M3_weighing_intercontinental	-,0001500	,0216669	,0076604	-,0182640	,0179640	-,020	7	,985
Pair 15	M1_mail_weighbridge - M2_mail_weighbridge	-,0636000	,0008552	,0003024	-,0643150	-,0628850	-210,337	7	**,000**
Pair 16	M2_mail_weighbridge - M3_mail_weighbridge	-,0001000	,0015062	,0005325	-,0013592	,0011592	-,188	7	,856

Table 62: Results of the paired t-test of the EQ resource utilization rates

		Paired Differences							
					95% Confidence Interval				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	Sig. (2-tailed)
Pair 1	M1_checker - M2_checker	-,0008125	,0020884	,0007383	-,0025584	,0009334	-1,100	7	,308
Pair 2	M2_checker - M3_checker	-,0052375	,0027964	,0009887	-,0075753	-,0028997	-5,297	7	**,001**
Pair 3	M1_bring_away - M2_bring_away	,1818750	,0020742	,0007333	,1801410	,1836090	248,014	7	**,000**
Pair 4	M2_bring_away - M3_bring_away	,0001000	,0010488	,0003708	-,0007768	,0009768	,270	7	,795
Pair 6	M2_break_down - M3_break_down	-,0128875	,0000641	,0000227	-,0129411	-,0128339	-568,779	7	**,000**
Pair 7	M1_weigh_opening - M2_weigh_opening	,2091375	,0007782	,0002751	,2084869	,2097881	760,164	7	**,000**
Pair 8	M2_weigh_opening - M3_weigh_opening	-,0000500	,0008018	,0002835	-,0007203	,0006203	-,176	7	,865
Pair 9	M1_weighbridge - M2_weighbridge	,2227125	,0039263	,0013881	,2194301	,2259949	160,439	7	**,000**
Pair 10	M2_weighbridge - M3_weighing	,0008500	,0047800	,0016900	-,0031462	,0048462	,503	7	,630
Pair 11	M1_export_acceptance - M2_export_acceptance	,2264875	,0027777	,0009821	,2241653	,2288097	230,625	7	**,000**
Pair 12	M2_export_acceptance - M3_export_acceptance	-,0129625	,0009425	,0003332	-,0137505	-,0121745	-38,898	7	**,000**
Pair 13	M1_lateral_sorter - M2_lateral_sorter	,1485000	,0052601	,0018597	,1441025	,1528975	79,851	7	**,000**
Pair 14	M2_lateral_sorter - M3_lateral_sorter	-,0251875	,0032665	,0011549	-,0279183	-,0224567	-21,810	7	**,000**
Pair 15	M1_lateral_driver - M2_lateral_driver	-,0088500	,0084569	,0029900	-,0159202	-,0017798	-2,960	7	**,021**
Pair 16	M2_lateral_driver - M3_lateral_driver	,0042750	,0075214	,0026592	-,0020130	,0105630	1,608	7	,152
Pair 17	M1_equipment_eq_weighbridge - M2_equipment_eq_weighbridge	,0787250	,0029163	,0010311	,0762869	,0811631	76,352	7	**,000**
Pair 18	M2_equipment_eq_weighbridge - M3_eq_weighbridge	-,0004375	,0040196	,0014211	-,0037979	,0029229	-,308	7	,767

Table 63: Results of the paired t-test of mail handling times

		Paired Differences							
					95% Confidence Interval				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	Sig. (2-tailed)
Pair 1	M1_arrival_input_location_to_ready_in_belly_wagon - M2_arrival_input_location_to_ready_in_belly_wagon	-,0679712	,0143500	,0050735	-,0799681	-,0559744	-13,397	7	**,000**
Pair 2	M2_arrival_input_location_to_ready_in_belly_wagon - M3_arrival_input_location_to_ready_in_belly_wagon	-,0500831	,0112811	,0039885	-,0595143	-,0406519	-12,557	7	**,000**
Pair 3	M1_Export_arrival_input_location_to_ready_in_belly_wagon - M2_Export_arrival_input_location_to_ready_in_belly_wagon	-,0622757	,0137229	,0048518	-,0737483	-,0508030	-12,836	7	**,000**
Pair 4	M2_Export_arrival_input_location_to_ready_in_belly_wagon - M3_Export_arrival_input_location_to_ready_in_belly_wagon	-,0593823	,0215558	,0076211	-,0774034	-,0413612	-7,792	7	**,000**
Pair 5	M1_Transit_arrival_input_location_to_ready_in_belly_wagon - M2_Transit_arrival_input_location_to_ready_in_belly_wagon	-,0672182	,0162691	,0057520	-,0808195	-,0536169	-11,686	7	**,000**
Pair 6	M2_Transit_arrival_input_location_to_ready_in_belly_wagon - M3_Transit_arrival_input_location_to_ready_in_belly_wagon	-,0517784	,0121587	,0042988	-,0619433	-,0416134	-12,045	7	**,000**
Pair 7	M1_Import_arrival_input_location_to_ready_in_belly_wagon - M2_Import_arrival_input_location_to_ready_in_belly_wagon	-,0737300	,0127246	,0044988	-,0843681	-,0630920	-16,389	7	**,000**
Pair 8	M2_Import_arrival_input_location_to_ready_in_belly_wagon - M3_Import_arrival_input_location_to_ready_in_belly_wagon	-,0372376	,0092639	,0032753	-,0449824	-,0294928	-11,369	7	**,000**
Pair 9	M1_ready_in_belly_wagon_to_collection - M2_ready_in_belly_wagon_to_collection	,2972200	,0756002	,0267287	,2340166	,3604233	11,120	7	**,000**
Pair 10	M2_ready_in_belly_wagon_to_collection - M3_ready_in_belly_wagon_to_collection	-,0799367	,0399979	,0141414	-,1133758	-,0464976	-5,653	7	**,001**
Pair 11	M1_collection_to_ready_at_transport - M2_collection_to_ready_at_transport	-,1267593	,0033616	,0011885	-,1295697	-,1239489	-106,655	7	**,000**
Pair 12	M2_collection_to_ready_at_transport - M3_collection_to_ready_at_transport	,0002325	,0040082	,0014171	-,0031184	,0035834	,164	7	,874
Pair 13	M1_turnaround_time_mail_arrival_FB1_to_ready_at_transpor - M2_turnaround_time_mail_arrival_FB1_to_ready_at_transpor	,0956993	,0784567	,0277386	,0301079	,1612907	3,450	7	**,011**
Pair 14	M2_turnaround_time_mail_arrival_FB1_to_ready_at_transpor - M3_turnaround_time_mail_arrival_FB1_to_ready_at_transpor	-,0916352	,0660939	,0233677	-,1468910	-,0363793	-3,921	7	**,006**
Pair 15	M1_turnaround_time_mail_STA_to_ATD_plane - M2_turnaround_time_mail_STA_to_ATD_plane	-,0336298	,0884629	,0312764	-,1075866	,0403271	-1,075	7	,318
Pair 16	M2_turnaround_time_mail_STA_to_ATD_plane - M3_turnaround_time_mail_STA_to_ATD_plane	-,0987391	,0694939	,0245698	-,1568375	-,0406408	-4,019	7	**,005**

Table 64: Results of the paired t-test of EQ handling times

		Paired Differences							
					95% Confidence Interval				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	Sig. (2-tailed)
Pair 1	M1_export_acceptance_EQ_to_ready_in_belly_wagon_at_EQ - M2_export_acceptance_EQ_to_ready_in_belly_wagon_at_EQ	,1450522	,0099463	,0035166	,1367369	,1533675	41,248	7	**,000**
Pair 2	M2_export_acceptance_EQ_to_ready_in_belly_wagon_at_EQ - M3_export_acceptance_EQ_to_ready_in_belly_wagon_at_EQ	-,0019687	,0038434	,0013589	-,0051819	,0012444	-1,449	7	,191
Pair 3	M1_arrival_breakdown_to_ready_in_belly_wagon_at_EQ_excl_temp - M2_arrival_breakdown_to_ready_in_belly_wagon_at_EQ_excl_temp	,2903184	,0258016	,0091222	,2687477	,3118891	31,825	7	**,000**
Pair 4	M2_arrival_breakdown_to_ready_in_belly_wagon_at_EQ_excl_temp - M3_arrival_breakdown_to_ready_in_belly_wagon_at_EQ_excl_temp	-,0081516	,0144968	,0051254	-,0202712	,0039680	-1,590	7	,156
Pair 5	M1_arrival_breakdown_to_ready_at_import_EQ - M2_arrival_breakdown_to_ready_at_import_EQ	,1800143	,0169141	,0059800	,1658737	,1941548	30,102	7	**,000**
Pair 6	M2_arrival_breakdown_to_ready_at_import_EQ - M3_arrival_breakdown_to_ready_at_import_EQ	-,0067637	,0085142	,0030102	-,0138817	,0003543	-2,247	7	,059
Pair 7	M1_ready_in_belly_wagon_to_collection - M2_ready_in_belly_wagon_to_collection	1,7358638	,0437358	,0154629	1,6992998	1,7724278	112,260	7	**,000**
Pair 8	M2_ready_in_belly_wagon_to_collection - M3_ready_in_belly_wagon_to_collection	,0122352	,0554234	,0195951	-,0340999	,0585703	,624	7	,552
Pair 9	M1_Export_ready_in_belly_wagon_to_collection - M2_Export_ready_in_belly_wagon_to_collection	,7071418	,0128272	,0045351	,6964179	,7178656	155,926	7	**,000**
Pair 10	M2_Export_ready_in_belly_wagon_to_collection - M3_Export_ready_in_belly_wagon_to_collection	,0030078	,0079259	,0028022	-,0036184	,0096340	1,073	7	,319
Pair 11	M1_Transit_ready_in_belly_wagon_to_collection - M2_Transit_ready_in_belly_wagon_to_collection	,8416577	,0948509	,0335349	,7623604	,9209551	25,098	7	**,000**
Pair 12	M2_Transit_ready_in_belly_wagon_to_collection - M3_Transit_ready_in_belly_wagon_to_collection	,0202815	,1217348	,0430397	-,0814914	,1220543	,471	7	,652
Pair 13	M1_Lateral_ready_in_belly_wagon_to_collection - M2_Lateral_ready_in_belly_wagon_to_collection	4,1094722	,0703687	,0248791	4,0506425	4,1683019	165,178	7	**,000**
Pair 14	M2_Lateral_ready_in_belly_wagon_to_collection - M3_Lateral_ready_in_belly_wagon_to_collection	,0177760	,0553568	,0195716	-,0285034	,0640555	,908	7	,394
Pair 15	M1_collection_to_ready_at_transport - M2_collection_to_ready_at_transport	,0494789	,0058252	,0020595	,0446089	,0543490	24,024	7	**,000**
Pair 16	M2_collection_to_ready_at_transport - M3_collection_to_ready_at_transport	,0010179	,0064083	,0022657	-,0043396	,0063754	,449	7	,667
Pair 17	M1_turnaround_time_eq_FB1 - M2_turnaround_time_eq_FB1	5,1524104	,1252574	,0442852	5,0476926	5,2571282	116,346	7	**,000**
Pair 18	M2_turnaround_time_eq_FB1 - M3_turnaround_time_eq_FB1	,0079574	,1477123	,0522242	-,1155332	,1314479	,152	7	,883
Pair 19	M1_turnaround_time_eq_FB1_ATA_to_ATD_plane - M2_turnaround_time_eq_FB1_ATA_to_ATD_plane	5,1866299	,1202158	,0425027	5,0861269	5,2871328	122,031	7	**,000**
Pair 20	M2_turnaround_time_eq_FB1_ATA_to_ATD_plane - M3_turnaround_time_eq_FB1_ATA_to_ATD_plane	,0037973	,1470931	,0520053	-,1191756	,1267702	,073	7	,944

Table 65: Results of the paired t-test of small EQ handling times

		Paired Differences							
					the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	Sig. (2-tailed)
Pair 1	M2_export_acceptance_EQ_to_belly_wagon_at_Mail_department - M3_export_acceptance_EQ_to_belly_wagon_at_Mail_department	-,1178981	,0077239	,0027308	-,1243554	-,1114407	-43,173	7	**,000**
Pair 2	M2_arrival_breakdown_to_ready_in_belly_wagon_at_Mail_department - M3_arrival_breakdown_to_ready_in_belly_wagon_at_Mail_department	-,1300783	,0222718	,0078743	-,1486980	-,1114586	-16,519	7	**,000**
Pair 3	M2_Averageturnaround_time_eq_FB1 - M3_Averageturnaround_time_eq_FB1	-,1184643	,0755418	,0267081	-,1816188	-,0553097	-4,436	7	**,003**
Pair 4	M2_Average_turnaround_time_eq_ATA_to_ATD_plane - M3_Average_turnaround_time_eq_ATA_to_ATD_plane	-,1145372	,0691764	,0244575	-,1723701	-,0567043	-4,683	7	**,002**

Table 66: Results of paired t-test of cargo on earlier flight and number of re-bookings

		Paired Differences							
					95% Confidence Interval				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	Sig. (2-tailed)
Pair 1	M1_nr_of_export_mailbags_collected_to_fly_on_earlier_flight - M2_nr_of_export_mailbags_collected_to_fly_on_earlier_flight	-26,750	3,955	1,398	-30,057	-23,443	-19,130	7	**,000**
Pair 2	M2_nr_of_export_mailbags_collected_to_fly_on_earlier_flight - M3_nr_of_export_mailbags_collected_to_fly_on_earlier_flight	9,500	4,140	1,464	6,039	12,961	6,490	7	**,000**
Pair 3	M1_nr_of_transit_mailbags_collected_to_fly_on_earlier_flight - M2_nr_of_transit_mailbags_collected_to_fly_on_earlier_flight	-2548,625	270,103	95,496	-2774,436	-2322,814	-26,688	7	**,000**
Pair 4	M2_nr_of_transit_mailbags_collected_to_fly_on_earlier_flight - M3_nr_of_transit_mailbags_collected_to_fly_on_earlier_flight	323,500	161,210	56,996	188,725	458,275	5,676	7	**,001**
Pair 5	M2_nr_of_export_rebookings_of_SMALL_EQ_collected_earlier - M3_nr_of_export_rebookings_of_SMALL_EQ_collected_earlier	2,500	1,195	,423	1,501	3,499	5,916	7	**,001**
Pair 6	M2_nr_of_rebookings_of_SMALL_EQ_collected_earlier_flight - M3_nr_of_transit_rebookings_of_SMALL_EQ_collected_earlier	17,375	7,652	2,705	10,978	23,772	6,422	7	**,000**
Pair 7	M2_nr_of_rebookings_of_EQ_collected_to_fly_on_earlier_flight - M3_nr_of_rebookings_of_EQ_collected_to_fly_on_earlier_flight	,125	1,553	,549	-1,173	1,423	,228	7	,826
Pair 9	M2_Transit_nr_of_rebookings_of_EQ_ollected_early - M3_Transit_nr_of_rebookings_of_EQ_ollected_early	,125	,835	,295	-,573	,823	,424	7	,685
Pair 10	M2_Lateral_in_nr_of_rebookings_of_EQ_ollected_early - M3_Lateral_in_nr_of_rebookings_of_EQ_ollected_early	,000	1,512	,535	-1,264	1,264	,000	7	1,000

Table 67: Results of paired t-test of cargo that missed their flight and of the space requirement at mail and EQ

		Paired Differences							
					the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	Sig. (2-tailed)
Pair 1	M1_nr_of_mailbags_which_will_miss_flight_at_collection - M2_nr_of_mailbags_which_will_miss_flight_at_collection	-374,375	140,260	49,589	-491,635	-257,115	-7,550	7	**,000**
Pair 2	M2_nr_of_mailbags_which_will_miss_flight_at_collection - M3_nr_of_mailbags_which_will_miss_flight_at_collection	-346,375	197,646	69,878	-511,611	-181,139	-4,957	7	**,002**
Pair 3	M1_nr_of_mailbags_which_will_miss_flight_at_transportation - M2_nr_of_mailbags_which_will_miss_flight_at_transportation	2497,250	363,837	128,636	2193,074	2801,426	19,413	7	**,000**
Pair 4	M2_nr_of_mailbags_which_will_miss_flight_at_transportation - M3_nr_of_mailbags_which_will_miss_flight_at_transportation	120,875	257,481	91,033	-94,385	336,135	1,328	7	,226
Pair 5	M1_AWBs_missing_flight_due_to_flight_closing - M2_AWBs_missing_flight_due_to_flight_closing	81,250	1,669	,590	79,855	82,645	137,689	7	**,000**
Pair 7	M1_AWBs_missing_flight_at_transportation - M2_AWBs_missing_flight_at_transportation	-13,125	12,999	4,596	-23,993	-2,257	-2,856	7	**,024**
Pair 8	M2_AWBs_missing_flight_at_transportation - M3_AWBs_missing_flight_at_transportation	,625	5,854	2,070	-4,269	5,519	,302	7	,771
Pair 9	M2_AWBs_missing_flight_at_mail_at_collection - M3_AWBs_missing_flight_at_mail_at_collection	-14,125	2,416	,854	-16,145	-12,105	-16,533	7	**,000**
Pair 10	M2_AWBs_missing_flight_at_mail_at_transportation - M3_AWBs_missing_flight_at_mail_at_transportation	8,000	27,092	9,579	-14,650	30,650	,835	7	,431
Pair 11	M1_max_nr_of_locations_required_at_mail_in_simulation - M2_max_nr_of_locations_required_at_mail_in_simulation	-20,750	1,389	,491	-21,911	-19,589	-42,262	7	**,000**
Pair 12	M2_max_nr_of_locations_required_at_mail_in_simulation - M3_max_nr_of_locations_required_at_mail_in_simulation	1,125	1,356	,479	-,009	2,259	2,346	7	,051
Pair 13	M1_max_nr_of_locations_required_at_EQ_in_simulation - M2_max_nr_of_locations_required_at_EQ_in_simulation	136,375	1,847	,653	134,831	137,919	208,861	7	**,000**
Pair 14	M2_max_nr_of_locations_required_at_EQ_in_simulation - M3_max_nr_of_locations_required_at_EQ_in_simulation	1,125	1,553	,549	-,173	2,423	2,049	7	,080

Y.5 Simulation results base model and refined model

Table 68: Simulation results base model and refined model (significant difference are marked grey)

Performance indicators	Unit	BM	Change	RM
Resource usage mail		**Average**	**Change**	**Average**
hr_mail_unload	% of scheduled FTE	**0.71**	0%	**0.71**
hr_mail_scanning	% of scheduled FTE	**0.70**	0%	**0.70**
hr_mail_switching	% of scheduled FTE	**0.29**	0%	**0.29**
hr_mail_carousel_EUR	% of scheduled FTE	**0.19**	0%	**0.19**
hr_mail_carousel_ICA	% of scheduled FTE	**0.21**	0%	**0.21**
hr_mail_carousel_USA	% of scheduled FTE	**0.16**	0%	**0.16**
hr_mail_weighing_EUR	% of scheduled FTE	**0.41**	12%	**0.46**
hr_mail_weighing_intercontinental	% of scheduled FTE	**0.49**	4%	**0.51**
equipment_mail_weighbridge	% of scheduled FTE	**0.19**	10%	**0.21**
Resource usage eq		**Average**	**Change**	**Average**
hr_eq_checker	% of scheduled FTE	**0.27**	0%	**0.27**
hr_eq_bring_away	% of scheduled FTE	**0.38**	6%	**0.40**
hr_eq_break_down	% of scheduled FTE	**0.33**	0%	**0.33**
hr_eq_weigh_opening	% of scheduled FTE	**0.31**	-14%	**0.27**
hr_eq_weighbridge	% of scheduled FTE	**0.51**	-2%	**0.50**
hr_eq_export_acceptance	% of scheduled FTE	**0.48**	0%	**0.48**
hr_eq_lateral_sorter	% of scheduled FTE	**0.36**	-41%	**0.21**
hr_eq_lateral_driver	% of scheduled FTE	**0.27**	1%	**0.27**
equipment_eq_weighbridge	% of scheduled FTE	**0.19**	-2%	**0.19**
Handling times mail dep		**Average**	**Change**	**Average**
Time between arrival input location - ready in belly wagon	hour	**0.39**	1%	**0.39**
Export - Time between arrival input location - ready in belly wagon	hour	***0.19***	*4%*	***0.20***
Transit - Time between arrival input location - ready in belly wagon	hour	***0.40***	*1%*	***0.41***
Import - Time between arrival input location - ready in belly wagon	hour	***0.31***	*1%*	***0.31***
Time between ready in belly wagon - collection	hour	**7.32**	-4%	**7.05**
Time between collection - ready at transport	hour	**0.16**	4%	**0.17**
Average turnaround time mail; arrival FB1 -ready at transport	hour	**7.99**	-3%	**7.75**
Average turnaround time mail STA-ATD plane	hour	**9.99**	0%	**10.02**
Handling times eq dep		**Average**	**Change**	**Average**
Time between export acceptance EQ - ready in belly wagon at EQ	hour	**0.40**	2%	**0.41**
Time between arrival breakdown - ready in belly wagon at EQ	hour	**2.87**	n.a.	**n.a.**
Time between arrival breakdown - ready in belly wagon at EQ	hour	**0.60**	11%	**0.66**
Time between arrival breakdown - ready at import EQ	hour	**0.48**	12%	**0.54**
Time between ready in belly wagon - collection	hour	**8.61**	-13%	**7.51**
Export - Time between ready in belly wagon - collection	hour	***7.47***	-14%	***6.46***
Transit - Time between ready in belly wagon - collection	hour	***9.55***	-5%	***9.09***
Lateral - Time between ready in belly wagon - collection	hour	***8.41***	-47%	***4.50***
Time between collection - ready at transport	hour	**0.30**	-6%	**0.28**
Average turnaround time eq FB1	hour	**14.42**	-31%	**9.94**
Average turnaround time eq FB1 ATA-ATD plane	hour	**16.57**	-27%	**12.14**
Handling times eq SMALL		**Average**	**Change**	**Average**
Time between export acceptance EQ - belly wagon at Mail department	hour	**n.a.**	n.a.	**n.a.**
Time between arrival breakdown - ready in belly wagon at Mail department	hour	**n.a.**	n.a.	**n.a.**
Averageturnaround time eq FB1	hour	**n.a.**	n.a.	**n.a.**
Average turnaround time eq ATA-ATD plane	hour	**n.a.**	n.a.	**n.a.**
Number of mailbags flown on earlier flight		**Average**	**Change**	**Average**
Number of export mailbags collected to fly on earlier flight	collo	**126**	22%	**154**
Number of transit mailbags collected to fly on earlier flight	collo	**16727**	16%	**19460**
Sum of mailbags flown on earlier flight	collo	**16853**	16%	**19614**
Number of re-bookings for EQ flown on earlier flight		**Average**	**Change**	**Average**
Number of rebookings of SMALL EQ collected to fly on earlier flight	AWB	**n.a.**	n.a.	**n.a.**
Number of rebookings of SMALL EQ collected to fly on earlier flight	AWB	**n.a.**	n.a.	**n.a.**
Number of rebookings of EQ collected to fly on earlier flight	AWB	**n.a.**	n.a.	**634**
Export	AWB	***n.a.***	*n.a.*	***9***
Transit	AWB	***n.a.***	*n.a.*	***104***
Lateral in	AWB	***n.a.***	*n.a.*	***521***
Sum of rebookings for EQ flown on earlier flight	AWB	**n.a.**	n.a.	**634**
Missed flights mail		**Average**	**Change**	**Average**
Number of mailbags which will miss flight at collection	collo	**1474**	21%	**1783**
Number of mailbags which will miss flight at transportation	collo	**3881**	-77%	**894**
Sum of mailbags which will miss made flight	collo	**5355**	-50%	**2677**
Missed bookings EQ		**Average**	**Change**	**Average**
Number of EQ AWBs that will miss their booked flight due to flight closing	AWB	**94**	-29%	**67**
Number of EQ AWBs that will miss their booked flight at transportation	AWB	**47**	128%	**107**
Number of EQ AWBs that will miss their booked flight at mail at collection	AWB	n.a.	n.a.	**n.a.**
Number of EQ AWBs that will miss their booked flight at mail at transportation	AWB	n.a.	n.a.	**n.a.**
Sum of missed EQ bookings	AWB	**141**	23%	**174**
Space requirments mail		**Average**	**Change**	**Average**
Maximum number of locations required at mail in simulation	locations	**81**	-1%	**80**
Space requirments EQ		**Average**	**Change**	**Average**
Maximum number of locations required at eq in simulation	locations	**187**	-47%	**99**

Y.6 Results paired samples t-test base model and refined model

Due to te use of a Dutch version of SPSS, the decimal separator is a comma in the tables below. The significant differences are marked grey.

Table 69: Results of paired t-test of the mail resource utilization rates

		Paired Differences							
					Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	Sig. (2-tailed)
Pair 1	M1_unload - M4_unload	-,00031	,0017788	,0006289	-,0017996	,0011746	-,497	7	,634
Pair 2	M1_scanning - M4_scanning	-,00011	,0009702	,0003430	-,0009236	,0006986	-,328	7	,753
Pair 3	M1_switching - M4_switching	-,00008	,0001669	,0000590	-,0002145	,0000645	-1,271	7	,244
Pair 4	M1_carousel_EUR - M4_carousel_EUR	-,00004	,0003292	,0001164	-,0003127	,0002377	-,322	7	,757
Pair 5	M1_carousel_ICA - M4_carousel_ICA	,00010	,0003024	,0001069	-,0001528	,0003528	,935	7	,381
Pair 6	M1_carousel_USA - M4_carousel_USA	-,00016	,0004207	,0001487	-,0005142	,0001892	-1,093	7	,311
Pair 7	M1_weighing_EUR - M4_weighing_EUR	-,05079	,0047082	,0016646	-,0547236	-,0468514	-30,510	7	,000
Pair 8	M1_weighing_intercontinental - M4_weighing_intercontinental	-,01828	,0033868	,0011974	-,0211065	-,0154435	-15,262	7	,000
Pair 9	M1_mail_weighbridge - M4_mail_weighbridge	-,02021	,0008408	,0002973	-,0209154	-,0195096	-67,993	7	,000

Table 70: Results of paired t-test of the EQ resource utilization rates

		Paired Differences							
					Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	Sig. (2-tailed)
Pair 1	M1_checker - M4_checker	-,00076	,001700	,000601	-,0021833	,0006583	-1,269	7	,245
Pair 2	M1_bring_away - M4_bring_away	-,02438	,001830	,000647	-,0259047	-,0228453	-37,680	7	,000
Pair 4	M1_weigh_opening - M4_weigh_opening	,04193	,000673	,000238	,0413620	,0424880	176,074	7	,000
Pair 5	M1_weighbridge - M4_weighbridge	,00998	,004932	,001744	,0058517	,0140983	5,720	7	,001
Pair 6	M1_export_acceptance - M4_export_acceptance	-,00191	,003396	,001201	-,0047513	,0009263	-1,593	7	,155
Pair 7	M1_lateral_sorter - M4_lateral_sorter	,14509	,003826	,001353	,1418889	,1482861	107,258	7	,000
Pair 8	M1_lateral_driver - M4_lateral_driver	-,00271	,003653	,001292	-,0057664	,0003414	-2,100	7	,074
Pair 9	M1_equipment_eq_weighbridge - M4_equipment_eq_weighbridge	,00294	,003652	,001291	-,0001153	,0059903	2,275	7	,057

Table 71: Results of paired t-test of mail handling times

		Paired Differences							
					Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	Sig. (2-tailed)
Pair 1	M1_arrival_input_location_to_ready_in_belly_wagon - M4_arrival_input_location_to_ready_in_belly_wagon	-,00521	,0076210	,0026944	-,0115859	,0011567	-1,935	7	,094
Pair 2	M1_Export_arrival_input_location_to_ready_in_belly_wagon - M4_Export_arrival_input_location_to_ready_in_belly_wagon	-,00770	,0147118	,0052014	-,0200038	,0045950	-1,481	7	,182
Pair 3	M1_Transit_arrival_input_location_to_ready_in_belly_wagon - M4_Transit_arrival_input_location_to_ready_in_belly_wagon	-,00567	,0079574	,0028134	-,0123182	,0009869	-2,014	7	,084
Pair 4	M1_Import_arrival_input_location_to_ready_in_belly_wagon - M4_Import_arrival_input_location_to_ready_in_belly_wagon	-,00170	,0124726	,0044097	-,0121274	,0087274	-,386	7	,711
Pair 5	M1_ready_in_belly_wagon_to_collection - M4_ready_in_belly_wagon_to_collection	,27610	,0543731	,0192238	,2306437	,3215579	14,362	7	,000
Pair 6	M1_collection_to_ready_at_transport - M4_collection_to_ready_at_transport	-,00647	,0020077	,0007098	-,0081498	-,0047928	-9,117	7	,000
Pair 7	M1_turnaround_time_mail_arrival_FB1_to_ready_at_transport - M4_turnaround_time_mail_arrival_FB1_to_ready_at_transport	,23811	,0632385	,0223582	,1852394	,2909769	10,650	7	,000
Pair 8	M1_Average_turnaround_time_mail_STA_to_ATD_plane - M4_Average_turnaround_time_mail_STA_to_ATD_plane	-,02177	,0472588	,0167085	-,0612835	,0177352	-1,303	7	,234

Table 72: Results of paired t-test of EQ handling times

		Paired Differences							
					Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	Sig. (2-tailed)
Pair 1	M1_export_acceptance_EQ_to_ready_in_belly_wagon_at_EQ - M4_export_acceptance_EQ_to_ready_in_belly_wagon_at_EQ	-,00673	,0087004	,0030761	-,0140051	,0005424	-2,188	7	,065
Pair 2	M1_arrival_breakdown_to_ready_in_belly_wagon_at_EQ_excl_temp - M4_arrival_breakdown_to_ready_in_belly_wagon_at_EQ_excl_temp	-,06624	,0319178	,0112846	-,0929201	-,0395522	-5,870	7	,001
Pair 3	M1_arrival_breakdown_to_ready_at_import_EQ - M4_arrival_breakdown_to_ready_at_import_EQ	-,05700	,0278200	,0098359	-,0802629	-,0337468	-5,796	7	,001
Pair 4	M1_ready_in_belly_wagon_to_collection - M4_ready_in_belly_wagon_to_collection	1,09853	,0353076	,0124831	1,0690164	1,1280521	88,002	7	,000
Pair 5	M1_Export_ready_in_belly_wagon_to_collection - M4_Export_ready_in_belly_wagon_to_collection	1,01494	,0118629	,0041942	1,0050233	1,0248585	241,989	7	,000
Pair 6	M1_Transit_ready_in_belly_wagon_to_collection - M4_Transit_ready_in_belly_wagon_to_collection	,45727	,0563883	,0199363	,4101320	,5044156	22,937	7	,000
Pair 7	M1_Lateral_ready_in_belly_wagon_to_collection - M4_Lateral_ready_in_belly_wagon_to_collection	3,91700	,0386974	,0136816	3,8846450	3,9493488	286,297	7	,000
Pair 8	M1_collection_to_ready_at_transport - M4_collection_to_ready_at_transport	,01847	,0059133	,0020907	,0135291	,0234164	8,836	7	,000
Pair 9	M1_turnaround_time_eq_FB1 - M4_turnaround_time_eq_FB1	4,47914	,0661298	,0233804	4,4238528	4,5344245	191,577	7	,000
Pair 10	M1_turnaround_time_eq_FB1_ATA_to_ATD_plane - M4_turnaround_time_eq_FB1_ATA_to_ATD_plane	4,43199	,0559218	,0197713	4,3852407	4,4787442	224,163	7	,000

Table 73: Results of the paired t-test of cargo on earlier flight and number of re-bookings

		Paired Differences							
					Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	Sig. (2-tailed)
Pair 1	M1_nr_of_export_mailbags_collected_to_fly_on_earlier_flight - M4_nr_of_export_mailbags_collected_to_fly_on_earlier_flight	-28,00	5,606	1,982	-32,687	-23,313	-14,127	7	,000
Pair 2	M1_nr_of_transit_mailbags_collected_to_fly_on_earlier_flight - M4_nr_of_transit_mailbags_collected_to_fly_on_earlier_flight	-2733,13	198,960	70,343	-2899,460	-2566,790	-38,854	7	,000

Table 74: Results of paired t-test of cargo that missed their flight and of the space requirement at mail and EQ

		Paired Differences							
					95% Confidence Interval				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	Sig. (2-tailed)
Pair 1	M1_nr_of_mailbags_which_will_miss_flight_at_collection - M4_nr_of_mailbags_which_will_miss_flight_at_collection	-309,38	115,653	40,890	-406,064	-212,686	-7,566	7	,000
Pair 2	M1_nr_of_mailbags_which_will_miss_flight_at_transportation - M4_nr_of_mailbags_which_will_miss_flight_at_transportation	2987,88	398,356	140,840	2654,841	3320,909	21,215	7	,000
Pair 3	M1_nr_EQ_AWBs_missing_their_booked_flight_at_flight_closing - M4_nr_EQ_AWBs_missing_their_booked_flight_at_flight_closing	27,50	2,449	,866	25,452	29,548	31,754	7	,000
Pair 4	M1_nr_EQ_AWBs_missing_their_booked_flight_at_transport - M4_nr_EQ_AWBs_missing_their_booked_flight_at_transport	-60,00	13,234	4,679	-71,064	-48,936	-12,823	7	,000
Pair 5	M1_max_nr_of_locations_required_at_mail_in_simulation - M4_max_nr_of_locations_required_at_mail_in_simulation	,75	,707	,250	,159	1,341	3,000	7	,020
Pair 6	M1_max_nr_of_locations_required_at_EQ_in_simulation - M4_max_nr_of_locations_required_at_EQ_in_simulation	88,50	2,268	,802	86,604	90,396	110,379	7	,000

Z Contact details

TU Delft

Prof.dr. G.P. van Wee
Faculty: Technology, Policy and Management
Department: Transport Policy and Logistics Organisation
Email: G.P.vanWee@tudelft.nl
Phone: +31 (0)15 27 87186
Address: Jaffalaan 5, 2628BX, Delft

Prof.dr.ir. A. Verbraeck
Faculty: Technology, Policy and Management
Department: Systems Engineering
Email: A.Verbraeck@tudelft.nl
Phone: +31 (0)15 27 83805
Address: Jaffalaan 5, 2628BX, Delft

Ir. T.C.A. Mensch
Faculty: Mechanical, Maritime & Materials Engineering
Department: Transport, Engineering & Logistics
Email: T.C.A.Mensch@tudelft.nl
Phone: +31 (0)15 27 86737
Address: Mekelweg 2, 2628CD, Delft

KLM Cargo

Drs. S. Bhalla
Company: KLM Cargo
Function: Former project manager Mail/Equation
Email: Shobha.Bhalla@klmcargo.nl
Phone: +31 (0)610977014

G. Bergkamp
Company: KLM Cargo
Function: Manager Product Support & Sales coordination
Email: Gerald.Bergkamp@klmcargo.nl
Phone: +31 (0)653411291

Student

G. van Amstel
Faculty: Technology, Policy and Management
Email: Gijsvanamstel@gmail.com
Phone: +31 (0)6 41363462