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

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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.

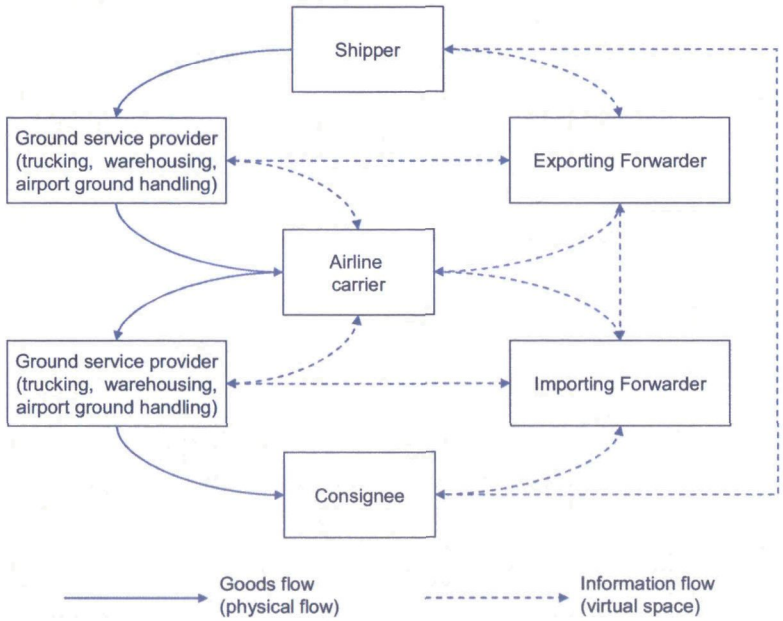

Figure 45: the traditional air cargo system (Schwarz, 2005)

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).

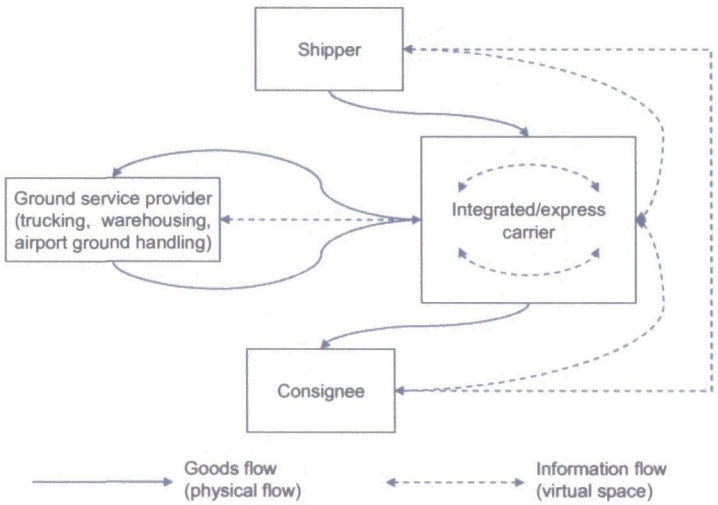

Figure 46: The supply chain with integrator (Schwarz, 2005)

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.

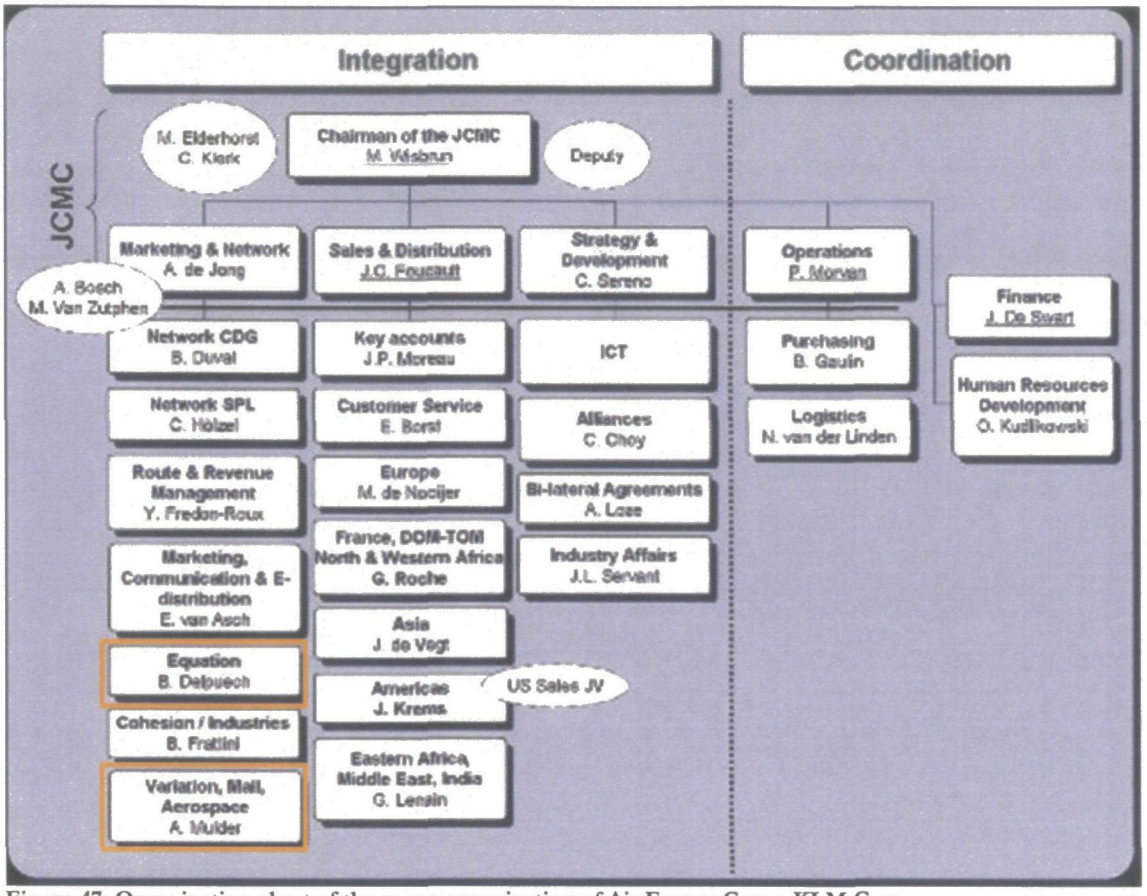

Figure 47: Organization chart of the cargo organization of Air France Cargo-KLM Cargo

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.

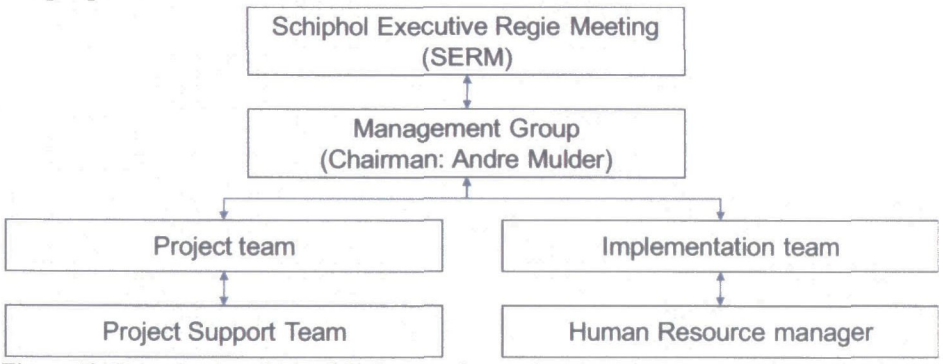

Figure 48: Organization chart of the integration project

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).
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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.

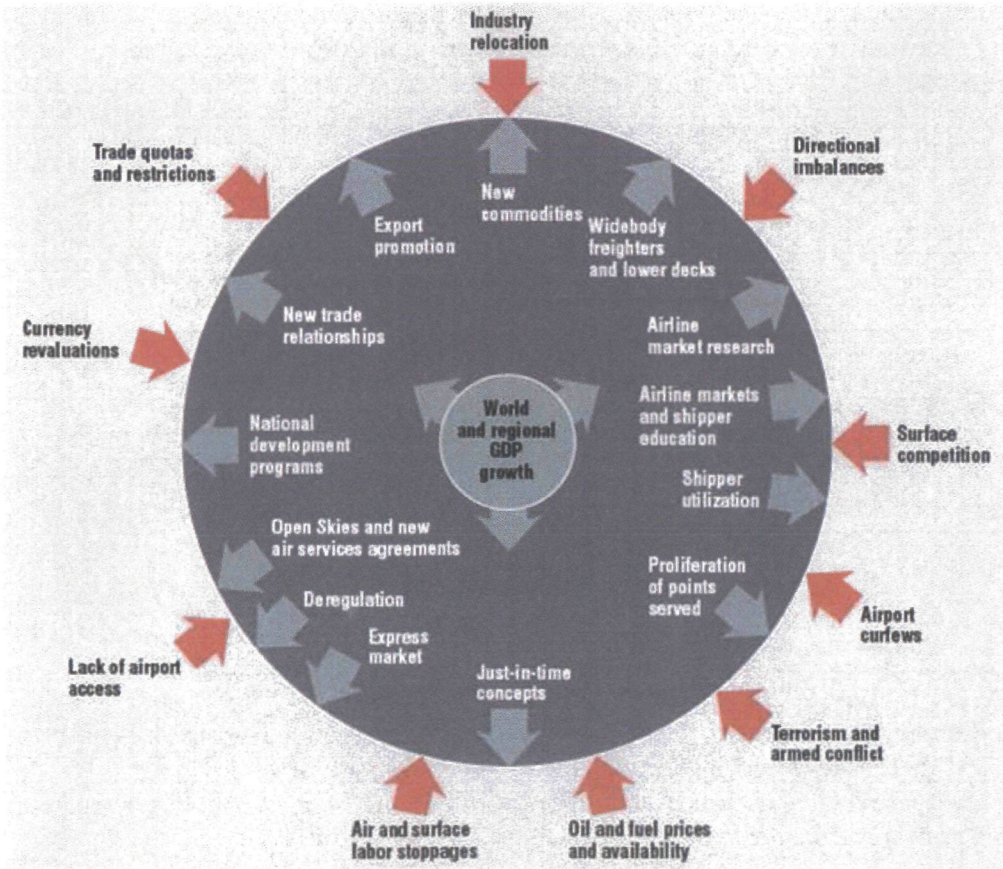


Figure 49: Forces and constraints for air cargo growth (Boeing, 2006, p. 13)

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.

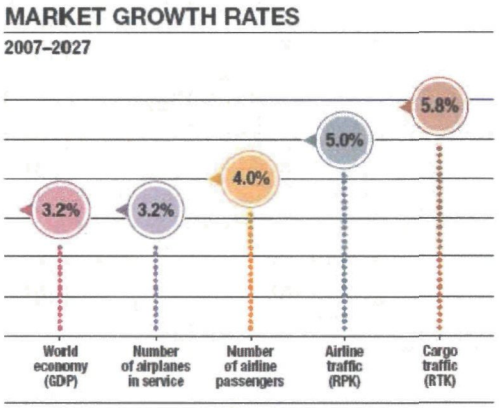


Figure 51: Summary of growth rates in the aviation industry (Boeing, 2008)

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

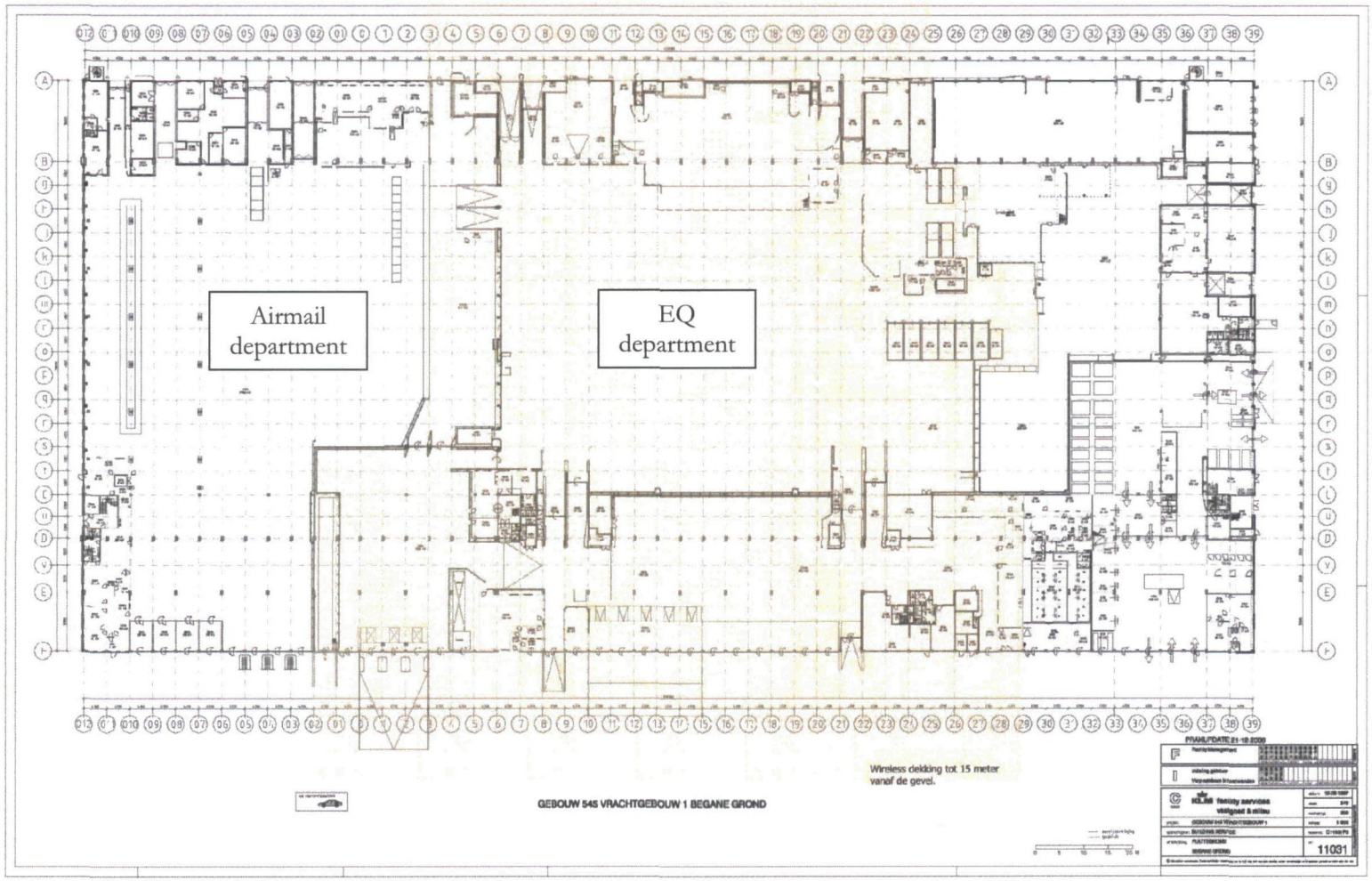


Figure 52: Map of FB1 with the airmail and EQ department (yellow surface)(KLM Cargo)

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)

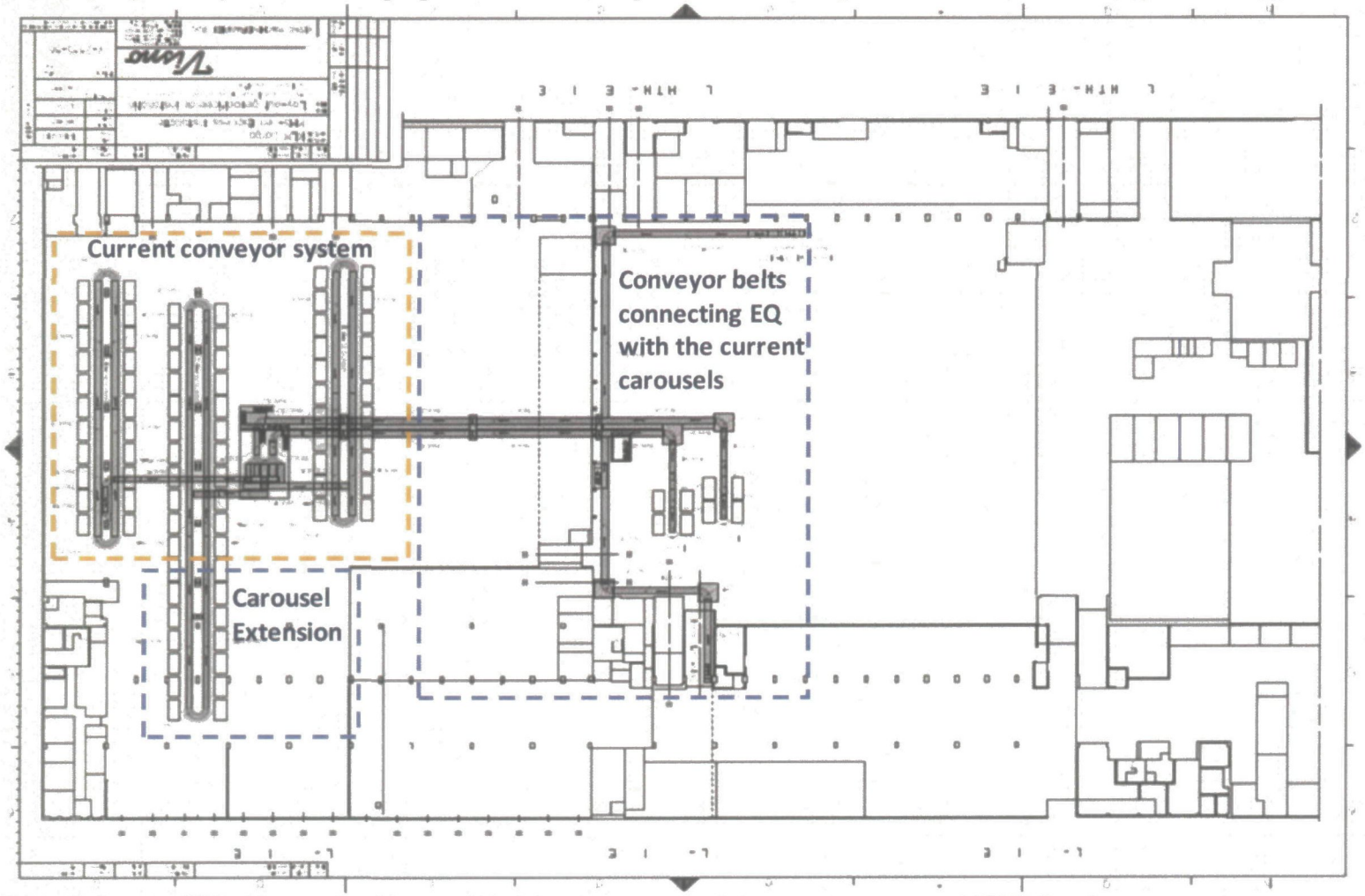


Figure 53: Layout of FB1 with extension (blue squares) of the current conveyor belt system (orange square) (KLM Cargo)

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 attirbute	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 attirbute	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

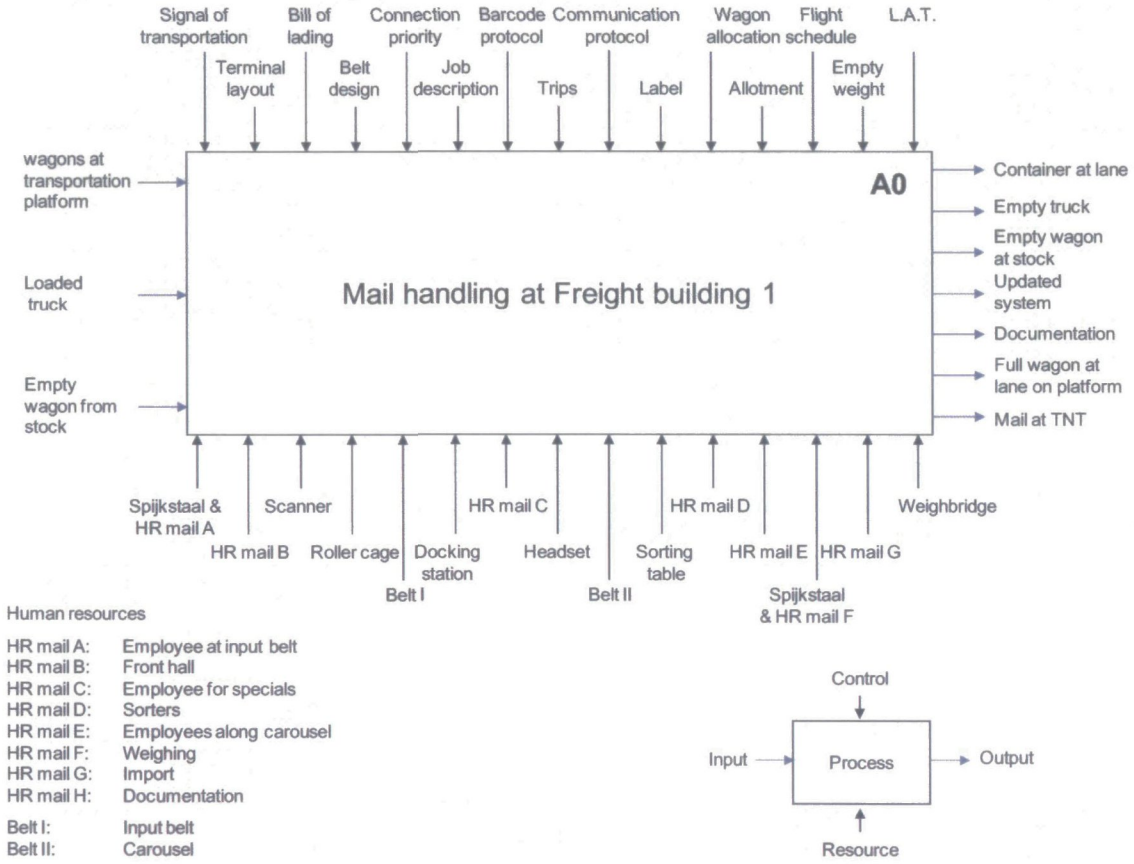
EQ department	Functions	Mail department	Functions
Scheduled utilization	hr_eq_checker	Scheduled utilization	hr_mail_unload
Scheduled utilization	hr_eq_bring_away	Scheduled utilization	hr_mail_scanning
Scheduled utilization	hr_eq_break_down	Scheduled utilization	hr_mail_switching
Scheduled utilization	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



Human resources

HR mail A:	Employee at input belt
HR mail B:	Front hall
HR mail C:	Employee for specials
HR mail D:	Sorters
HR mail E:	Employees along carousel
HR mail F:	Weighing
HR mail G:	Import
HR mail H:	Documentation
Belt I:	Input belt
Belt II:	Carousel

Figure 60: A0 diagram of mail handling, summarizing IDEF-0 diagrams of mail

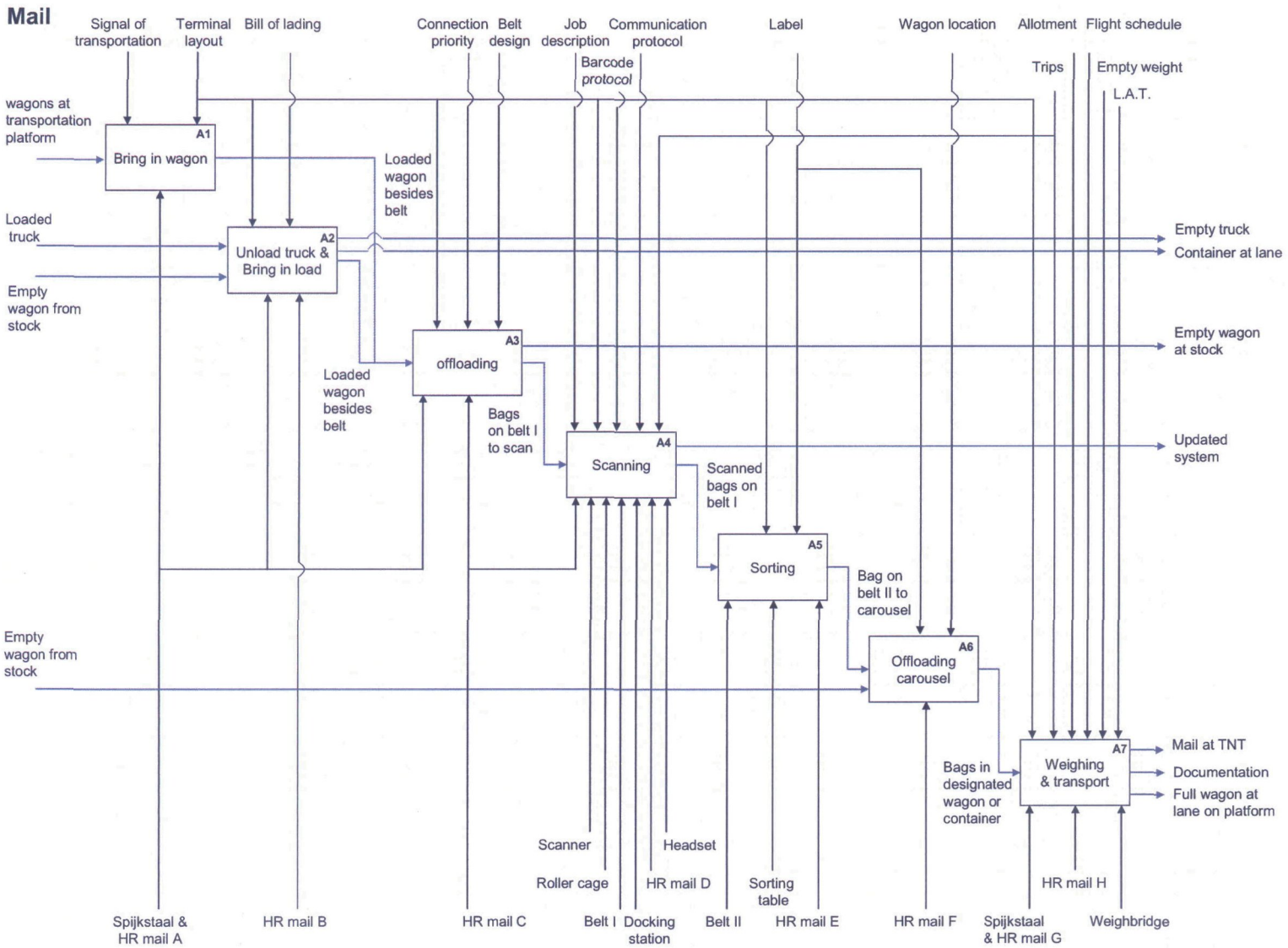


Figure 61: First decomposition of the A0 diagram of mail handling

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.

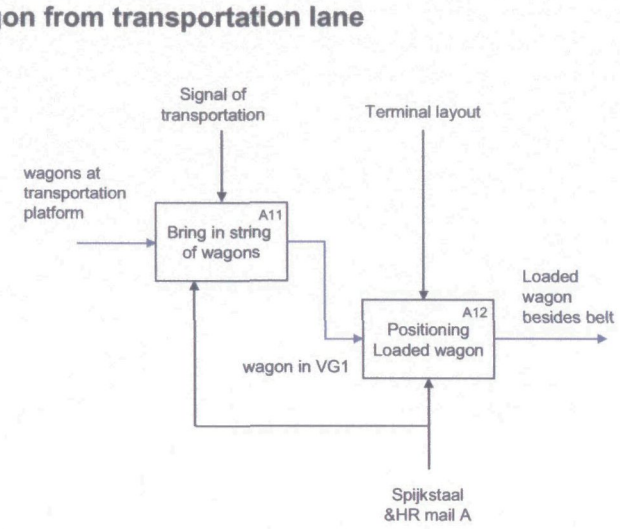


Figure 62: Mail activity A1 in detail: bringing in belly wagons from transportation

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).

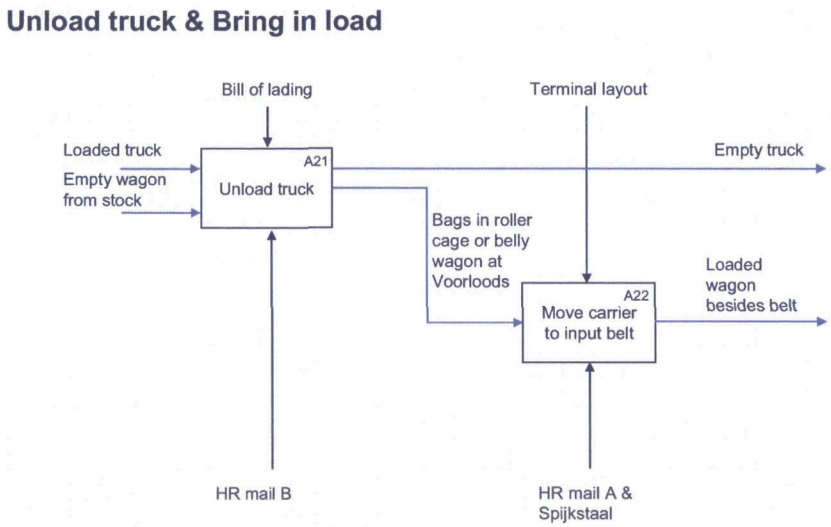


Figure 63: Mail activity A2 in detail: Unload truck and bring in load

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.

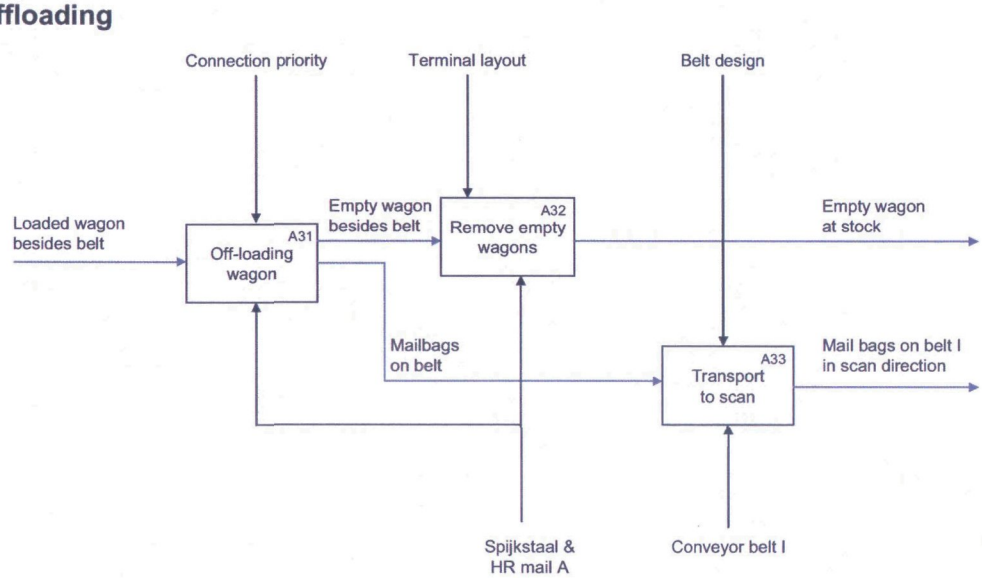
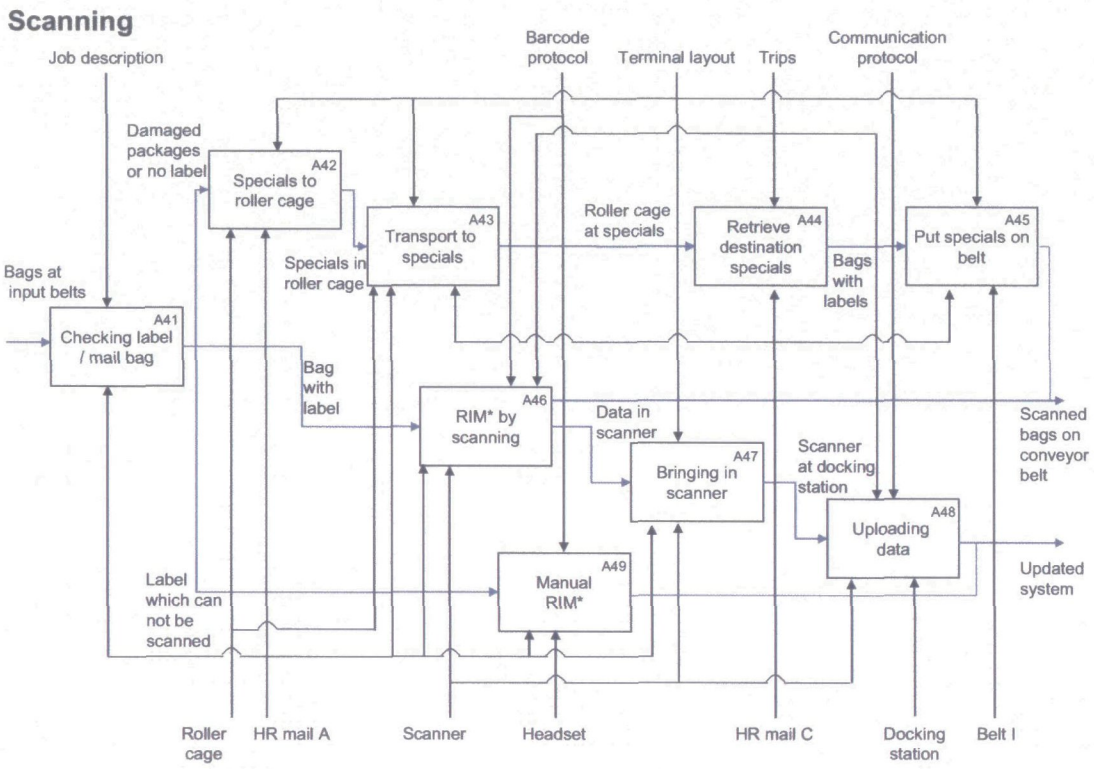


Figure 64: Mail activity A3 in detail: Offloading of belly wagons at input location

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.



* RIM = registration incoming mail

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.

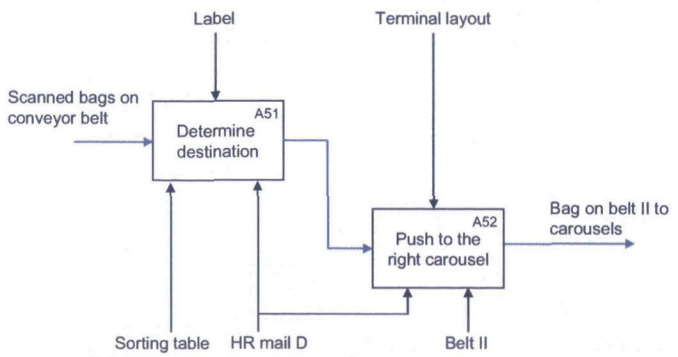


Figure 66: Mail activity A5 in detail: Sorting of mail bags at the switching location

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.

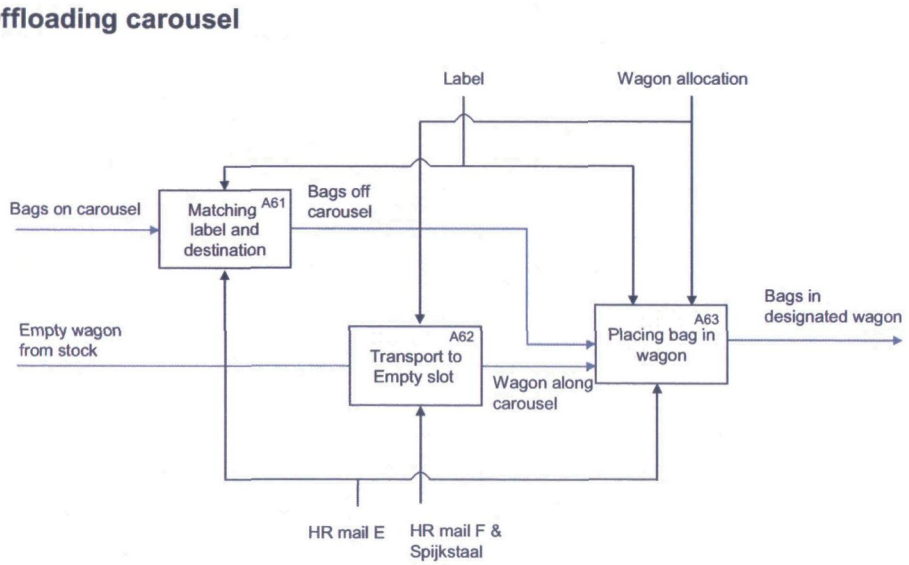


Figure 67: Mail activity A6 in detail: Offloading bags from the carousels

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.

Weighing & transport

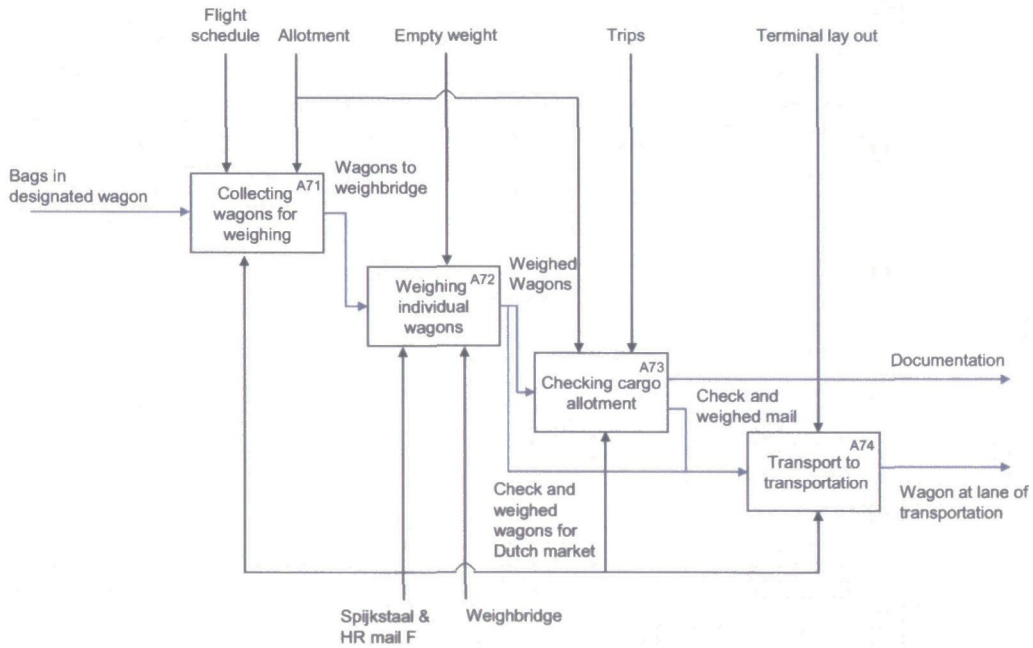


Figure 68: Mail activity A7 in detail: Weighing and transport of departing mail bags

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

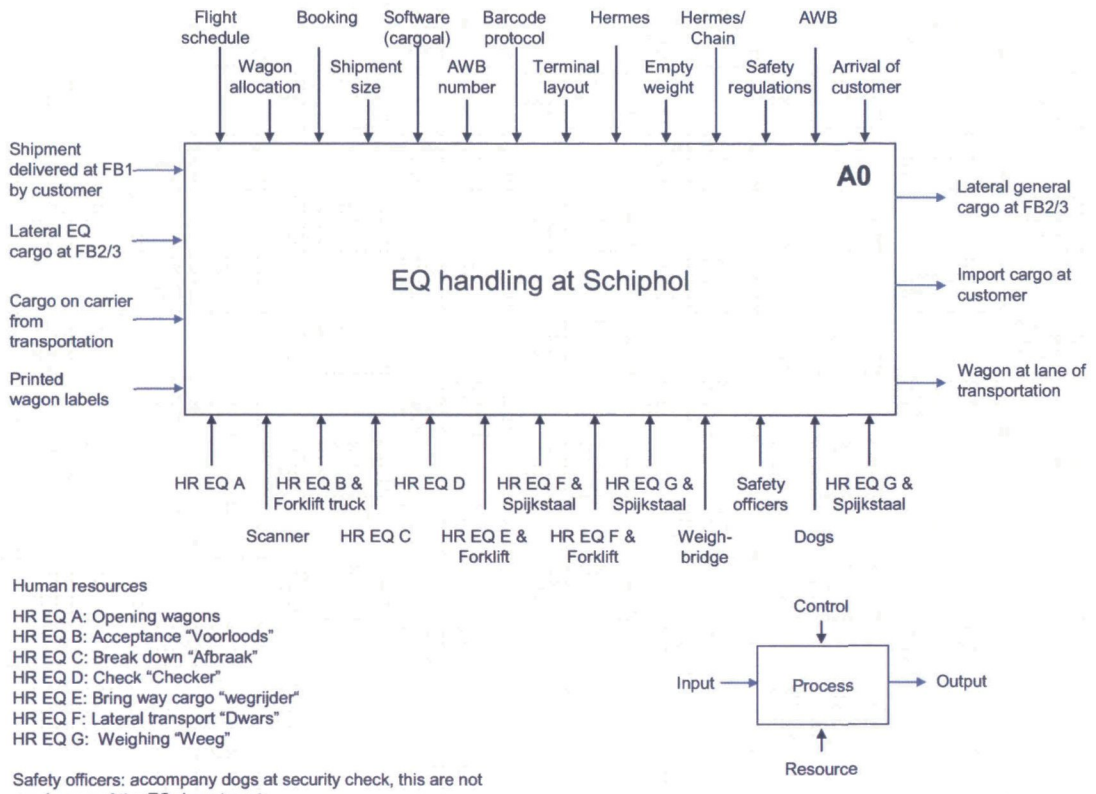


Figure 69: A0 diagram of EQ handling, summarizing IDEF-0 diagrams of Equation

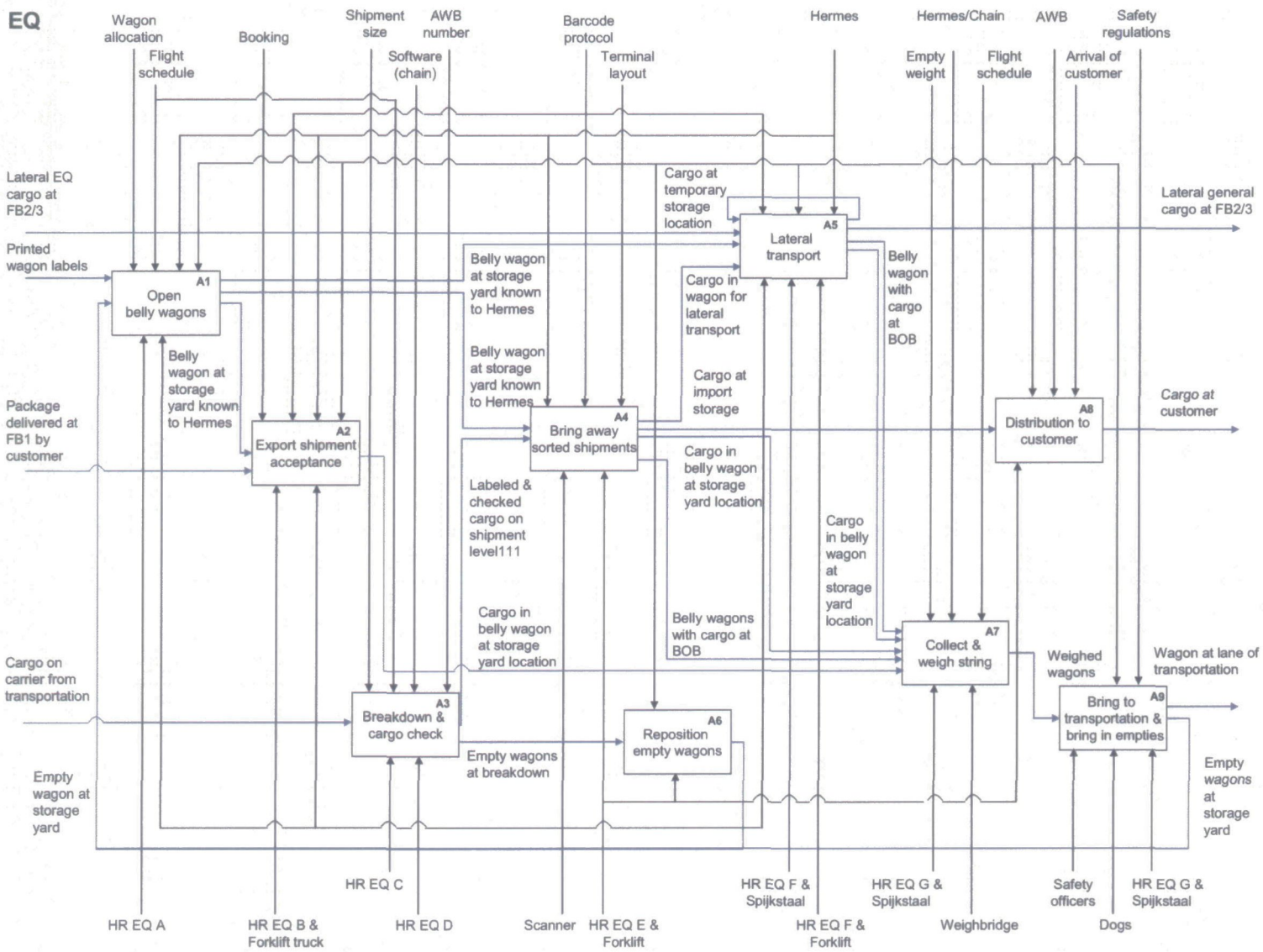


Figure 70: First decomposition of the A0 diagram of EQ handling

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)

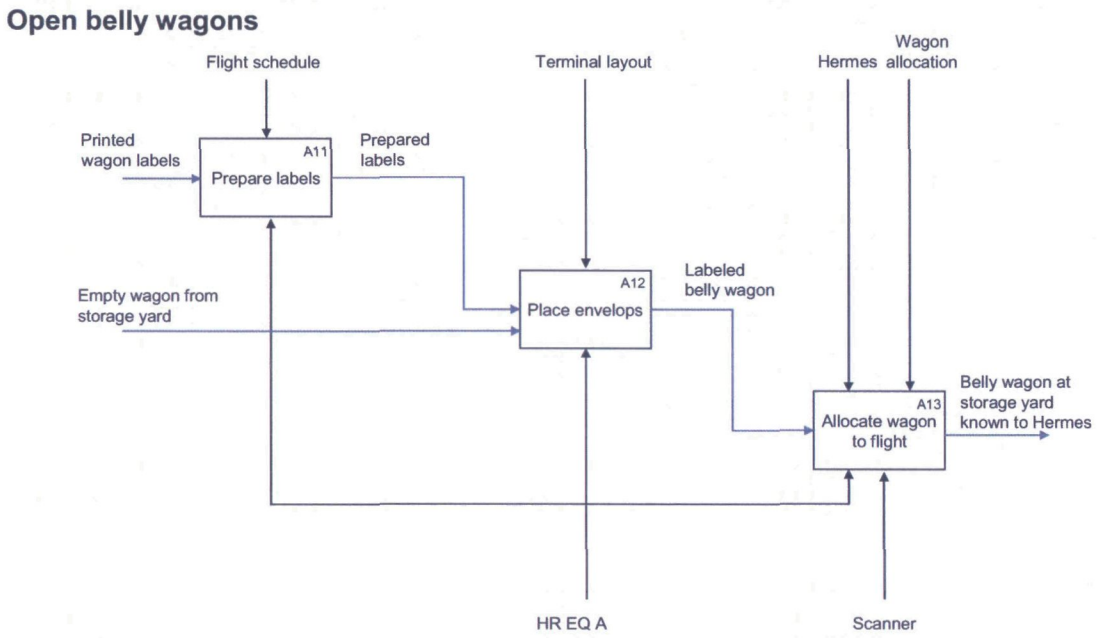


Figure 71: EQ activity A1 in detail: Open belly wagons

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.

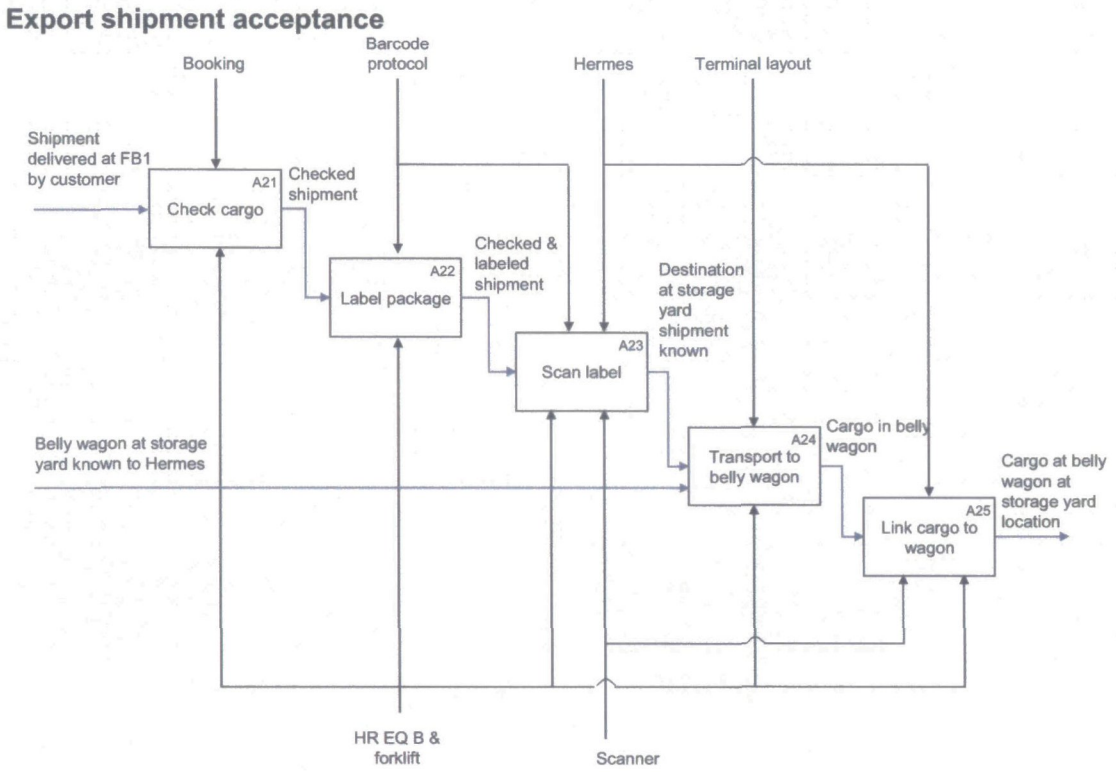


Figure 72: EQ activity A2 in detail: Export shipment acceptance

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.

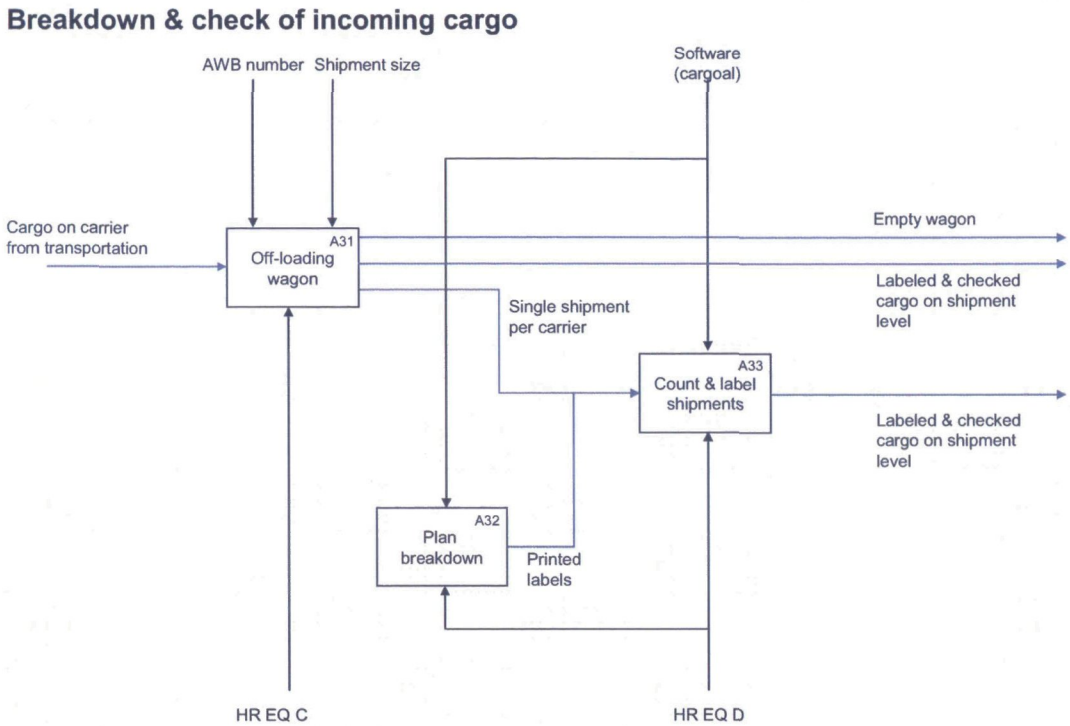


Figure 73: EQ activity A3 in detail: Breakdown and check of incoming cargo

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.

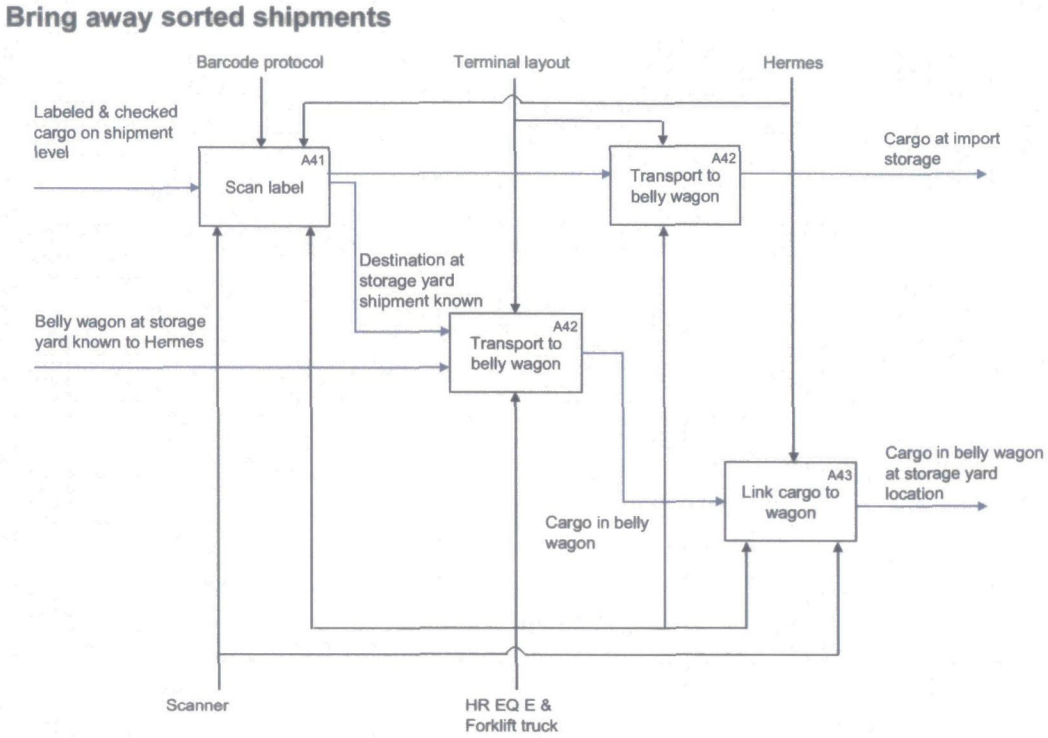


Figure 74: EQ activity A4 in detail: Bring away sorted shipments

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.

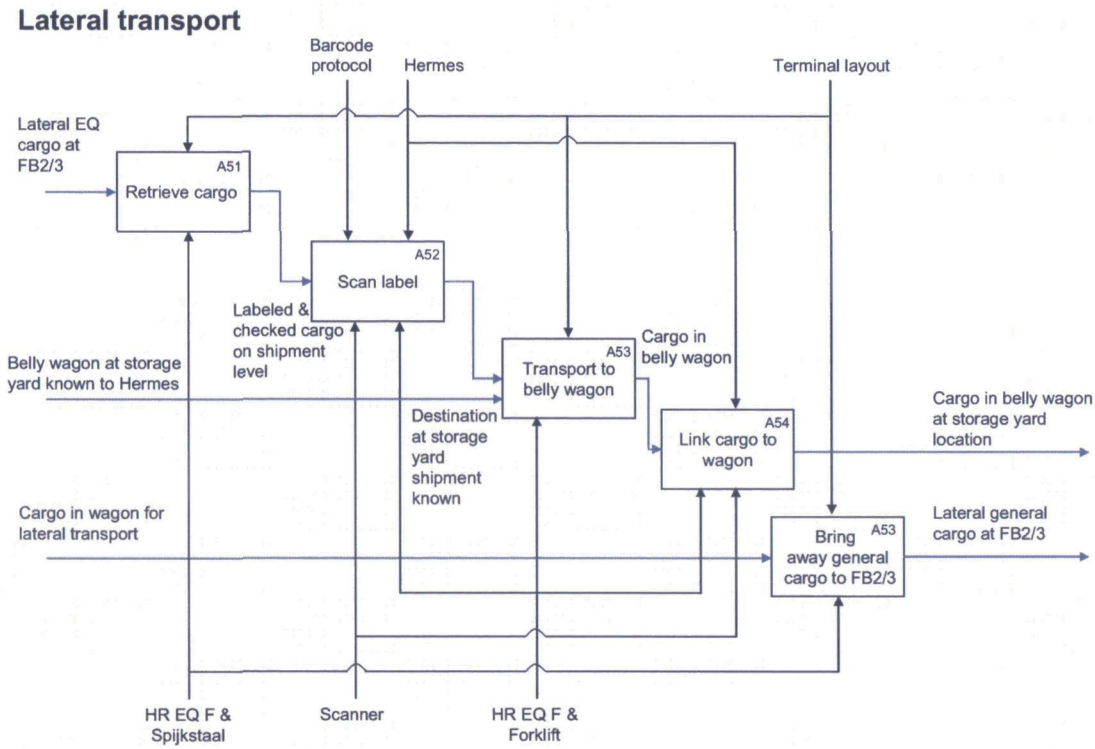


Figure 75: EQ activity A5 in detail: Lateral transport

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.

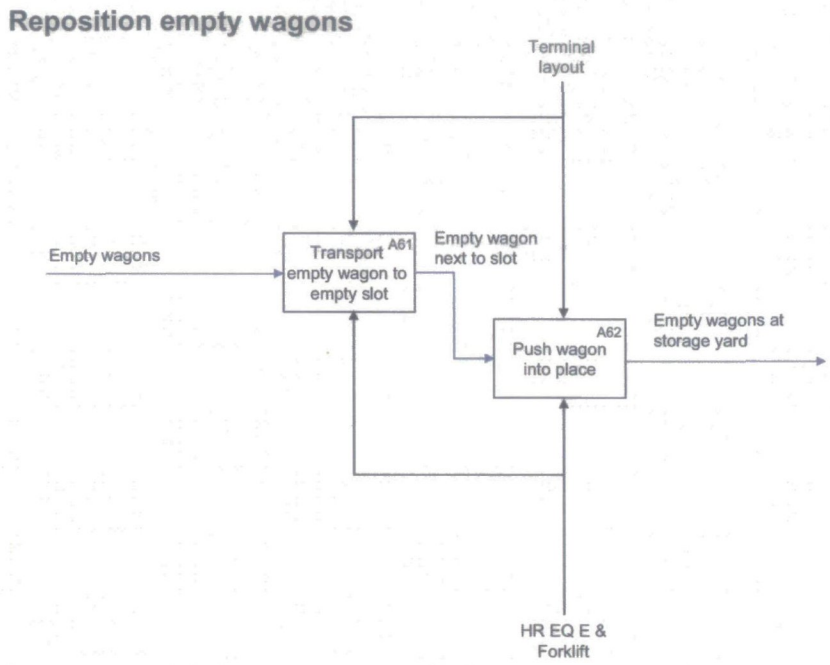


Figure 76: EQ activity A6 in detail: Repositioning empty belly wagons

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.

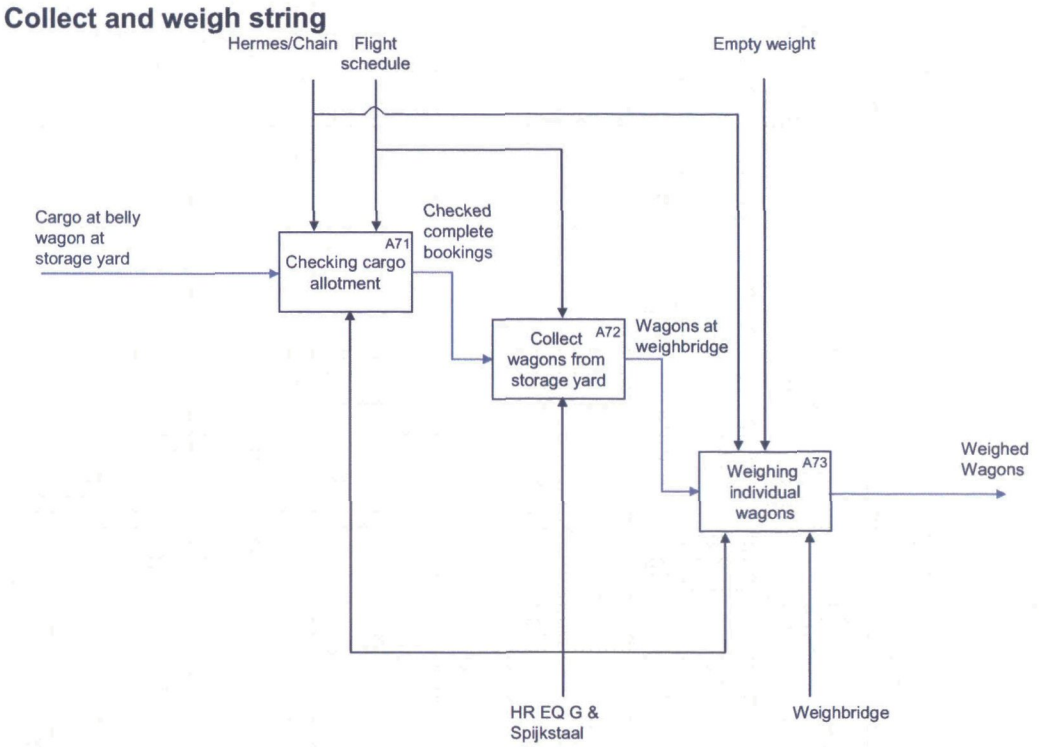


Figure 77: EQ activity A7 in detail Collect and weigh train of departing cargo

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).

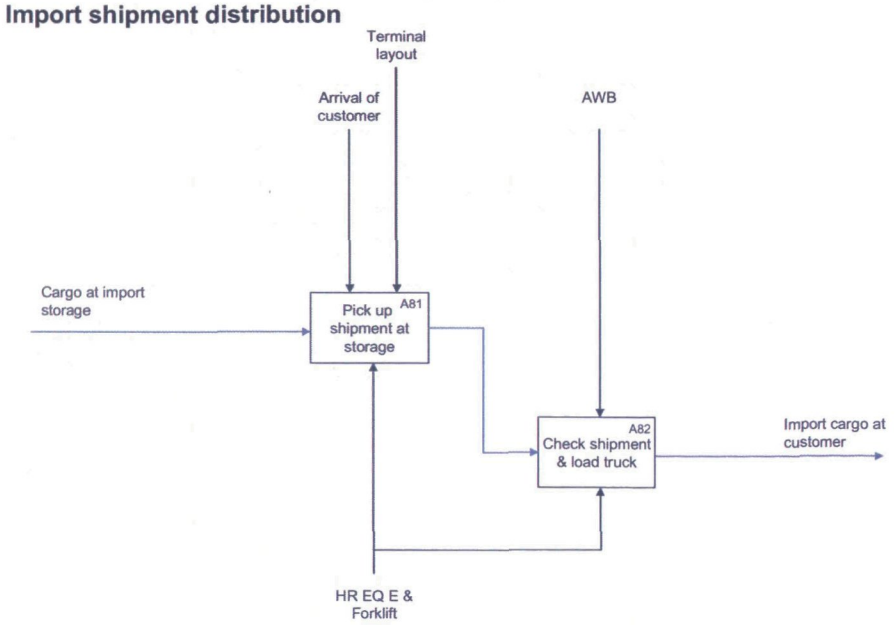


Figure 78: EQ activity A8 in detail: Import shipment distribution

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).

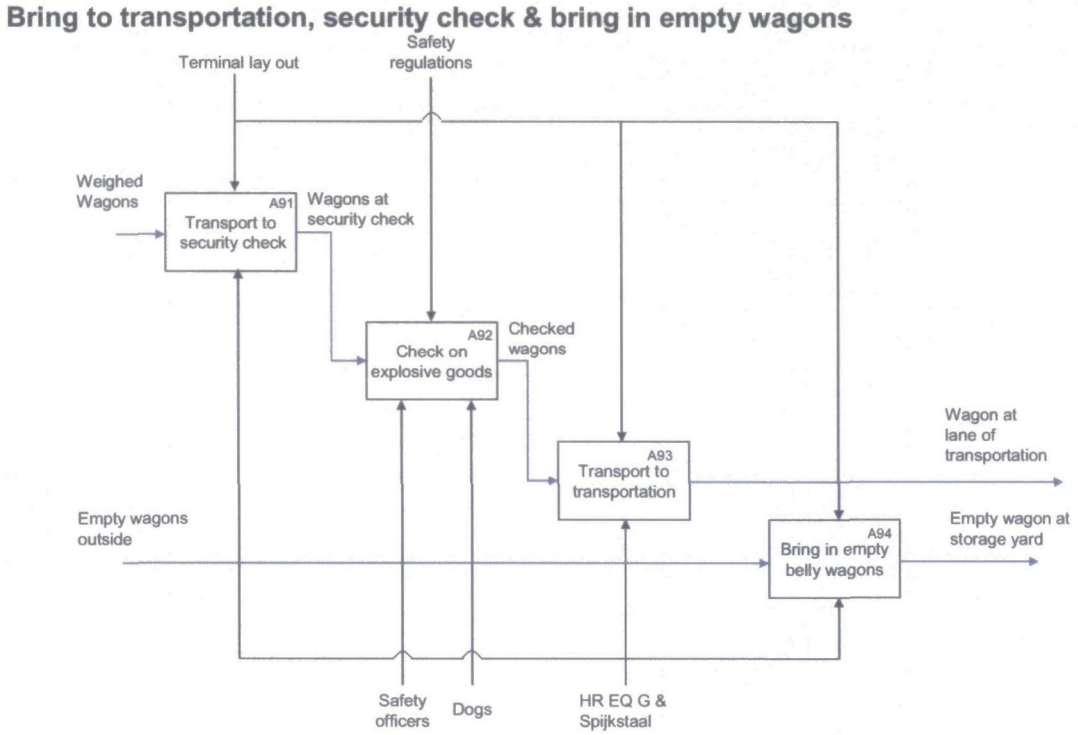


Figure 79: EQ activity A9 in detail: Bring belly wagons to transportation via security

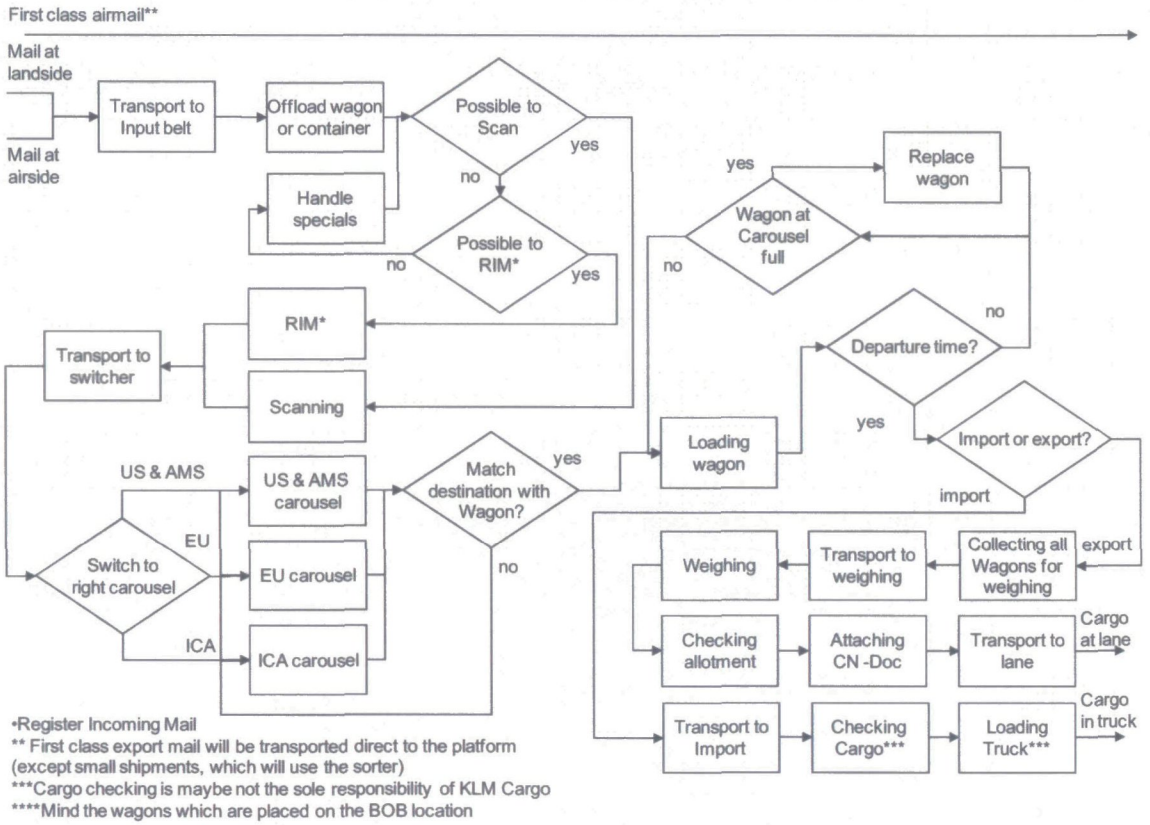
J Overview of belly wagons at EQ storage yard

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

Physical Flow chart Mail (Present situation)



•Register Incoming Mail
** First class export mail will be transported direct to the platform (except small shipments, which will use the sorter)
***Cargo checking is maybe not the sole responsibility of KLM Cargo
****Mind the wagons which are placed on the BOB location

Figure 80: Flowchart of mail operation

K.2 Equation operation

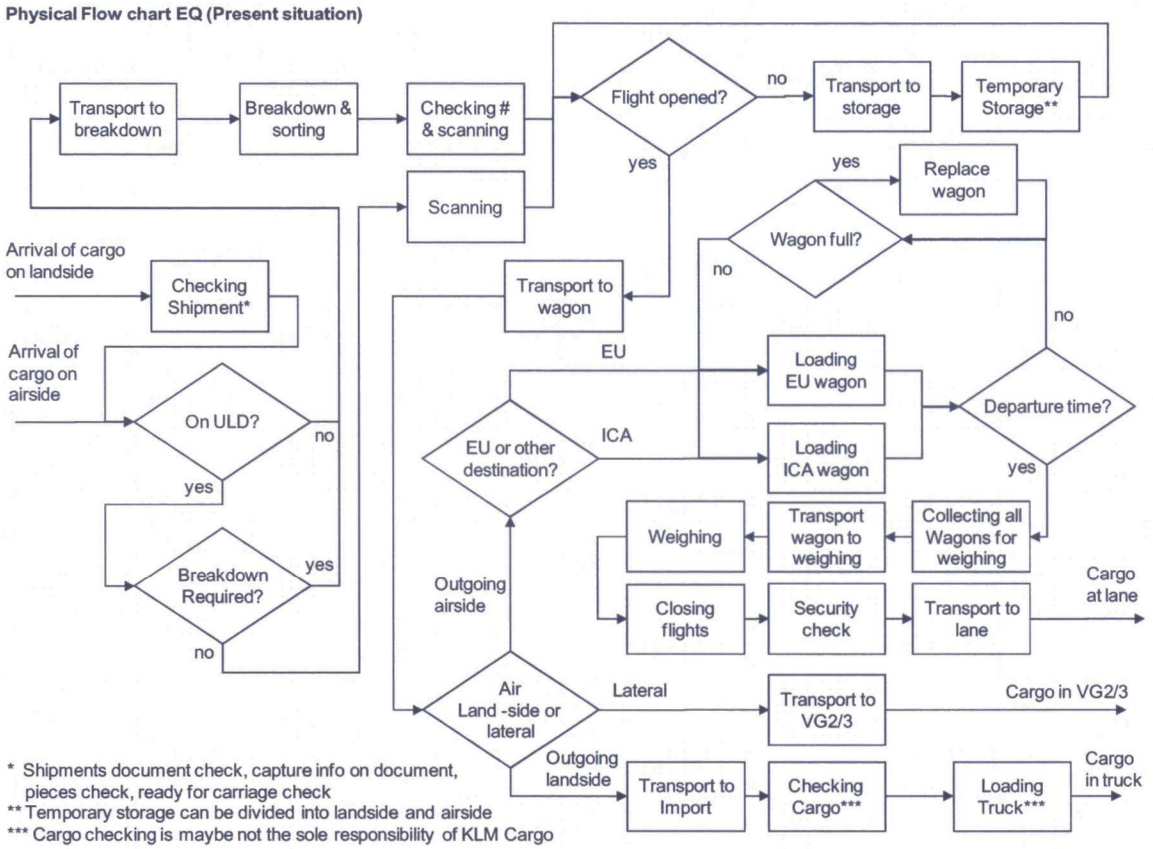


Figure 81: Flowchart of EQ operation

K.3 Flowchart of integrated operations

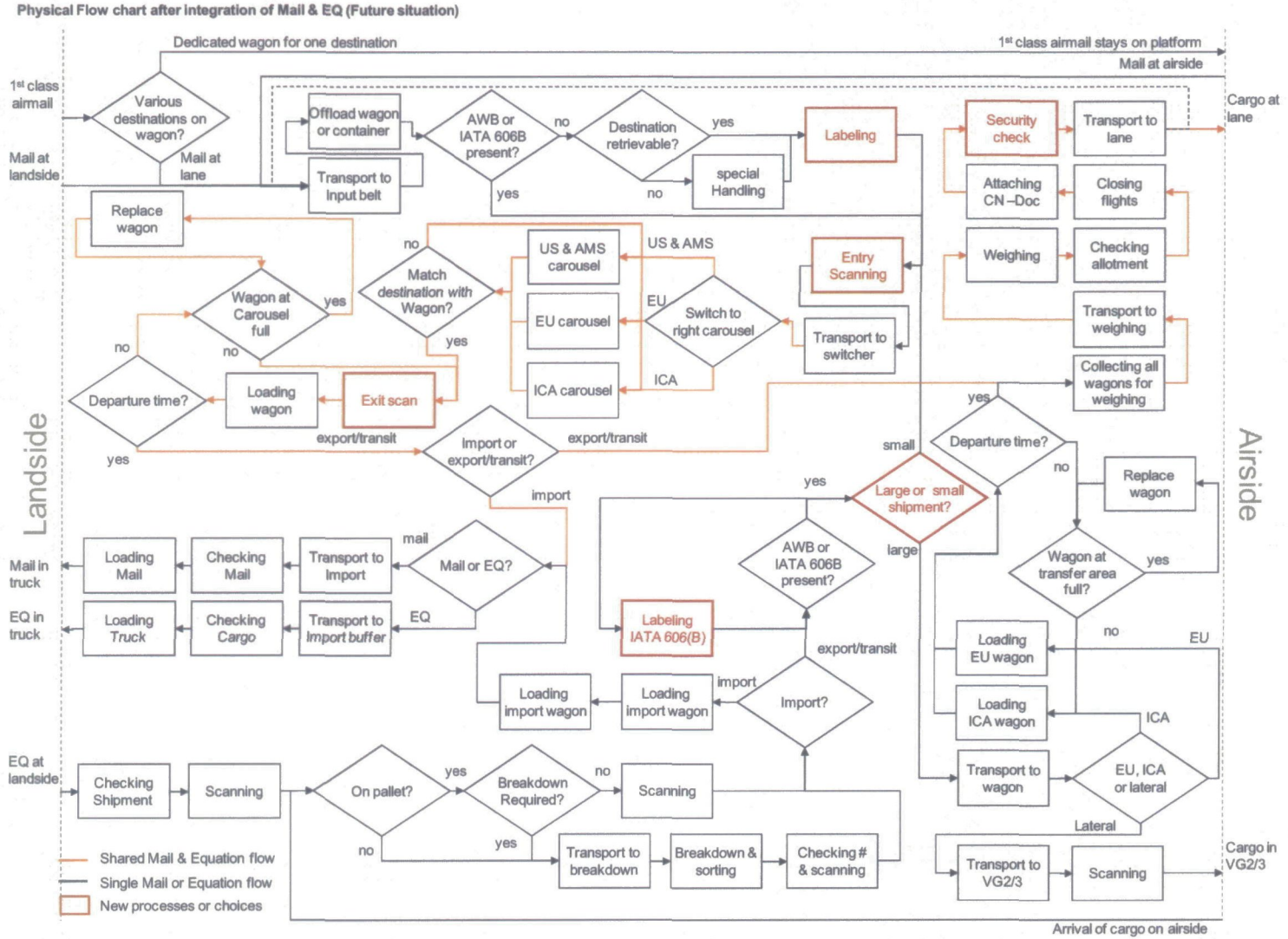


Figure 82: Flowchart of the future integrated operation

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.

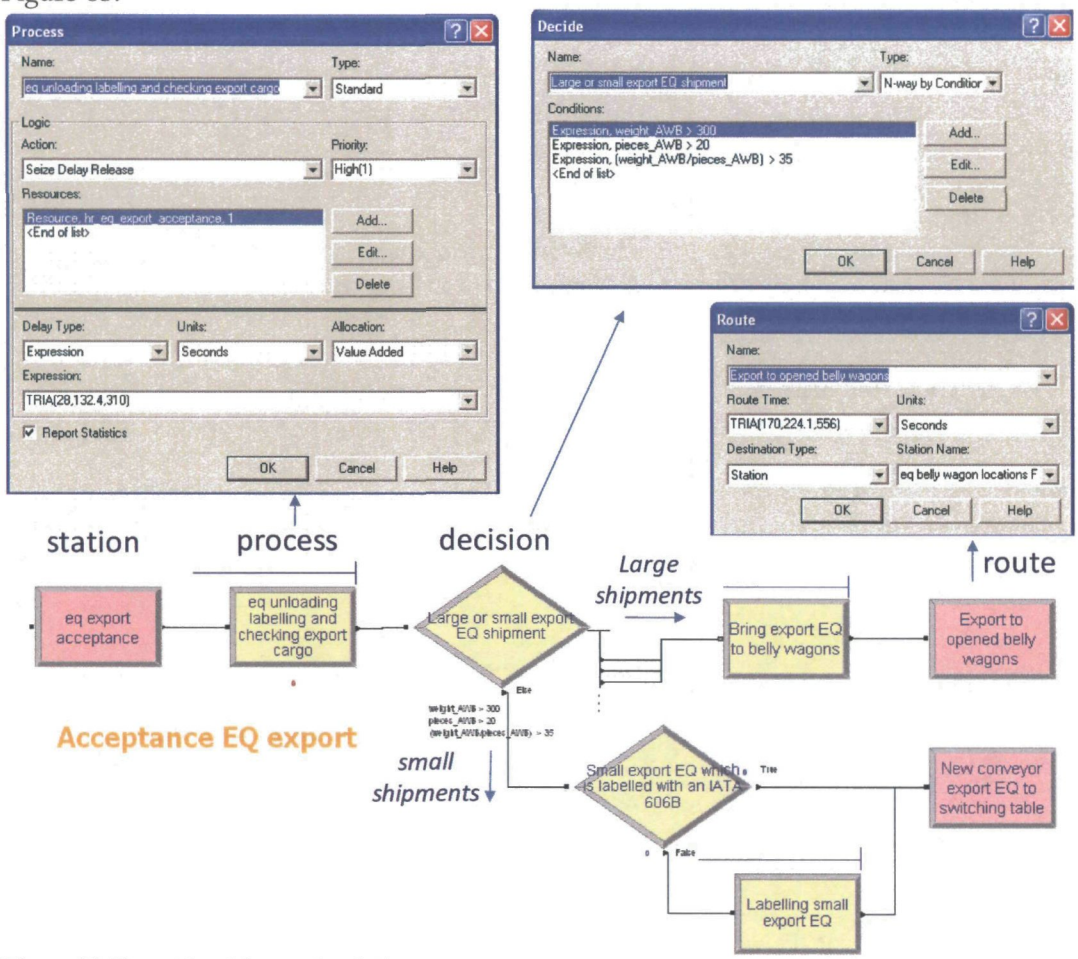


Figure 83: Example of Arena simulation

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.

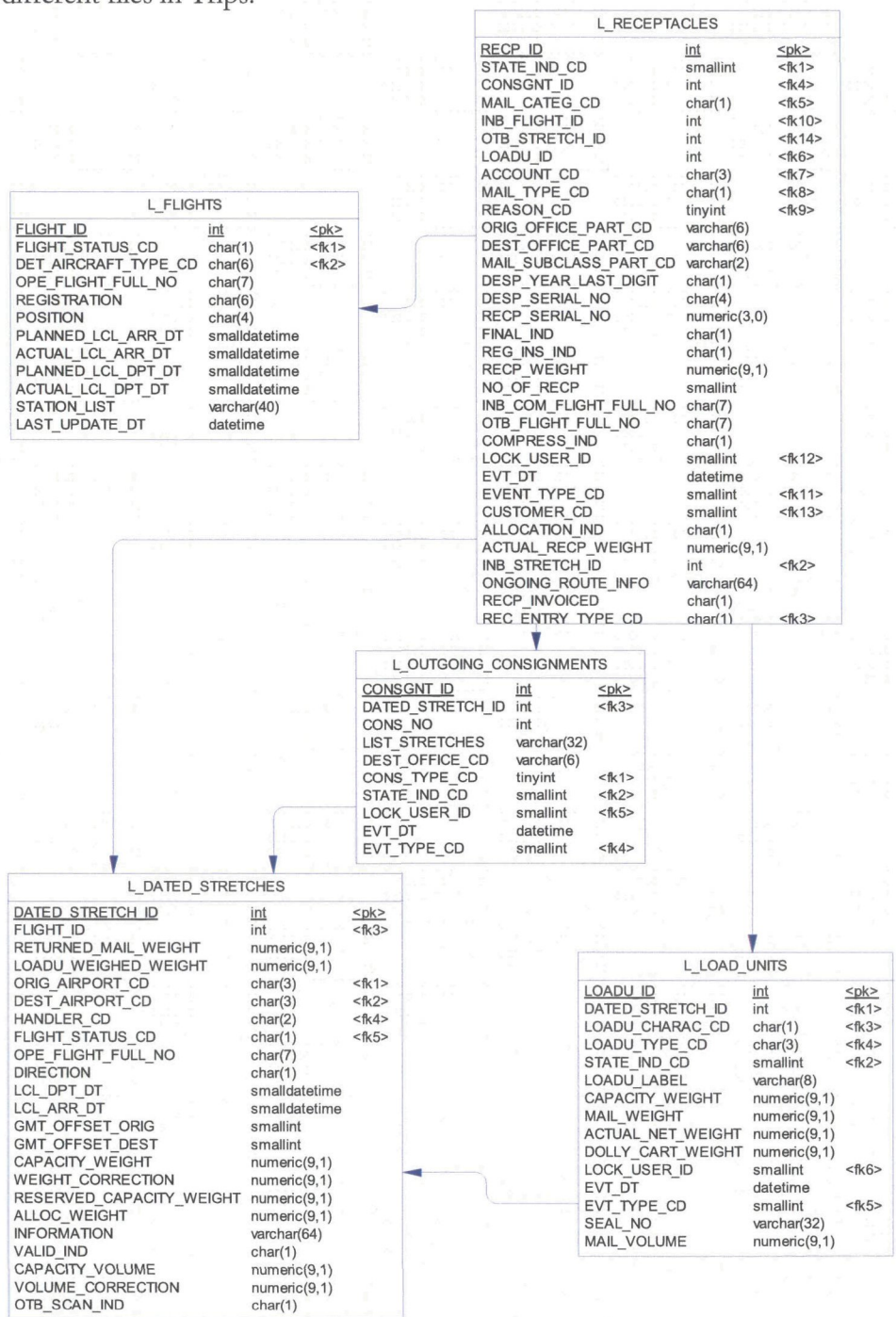


Figure 84: Relation between data files Trips (Universal postal union, 2005, p.17)

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).

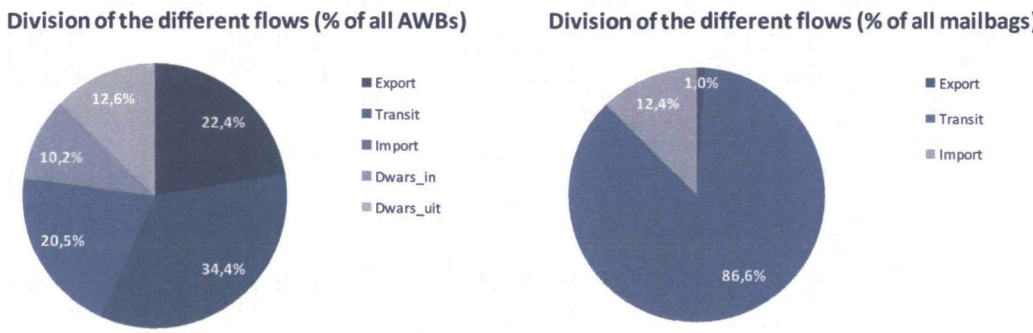


Figure 85: Flow division for both EQ (left) and airmail (right)

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.

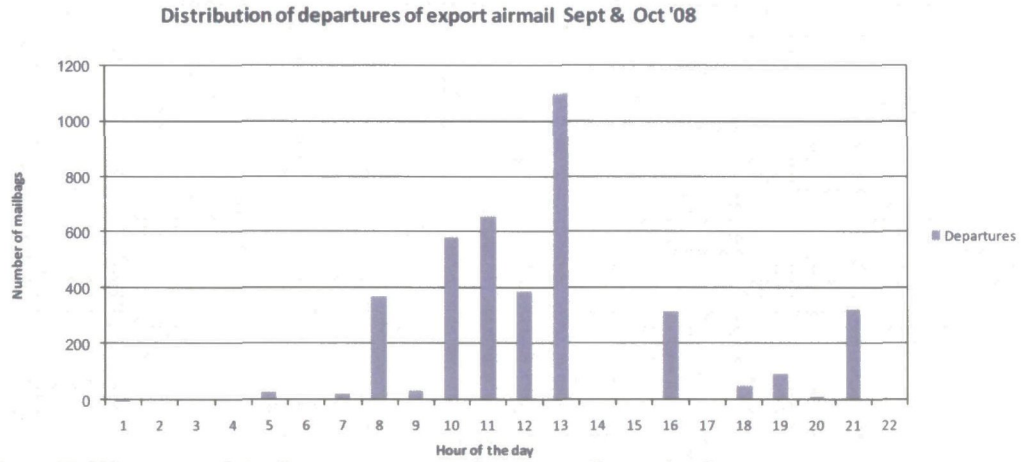


Figure 86: Histogram of the departure pattern of export mail over the day

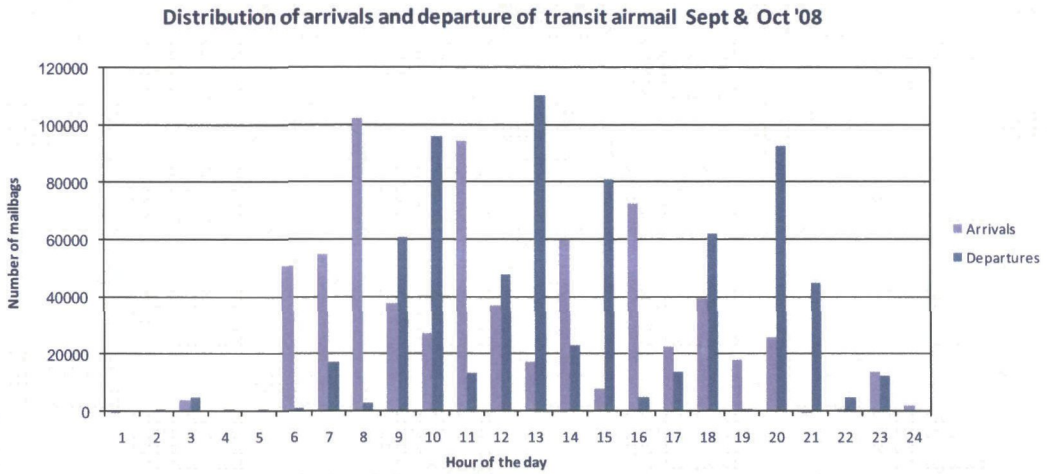


Figure 87: Histogram of the arrival and departure pattern of transit mail over the day

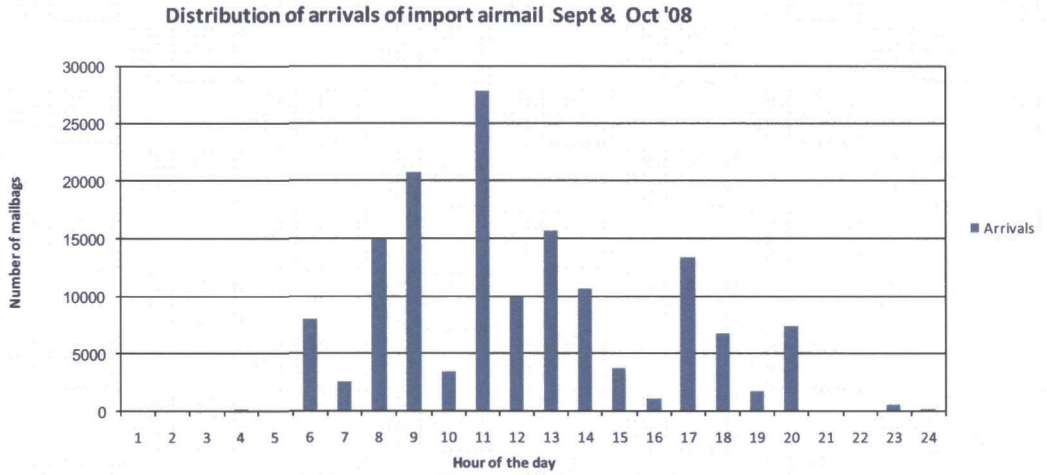


Figure 88: Histogram of the arrival pattern of import mail over the day

M.4 Arrival and departure planning per EQ cargo flow

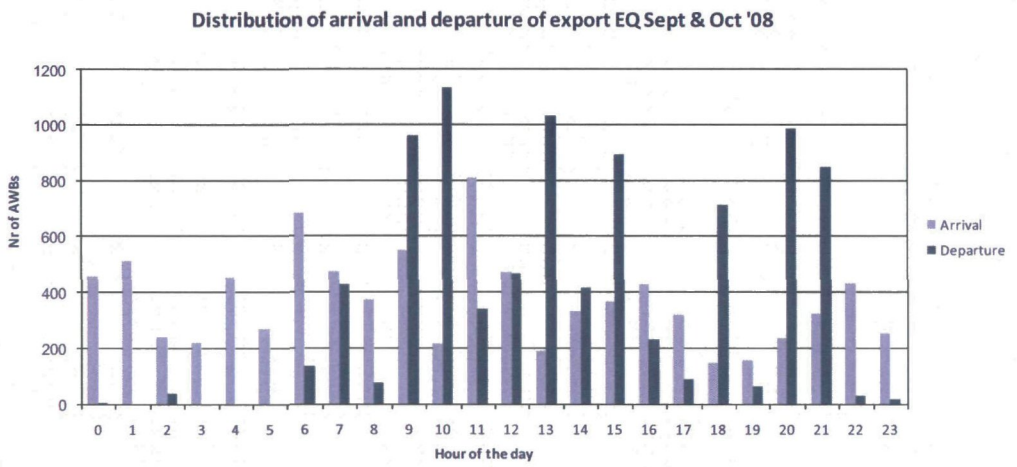


Figure 89: Histogram of the arrival and departure pattern of export EQ over the day

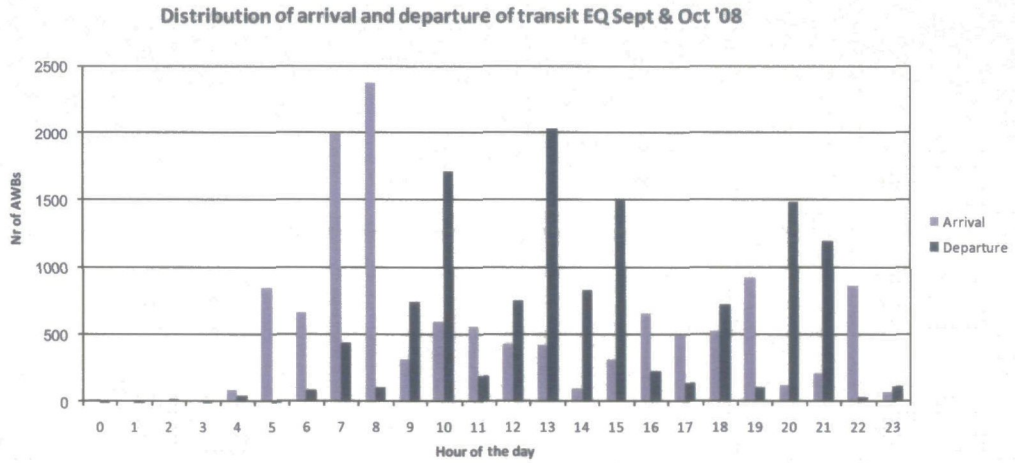


Figure 90: Histogram of the arrival and departure pattern of transit EQ over the day

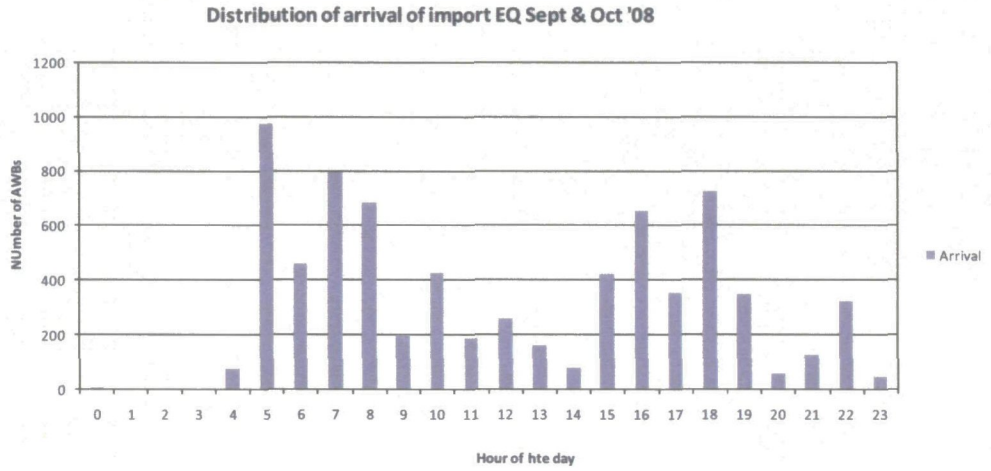


Figure 91: Histogram of the arrival pattern of import EQ over the day

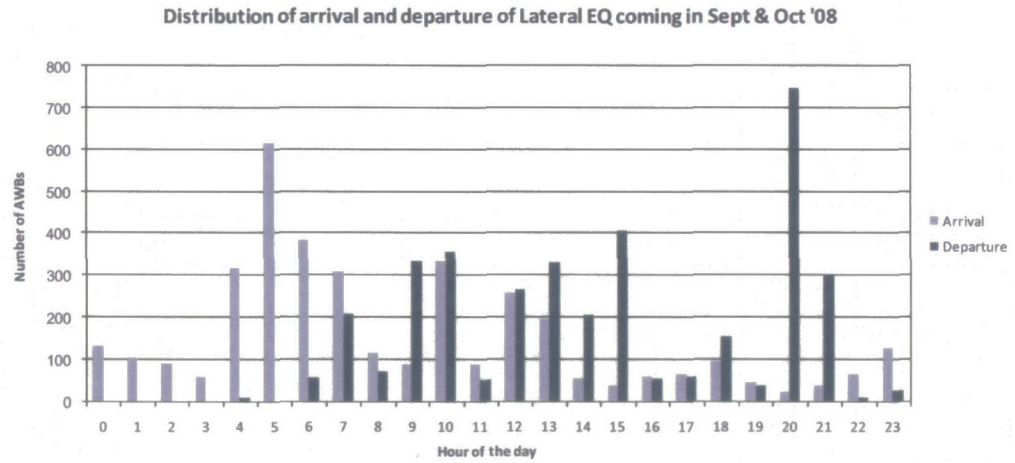


Figure 92: Histogram of the arrival and departure pattern of lateral incoming EQ over the day

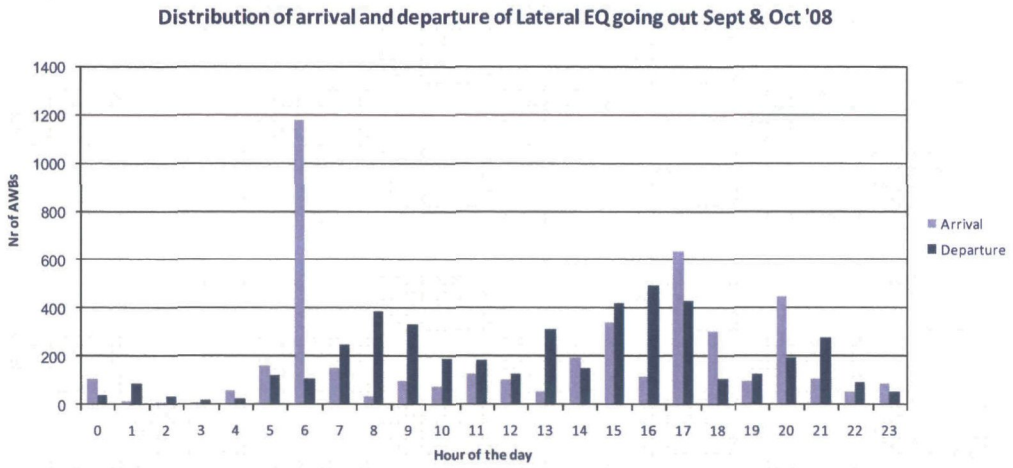


Figure 93: Histogram of the arrival and departure pattern of lateral outgoing EQ over the day

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.

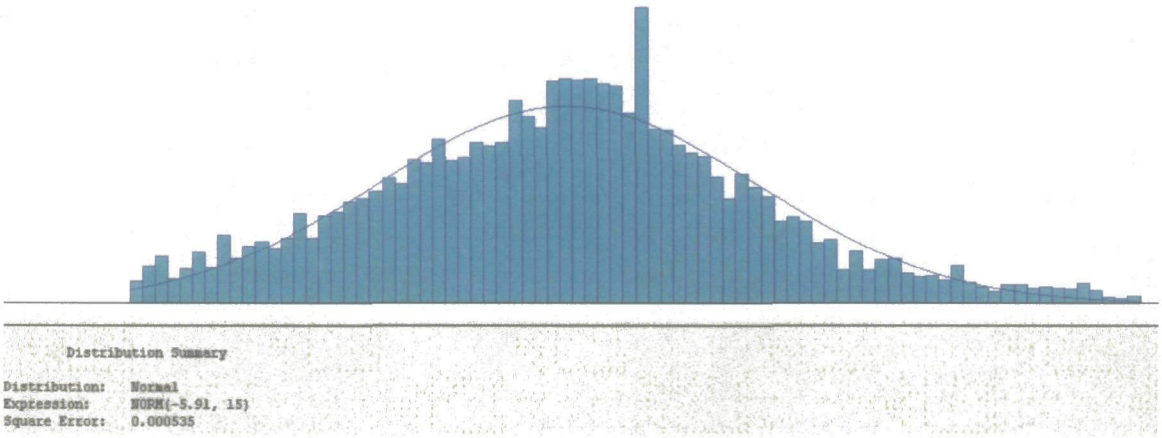


Figure 94: Arena input analyzer results for the difference between ATA and STA

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

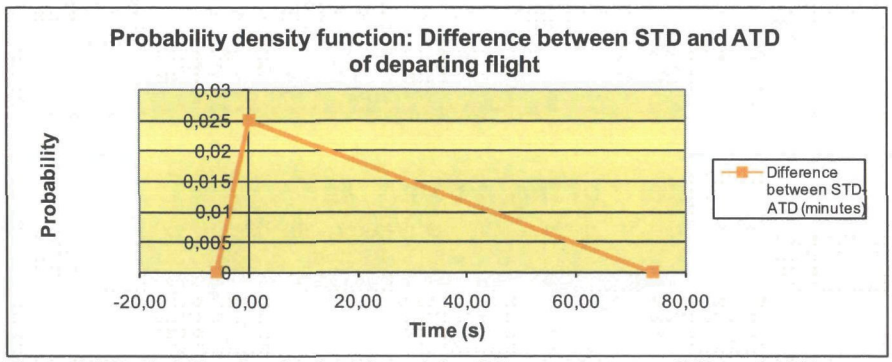


Figure 95: Probability density function of the difference between STD and ATD

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.

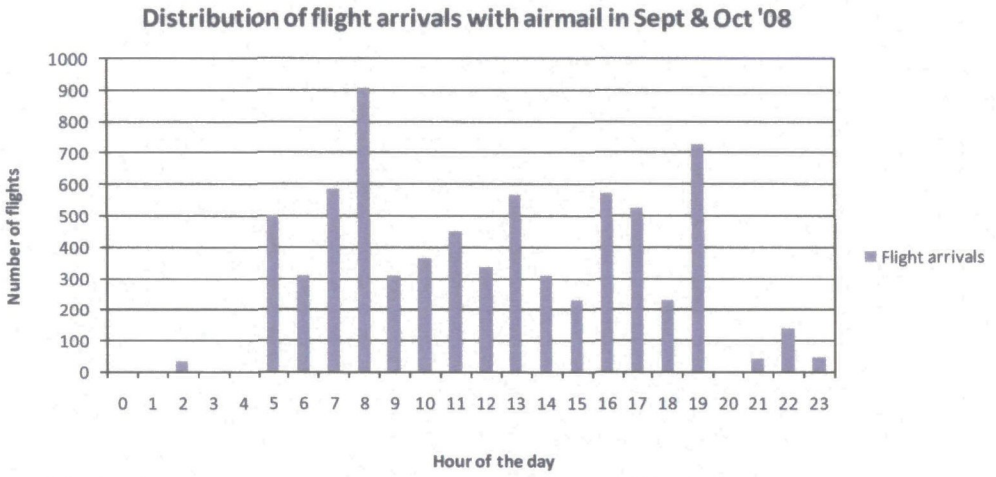


Figure 96: Histogram of the arrival pattern of flights with mail over the day

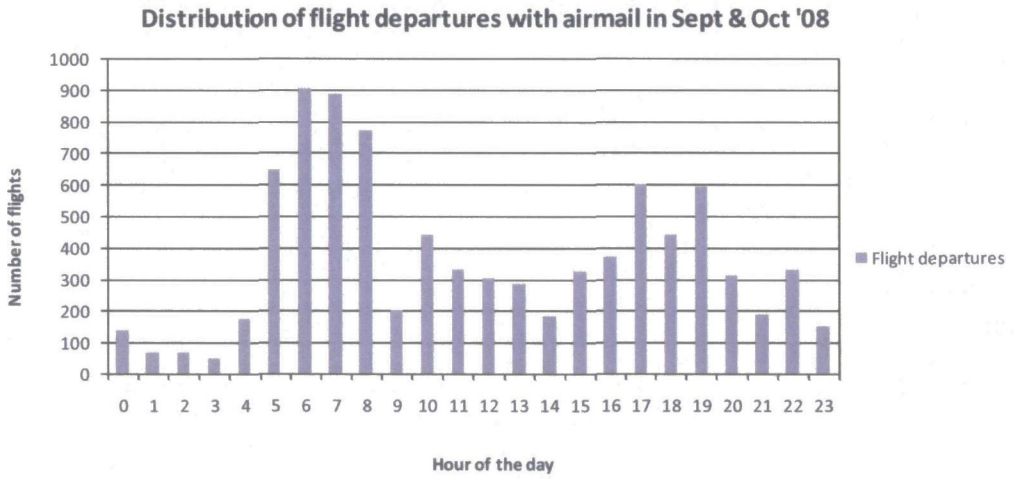


Figure 97: Histogram of the departure pattern of flights with mail over the day

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.

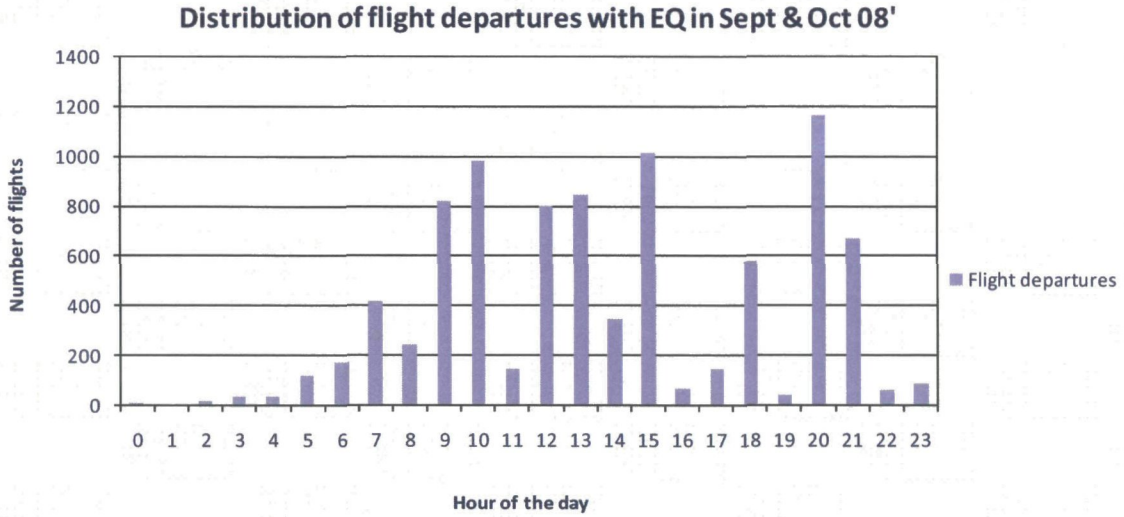


Figure 98: Histogram of the arrival pattern of flights with EQ over the day

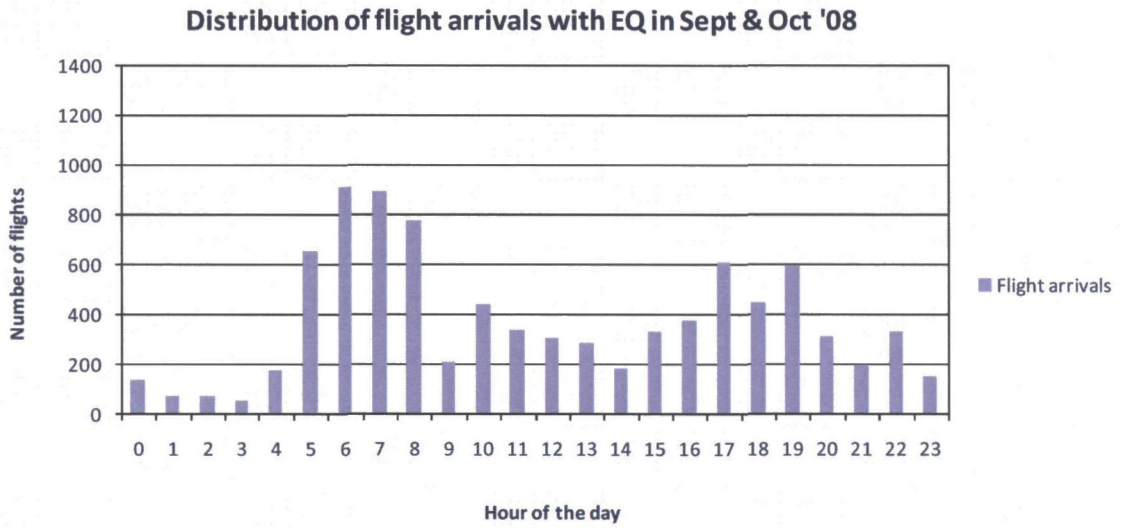


Figure 99: Histogram of the departure pattern of flights with EQ over the day

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**

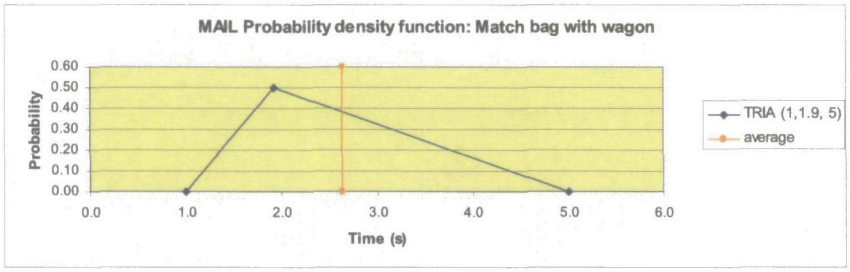


Figure 100: Example of the triangular distribution based on the process time measurements

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**

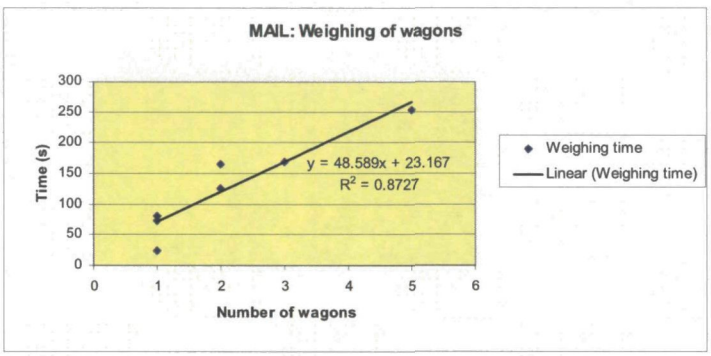


Figure 101: Example of linear regression analysis on the time measurements

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

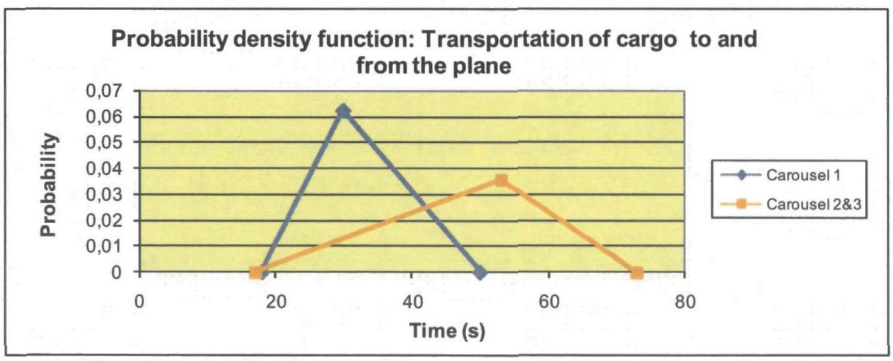


Figure 102: Triangular distribution of the transportation times between the gate and FB1

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

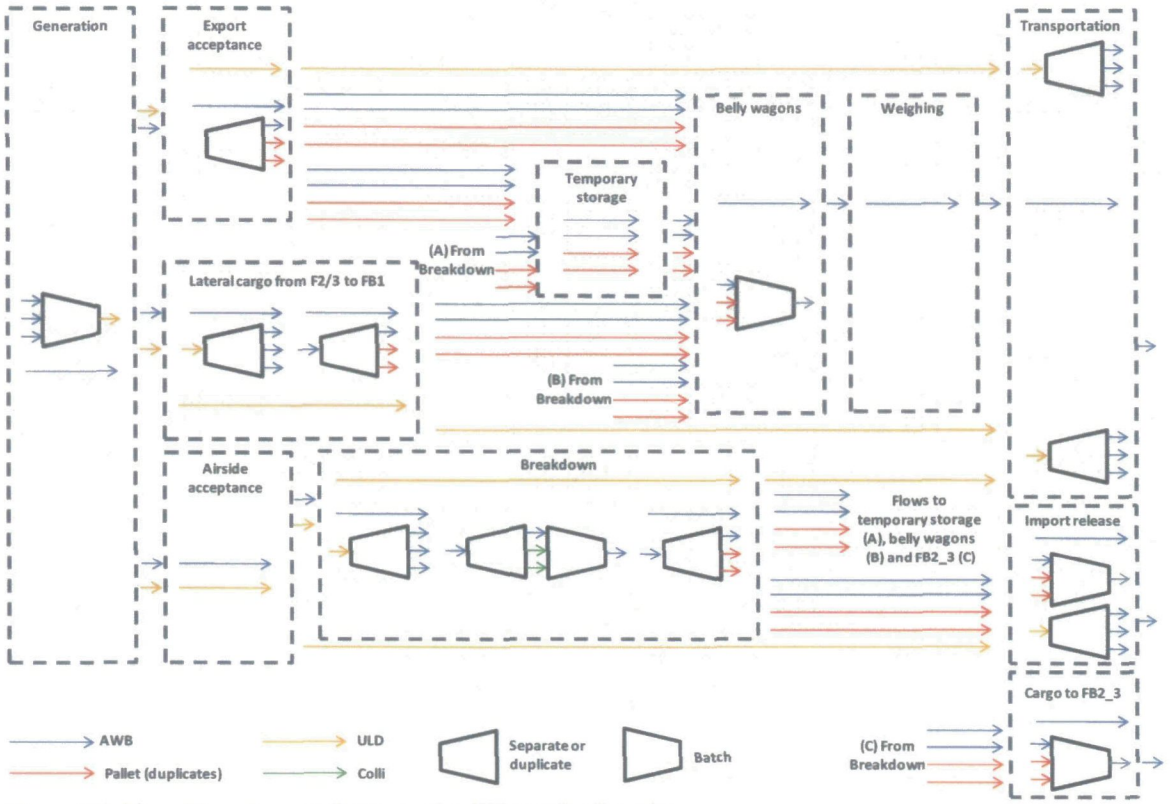


Figure 103: Transition structure between the different load carriers

Q.2 Deadlines prior to the scheduled flight departure of cargo

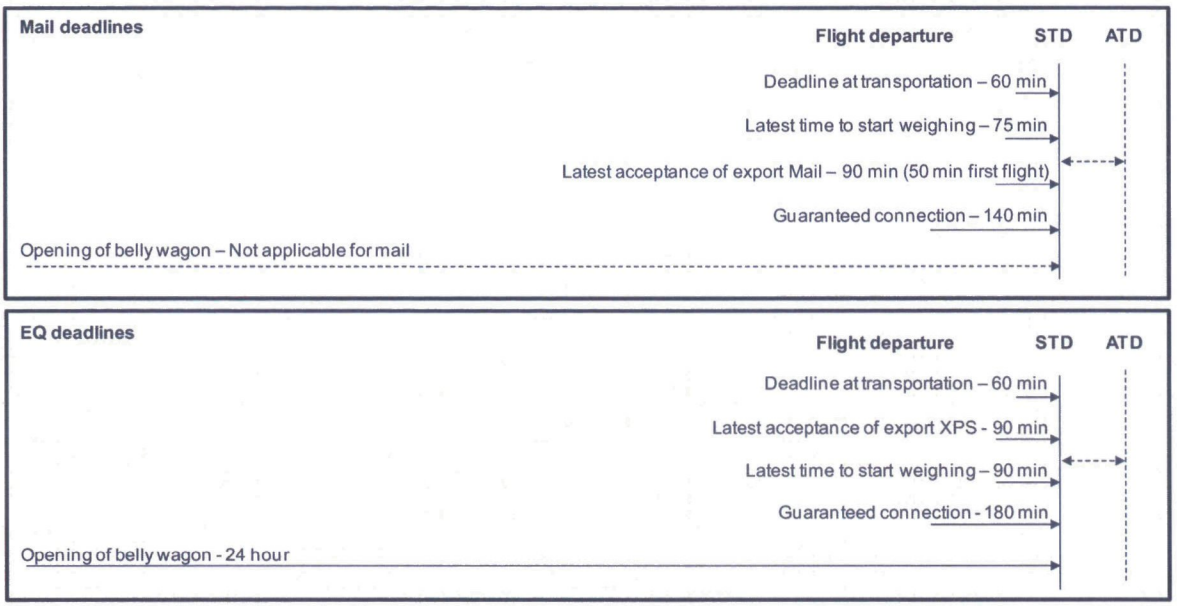
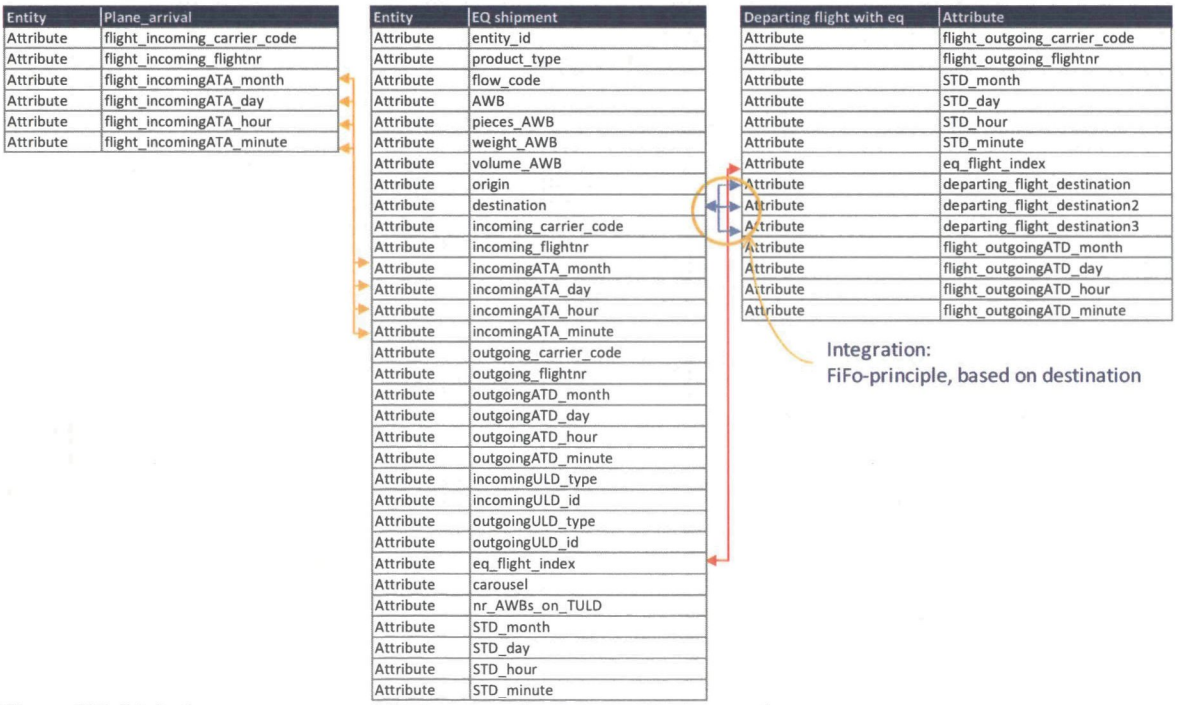


Figure 104: Deadlines prior to the flight departure for mail and EQ

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

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.

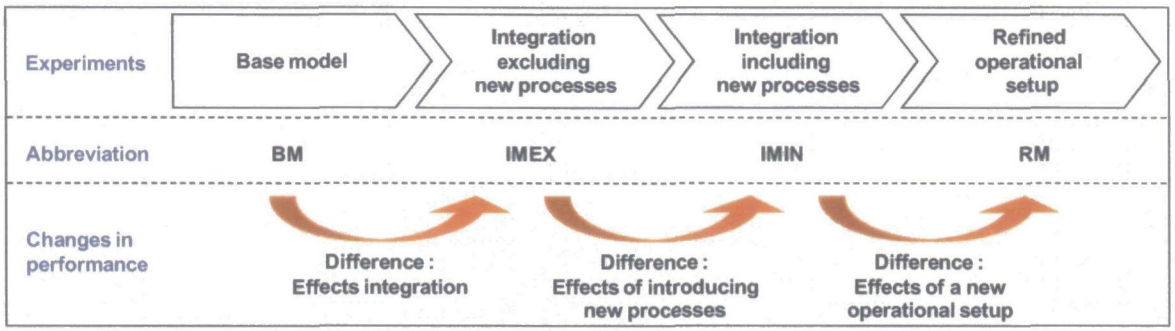


Figure 109: Sequence of simulation experiments

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.

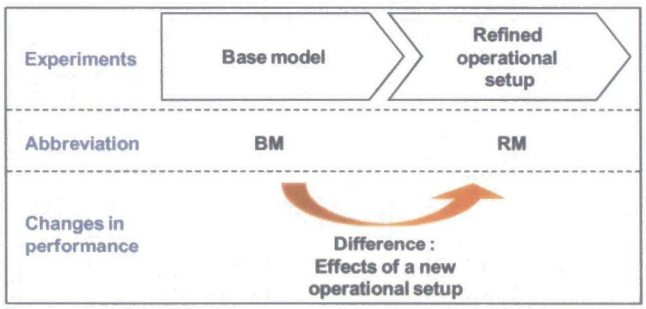


Figure 110: Modified sequence of experiments with respect to the refined model

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

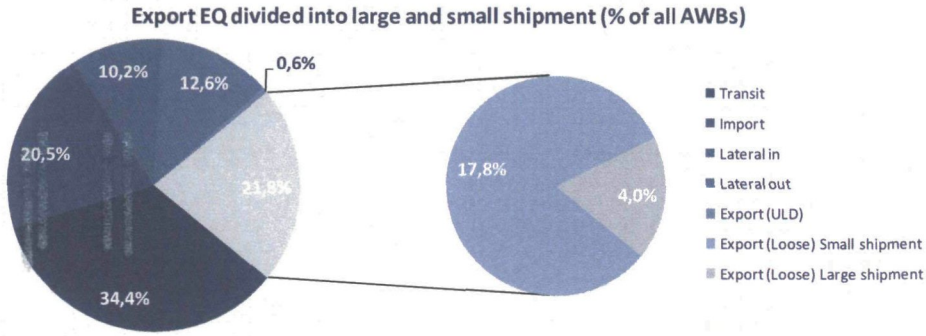


Figure 111: Sub-division of export EQ in shipment size based on number of AWBs

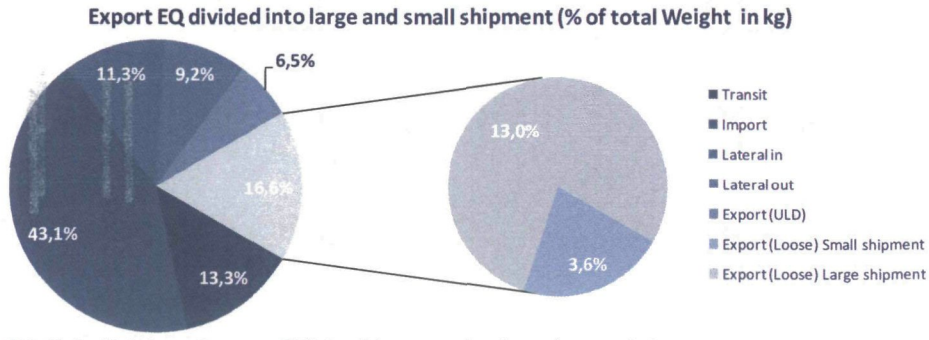


Figure 112: Sub-division of export EQ in shipment size based on weight

U.3 Division of shipment size for transit EQ

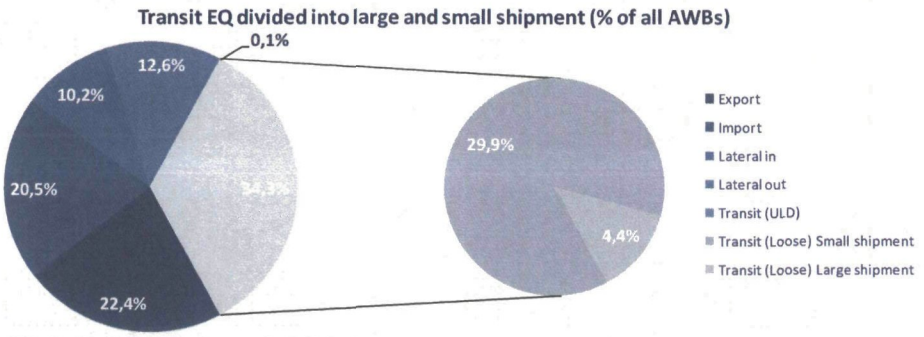


Figure 113: Sub-division of transit EQ in shipment size based on number of AWBs

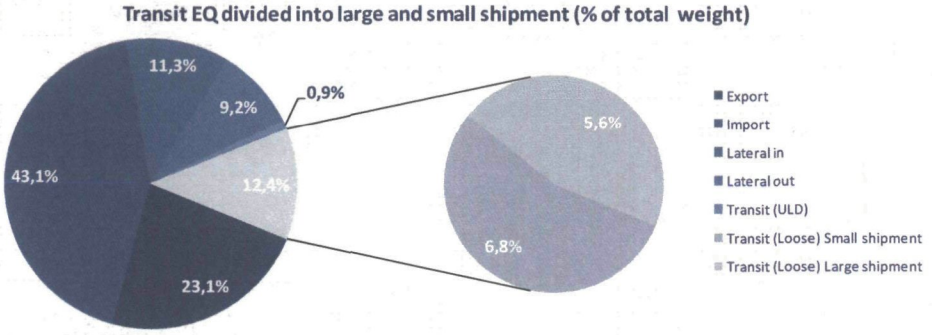


Figure 114: Sub-division of transit EQ in shipment size based on weight

U.4 Division of shipment size for lateral incoming cargo

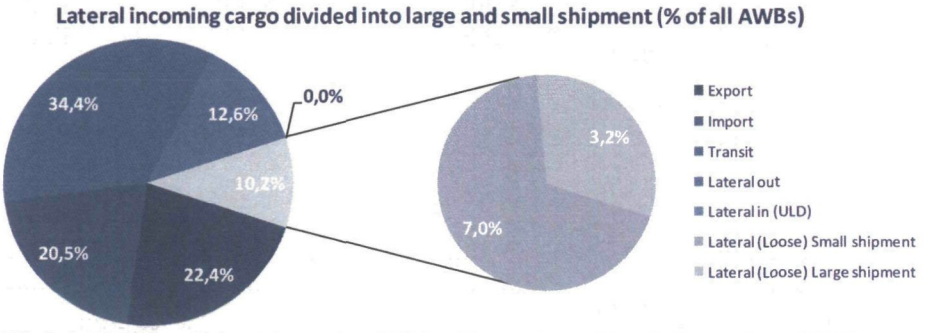


Figure 115: Sub-division of lateral incoming EQ in shipment size based on number of AWBs

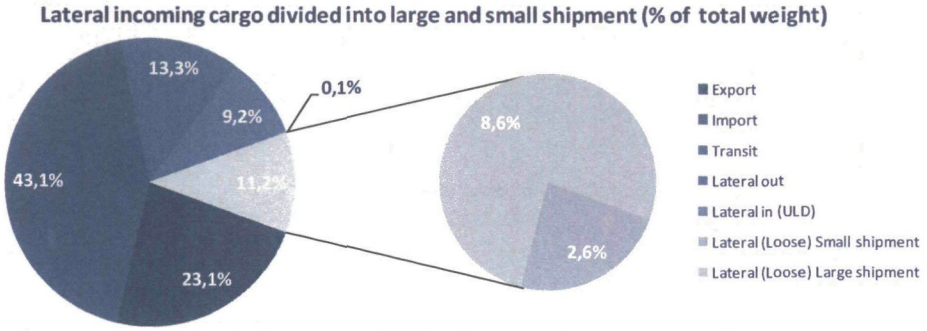


Figure 116: Sub-division of lateral incoming EQ in shipment size based on weight

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

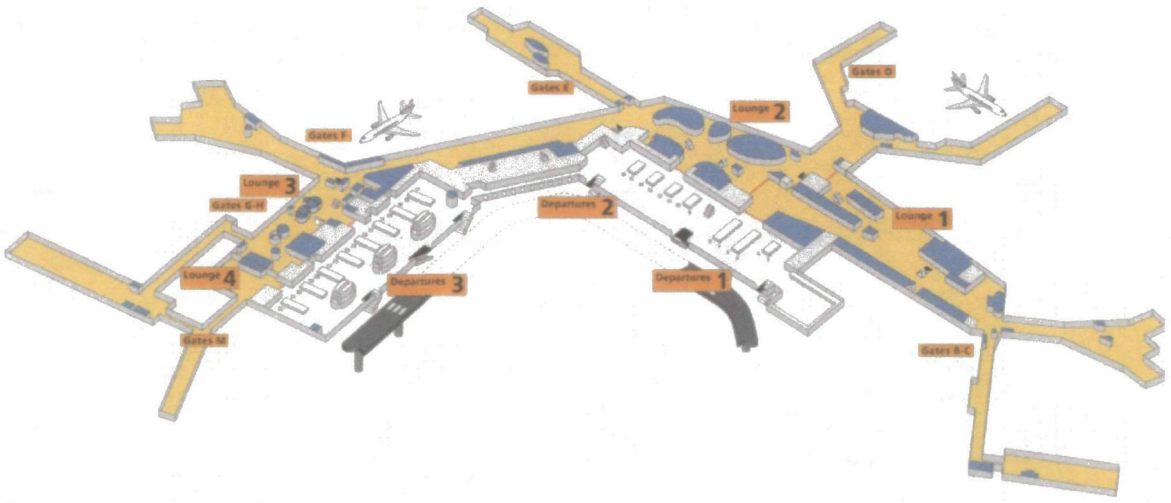


Figure 118: Overview of the gates used for departures at Schiphol airport (www.schiphol.nl, 1/3/2009)

W Current wagon allocation along the carousels

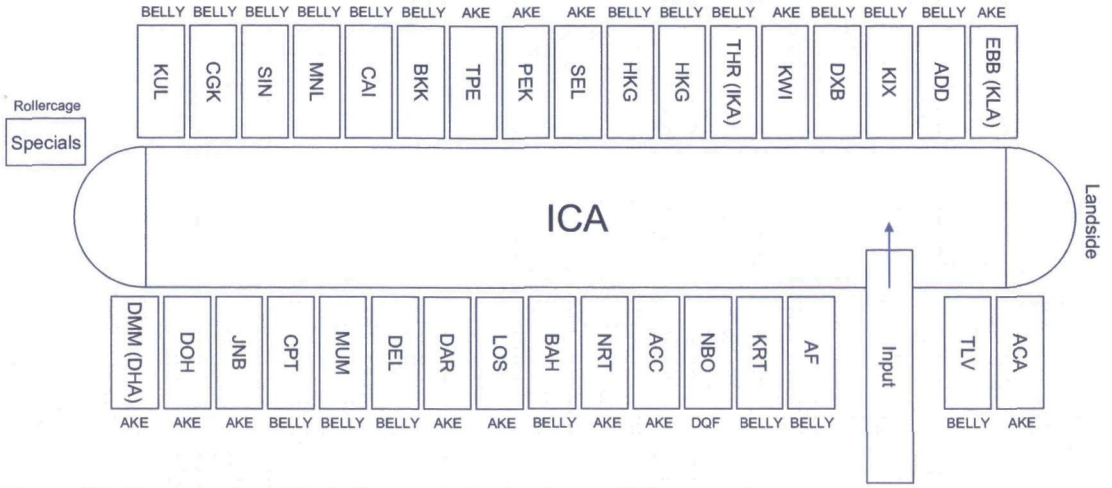


Figure 119: Airport codes of the belly wagon destinations at ICA carousel

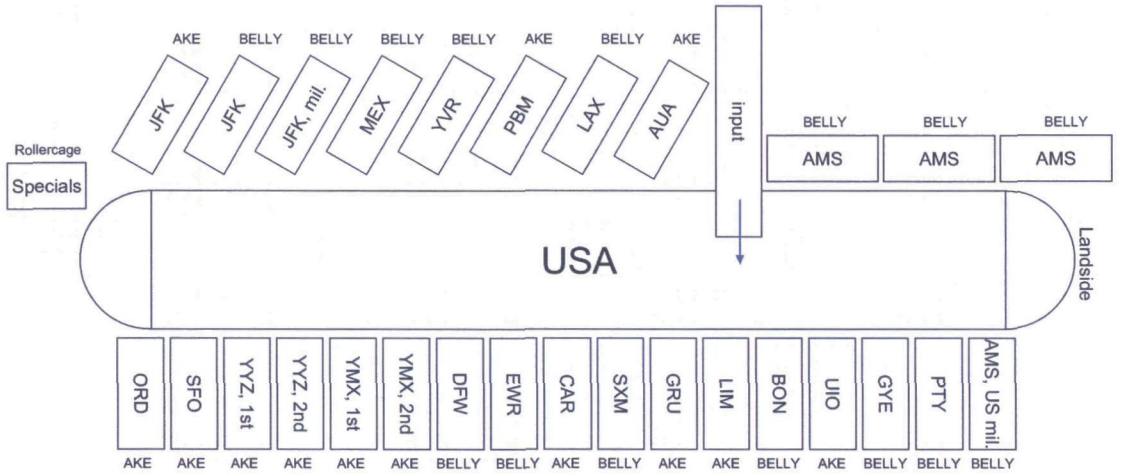


Figure 120: Airport codes of the belly wagon destinations at USA carousel

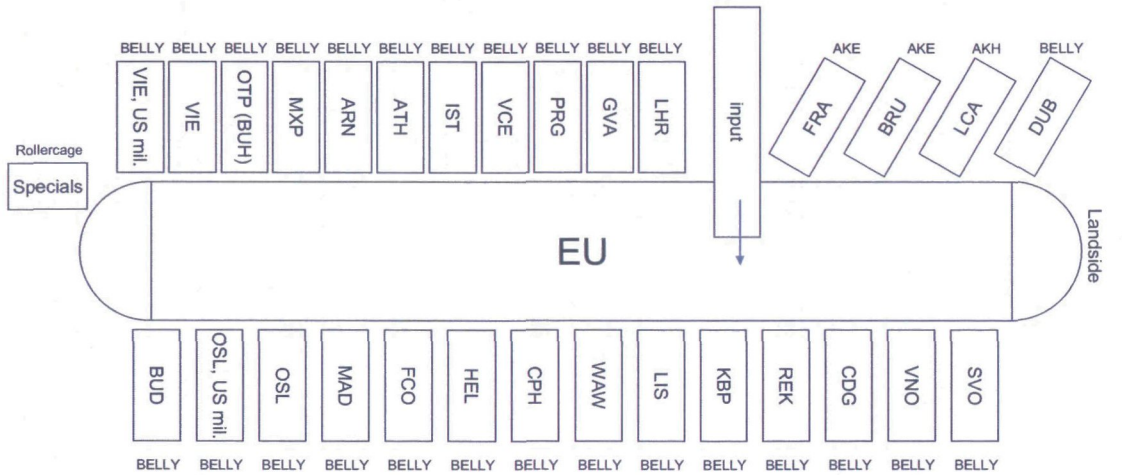


Figure 121: Airport codes of the belly wagon destinations at EU carousel

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					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval Lower	95% Confidence Interval Upper			
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					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval Lower	95% Confidence Interval Upper			
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					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	the Difference Lower	the Difference Upper			
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					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval Lower	95% Confidence Interval Upper			
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					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	the Difference Lower	the Difference Upper			
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					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval Lower	95% Confidence Interval Upper			
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

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