Is there enough capacity?

stochastic analysis of the trasition from full freighters to belly cargo of KLM

Author(s)
Mujica Mota, Miguel; el Makhloufi, Abdel; Hernández, Pedro González

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2 authors:

Miguel Mujica Mota
Aviation Academy. Amsterdam University of Applied Sciences

Abdel El Makhloufi
Amsterdam University of Applied Sciences

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Miguel Mujica Mota [a], Abdel El Makhloufi[b]

[a]Aviation Academy, Amsterdam University of Applied Sciences,
[b]Research group Smart Mobility & Logistics, Amsterdam University of Applied Sciences
1097 DZ Weesperzijde 190, Amsterdam, The Netherlands
[c] National Autonomous University of Mexico, Mexico

[a] m.mujica.mota@hva.nl, [b] a.el.makhloufi@hva.nl, [c] phetergh@gmail.com

ABSTRACT

KLM is downsizing the full-freight cargo fleet in Schiphol Airport, for that reason it is important for the company and the airport to explore the consequences of moving the cargo transported by the full freighters into the bellies of the passenger flights. The consequences of this action in terms of capacity and requirements are still unknown. The current study illustrates how to analyse the uncertainty present in the system for identifying the limitations and potential consequences of the reduction of full freighter fleet. The options we identify for coping with the current demand is by adjusting their load factors or increase the number of flights. The current model includes the airside operation of the airport, the truck movements and the traffic that arrives at Schiphol which allows addressing the impact of uncertainties of the operation as well as the limitations and potential problems of the phasing-out action.

Keywords: air cargo, airport operations, transhipment, full freighter, belly cargo, uncertainty, warehouses, KLM cargo

1. INTRODUCTION

On a worldwide level, the transport of commercial cargo is a key economic indicator of international trade as well as a thermometer for the state of the global economy. The supply chain and logistics industry exists to connect manufacturers with suppliers and middlemen shippers with the end customer (Feng, 2015) and for some valuable goods aviation plays an important role.

In terms of the business model between cargo operations and passenger operations, there exist many similarities as well as differences. According to some authors, the key differences between cargo and passenger operations are uncertainty, complexity and flexibility (Bartodziej et al., 2009; Leung et al., 2009; Li et al., 2009; Wang and Kao, 2008).

Air cargo transport is more complex than passenger transport because the former involves more players, more sophisticated processes, a combination of weight and volume, varied priority services, integration and consolidation strategies, and multiple itineraries of a network than the latter.

Key similarities include:

- Similar revenue management tools and concepts such as demand forecasting, overbooking, capacity forecasting, route generation and bid prices.
- A growing movement towards network capacity as opposed to leg capacity, in a similar fashion for passenger airlines. However, cargo shipments do not care about the quality of the service (nonstop vs. connecting) as much as passengers, disregarding time.

Major differences include:

- Cargo focuses on building customer, supplier, and retailer relationships because of a limited number of customers.
- Cargo focuses on profitability rather than load factor. Average load factors for passenger flights hovered around 80% in 2015 while cargo load factors in the passenger flights are around 40% and 70% in full freighters.
- Cargo requires medium to long term allotment management - optimal assignment of space to customers.
- Different optimization factors such as freight mix based on density of payload and revenue.
- Optimization of schedule based on alternate constraints on noise and airport utilization (night-time flying).
- Cargo ground transport in Europe is at least approximately 700 km radius from airport. For passengers is mostly less than 3 hr. travel.
- Air cargo transport has higher uncertainty than passenger transport in terms of capacity availability. In passenger transport, passengers may cancel reservations, and a small number of passengers may not show up. However, in capacity booking for air cargo, freight forwarders have to pledge the use of the cargo capacity on specific flights twelve or six months ahead (Amaruchkul et al., 2011).
- Because freight forwarders do not need to pay for unused capacity, they may book more than the actual needed capacity to cut risks or to compete with others forwarders.

- Many bookings in air cargo can be cancelled and/or rebooked because airlines typically do not charge for changing reservations. Therefore, the booking process is subject to considerable volatility (Petersen, 2007).
- Forecasting cargo capacity is more complex than forecasting passenger capacity. While the capacity of a passenger aircraft is fixed by its number of seats, cargo capacity depends on the type and dimensions of the container used (called unit load devices, ULDs), and specified according to pivot weight, pivot volume, type, and centre of gravity (Leung et al., 2009).
- Transhipment itineraries between an origin and destination (OD) pair for cargo transport benefit the airline more than they benefit passenger transport. In general, all major airlines operate within so-called hub-and-spoke networks. Both passengers and cargo are transported from many different origins to a small number of hubs, where passengers and cargo are consolidated and then transported further to other hubs by wide-body aircrafts. The total number of transits are limited for passenger transport, and much larger for air cargo transport i.e. air cargo can be transhipped via several intermediate airports from the origin to the destination to meet the delivery time (Amaruchkul et al., 2011). The airline only needs to declare the origin, stopover (transit) airports, and destination to the forwarders and can decide on the optimal use of transhipment itineraries of air networks.

Common items shipped by air include perishables, pharmaceutical products, high-tech and electronics, clothing, animals and high-value products such as diamond, art cars among others.

Because of these differences, air freight accounts for less than 1% of total freight carried by all transport modalities (air, sea, water, and road) in terms of both volume and weight. However, air freight accounts for about 40% of its value (Damme et al, 2014) and almost 1% of global GDP is spent on air transport (IATA 2016).

1.1 The Situation of KLM in Schiphol

The cargo operations at Schiphol airport faces major challenges from macro- developments (such as rapid changes in aviation sector and cargo market, technology/ICT revolution, transitions to green and circular economy, e-commerce and 3D-printing), increasing volumes and volatility and uncertainty of airfreight and logistics, and last but not least changes in freight strategy of the hub carrier KLM cargo. The last one consists in reducing its full-freighter and increasing cargo transport in the bellies of the passenger's aircrafts as following the current.

Schiphol is important for the logistics sector and economic growth of the Amsterdam metropolitan region economy. Airfreight operations are fully concentrated at Schiphol airport, with minimal cargo activities in other regional airports such as Maastricht and Eindhoven airports which makes it a key node of some important and valuable products such as flowers or pharmaceuticals.

Schiphol is ranked third in Europe in term of airfreight aggregated volumes (2 million tons in 2015), behind Charles-de-Gaulle and Frankfurt airports. The main carrier in Schiphol is KLM whose passenger operation accounts for more than 80% of the revenues of KLM-Air-France group, however, an important part of airfreight volumes are transported in combined (belly) aircrafts. In this way, revenues generated from airfreight operations are complementary to passenger operations, especially on intercontinental networks that are difficult to maintain financially.

During the financial year, the Group transported nine billion Revenue Ton-Kilometres of which 75% in the bellies of passenger aircraft and 25% in the dedicated full-freighter fleet, to a network of 316 destinations in 115 countries.

In 2010, confronted with the crisis in the sector, the Group adopted a new "priority to bellies and combis" strategy aimed at optimizing the economics of passenger aircraft bellies. Therefore, the full- freighter fleet is used as a complement to cover the routes not served with passenger flights or for products that cannot be carried in bellies or markets in which belly capacity is not adapted to demand.

Roughly speaking, 30% of the total cargo capacity of Schiphol is handled by KLM and Martinair (a cargo subsidiary of KLM). At December 31, 2015, the KLM fleet comprised 113 aircraft, of which 65 long-haul aircraft and 48 medium-haul aircraft. KLM reduced Martinair cargo fleet from 10 Full Freighters (FF) to only 4 (KLM 2016). This trend suggests that cargo transported in the Bellies is less costly and improve the profit margin of airlines. Especially the popular destinations such as New York and Shanghai, where more passengers are flying to, bellies offer new possibilities to improve operational costs and improve competitiveness of airlines. However, the transition from full freighters to more bellies has tremendous implications on the organization of airport operations (time slots, schedule and punctuality). As a result, cargo operations have to be alienated with the passenger's operations, where both processes should be combined in a limited and common airports areas.

The current study is a model-based approach for understanding the initial consequences of reducing the KLM fleet of full freighters at Schiphol and the knock on effects that this decision might have. As it has been mentioned, the downsizing of the fleet is expected to continue due to the situation previously mentioned. The understanding of the consequences of the phasing out of the remaining full freighters is key for improving the operational management of the airport systems in Schiphol which besides all the limitations its growth is still on with consequences in congestion, delays and capacity.

1.2 Similar studies

In the literature there are some studies that deal with some specific problems of the aviation industry where uncertainty is addressed in a particular fashion. For instance Chandran et al. (2007) proposed a dynamic programming algorithm for robust runway and their work considered uncertainties in the aircraft arrival times, ending up with a trade-off between runway throughput and the probability of violating separation minimum on the runway as objective. Kim and Feron (2011) focused their efforts in the robust gate assignment problem when stochastic delays are introduced. Arias et al. (2013) studied the stochastic aircraft recovery problem by employing constraint programming in combination with simulation techniques. In the work of Lee (2014) the airport surface congestion problem is studied combining optimization with simulation. The work of Mujica Mota et al. (2017) presents a high detailed model in which for the first time include the analysis of an airport operation with the ground handling operation. Other specific material for different problems in aviation can be found in literature however to the knowledge of the authors no similar problem that deals with the simulation of vehicles, and bellies can be found in literature. For this reason we proposed the use of simulation as the ultimate tool for addressing the situation of the presented problem.

2. METHODOLOGICAL APPROACH

Schiphol airport is one of the biggest hubs in Europe, it has 6 runways, however for the commercial traffic only 5 are under operation. The five runways have different dimensions and orientations. Table 1 shows the information of the runways and orientation.

Table 1. Schiphol's Runway Description

Number	Runway Direction/ code	Common Name	Length (m)
1	18R/36L	Polderbaan	3800
2	06/24	Kaagbaan	3500
3	09/27	Buitenveldertbaan	3453
4	18L/36R	Aalsmeerbaan	3400
5	18C/36C	Zwanenburgbaan	3300
6	04/22	Oostbaan	2014

The orientation of the different runways together with the taxiway system make the airport very complex. Figure 1 illustrates the runway system in which also the taxi ways can be appreciated.

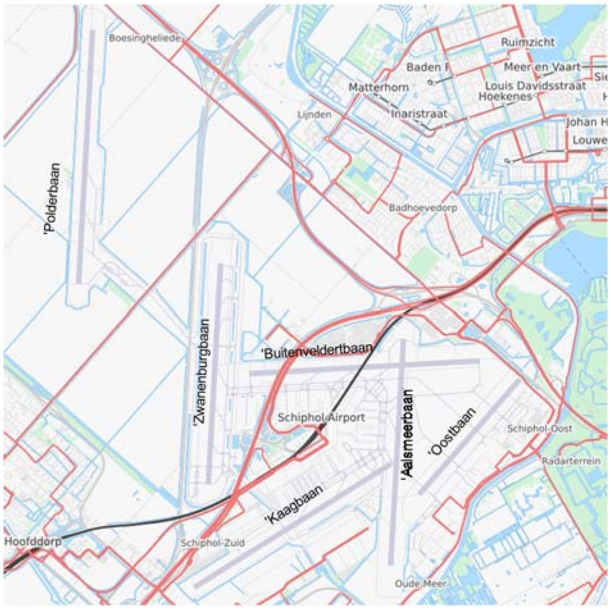

Figure 1. The location of runways in Schiphol

The runway configuration is continuously changed, in general terms it changes 16 times during the day due to the noise restrictions imposed to the system. The configuration is adjusted according to the noise quota and also to the peak hour of the day, for the departure peak sometimes 2 runways are used for departing and 1 runway for arriving while in arrival peaks 2 can be used for arriving and one for departing in an independent fashion. Just in exceptional cases 2+2 configuration can be used but that is not common. The Polderbaan is used very frequently due to its remote location from the city therefore the annoyances of noise are minimized by putting priority in the use of this runway.

Regarding the cargo operation, several companies are located in Schiphol, and KLM has its own warehouse in between the Kaagbaan and terminal building as Figure 2 illustrates. In that location the transhipment of goods is performed and also exporting products arrive to the airport via cargo trucks.

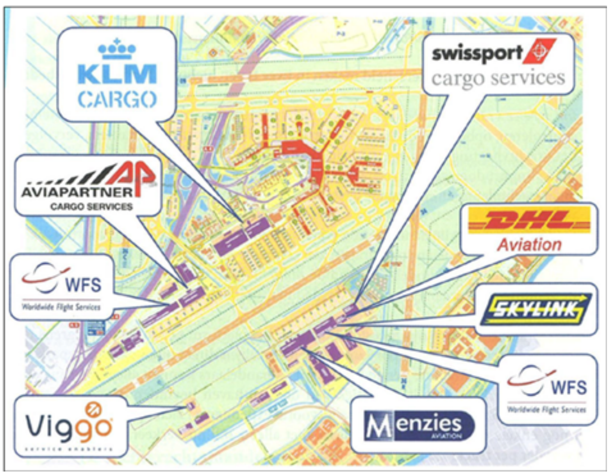

Figure 2. The most important warehouses in Schiphol

2.1 Assumptions of the model

For the evaluation of the transition from Full freighter to the transport of cargo in the bellies of the aircraft (A/C) we took the public information from KLM and Martinair together with the traffic numbers from OAG database for developing and analysing four different scenarios. We performed some assumptions based on different studies and reports and we came up with the initial numbers. These numbers together with the configuration of the airport allowed us to build the initial model in which the operation of vehicles+A/C can be simulated and the uncertainty of it addressed. The following table summarizes the main assumptions used for the model.

Table 2. Assumptions for the model

Parameter	Domain	Description
Traffic	Piers B- M	The traffic is generated only for KLM and Martin Air, based on a day of traffic. The allocation is performed on a probabilistic way based on the amount of available gates. Thus no attention is paid to the type of aircraft.
Runway usage	The scenario is based on a peak arrival mode: 2 RWY for arrival and 1 for departure	The arrival are Polderbaan and Zwanenburgbaan, departure is Kaagbaan
Load factor of Aircraft Passengers	0.4	The load factor for the cargo bellies is assumed 40%
Aircraft Output/Input Ratio	0.96	Based on public information the out/in ratio is 96%
Load factor of full freighters	0.7	The load factor of the full freighters is 70%
Truck Vehicles	5.2 tons	This corresponds to the capacity of the cargo trucks
Interarrival time of trucks	Exponential (1.4) hr.	The inter arrival time of trucks is 1.4 hr. average
Truck Ratio Output/Input Ratio	0	Due to the lack of information we assume that no cargo is taken by the trucks from the warehouse.
Runway and Taxi layout		The layout is based on the real configuration of taxiway system and runway system

The main assumption for estimating the amount of cargo that enters and leaves the airport is based on a mass balance of the total input/output reported by Schiphol (Schiphol Group 2016). Figure 3 illustrates the flow of gross tons in which roughly 30% corresponds to KLM+Martinair.

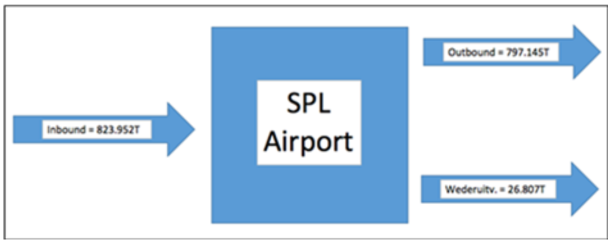

Figure 3. Simplified model of Schiphol Operation

Roughly speaking, from the inbound value, approximately 600 tons get into Schiphol via full freighters, bellies and trucks. As it can be appreciated, the outbound is less than the inbound so that is how the ratios out/in are estimated. The third flow is the amount of cargo that stays for being exported some days after it has arrived to Schiphol. The information was also used for developing the operational model which was developed using a discrete-event-oriented program called SIMIO (SIMIO 2017) which is very flexible for the types of operations performed in the airport. Figure 4 illustrates the simulation model developed which is composed by different elements such as the taxi way network, gates, runways, road for vehicles and the warehouse of KLM.

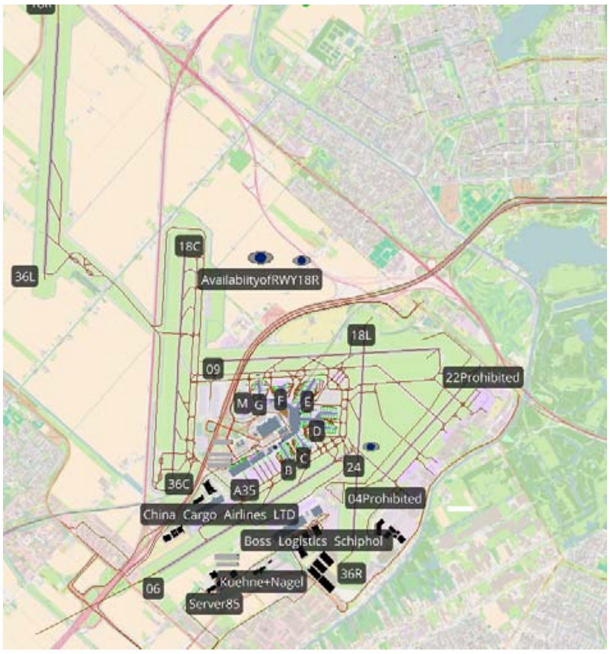

Figure 4. Discrete-event-oriented model of Schiphol

The program combines the object-oriented approach together with a process-based logic which makes it very flexible for making modular implementations and specify processes where the precedence is clearly identified.

3. EXPERIMENTAL DESIGN

Based on the previous assumptions+layout+ traffic we make the initial model of the cargo operation at Schiphol including some basic restrictions such as the limit of runway use by only 1 A/C at the time, runway occupancy times of approximately 50 seconds and the speeds of the taxi operations in approximately 40 km/hr.

With the initial model we were able to develop the base case in which the numbers are evaluated. It is worth to mention that the initial traffic includes the 4 Full freighters and the following scenarios are used for evaluating what would be the impact of phasing out the freighters:

- Scenario 1: reduction to 3 Full freighters and the increase of load factor of passenger A/C to 0.6
- Scenario 2: Reduction to 2 Full freighters at load factor of passenger A/C of 0.6
- Scenario 3: Reduction to 1 Full freighter and load factor of passenger A/C of 0.7
- Scenario 4: Reduction to 0 Full freighter with a load factor of 0.7

The scenarios were run with 15 replications for addressing the initial values of the operation. Table 3 presents the results of the different scenarios.

Table 3. Scenario Results

		Input (KG)	STD. Dev.	Output (KG)	STD. Dev.
Base Case	Bellies	309,875	10,400	298,909	12,923
	Full Freighters	277,900	0	268,729	0
	Total	587,775		567,638	
Scenario 1	Bellies	449,532	52,894	434,504	51,264
	Full Freighters	199,500	0	192,917	0
	Total	649,032		646,285	
Scenario 2	Bellies	468,411	1,134	450,467	1,096
	Full Freighters	133,000	0	128,611	0
	Total	601,411		581,565	
Scenario 3	Bellies	523,985	72,226	506,152	71,555
	Full Freighters	66,500	0	64,306	0
	Total	590,485		570,457	
Scenario 4	Bellies	546,980	0	528,930	0
	Full Freighters	0	0	0	0
	Total	546,980		528,930	

The previous scenarios assume that the passenger bellies are able to get to the load factor of the full freighters (0.7) but in reality this numbers need to be verified with the ground handlers.

As it can be appreciated from the results, as long as we reduce the amount of full freighters, we can counterbalance the lost in capacity of the full freighters by increasing the load factors of the passenger traffic. It is worth to note that until the scenario 3 we are able to counterbalance the lost in capacity by increasing to 0.7 the load factor of the passenger flights. However when we get to the final scenario it is not possible anymore to absorb the lost in capacity with the assumed limit for the load factors of 0.7. This results can be clearly appreciated in the Figure 5 where it can be appreciated the reduction of the operation of the full freighters while the amount of cargo transported by the bellies increases and they are able to transport the same quantity as the base scenario except in the final one.

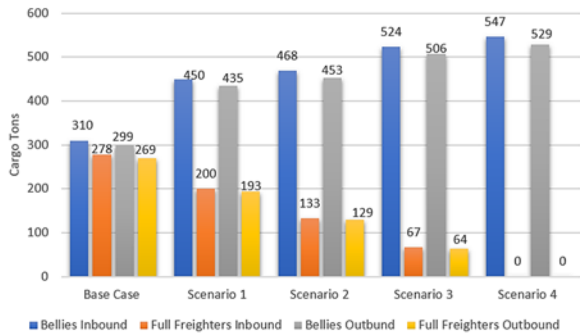

Figure 5. Inbound-Outbound cargo analysis

From the figure one can note that the outgoing cargo in the base case is approximately 570 tons; most of the scenarios are able to transport that amount of cargo except the final one (scenario 4) where the outbound is only 529 tons thus approximately 50 tons of cargo cannot be transported via the bellies of the cargo passengers.

The previous result is quite interesting since it suggests that if KLM is not able to increase their load factors to a higher value than 0.7 (which is the current value for the full freighters) the company will have to implement another strategy if they are not willing to lose the revenue that comes from the cargo operation.

4. CONCLUSIONS AND FUTURE WORK

It has been presented a simulation model of the airside of Schiphol airport which integrates the truck operation and the main elements of the airside operation for making an initial evaluation of what the impact will be once the full freighters of KLM are phased out. The results indicate that the company is able to counterbalance the lost in capacity by increasing the load factor of the passenger flights in the cargo compartments until reaching the level of the current full freighters. The analysis also suggests that if the assumption of the limit for increasing the load factor to the maximum value of 0.7 is correct then the company will have to take a different approach if the last full freighter is removed from the fleet. The strategy could be the increasing of the flight frequency or start new routes with new aircraft. Furthermore, if the company is not evaluating in the short term to take the suggested actions, they can follow a hybrid strategy in which part of the cargo can be transported in the passenger bellies increasing the load factors and at the same time keeping at least one full freighter.

The proposed approach allows to consider the uncertainty in the future decisions if KLM continues to reduce the fleet. In the future the authors will evaluate other important effects such as the uncertainty in the load factors at the bellies and by using real information it will be possible to evaluate what is the correct limitation for the load factors once the other restrictions that play an important role are included in the model such as turnaround times, capacity of ground handlers and on time performance limitations.

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