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Publication date
2018

Document Version
Author accepted manuscript (AAM)

Link to publication

Citation for published version (APA):
Mujica Mota, M., El Makhloufi, A., & Romero, R. (2018). *From Full Freighters to Belly Cargo Aircraft: Stochastic Analysis of Alternatives for Freight at Schiphol Airport*. Paper presented at The 22nd Air Transport Research Society World Conference, Seoul, Korea, Republic of.

From full freighters to belly cargo aircraft: stochastic analysis of alternatives for freight in Schiphol airport

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ABSTRACT

KLM has revealed the plan to downsize the full-freight cargo fleet in Schiphol Airport, for that reason the company requires to explore the consequences of moving the cargo transported by the full freighters into the bellies of the passenger flights. In this study, the authors analyze the implications of this decision by considering the variability of the load factors and the impact that replacing old aircraft might have. The study addresses how the transition towards the belly operation should impact the current operation of KLM at Schiphol. Our study show that the replacement of old aircraft with new 787s and 777s will have significant effect on the cargo capacity of the company. The results rise the discussion on future problems to be faced and how to make the transition from full freighter to belly operation.

Keywords: Air freight operations, optimum capacity, air-freight performance, Full Freighters, Belly capacity, scenario, multi-modal transport

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. As people become more productive, they become richer and they demand more goods. The supply chain and logistics industry exist to connect manufacturers with suppliers and middlemen

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shippers with the end customer (Feng, 2015).

In terms of the business model between cargo operations and passenger operations, there exist many similarities as well as differences. 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.

The key differences between cargo and passenger operations have been reported as uncertainty, complexity and flexibility (e.g., Bartodziej et al., 2009; Leung et al., 2009; Li et al., 2009; Wang and Kao, 2008):

- Uncertainty: 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. In contrast, capacity booking for air cargo, freight forwarders must 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 reduce risks or to compete with other forwarders. Many bookings in air cargo can be cancelled and/or rebooked because airlines typically do not charge for changing reservations. For this reason, the booking process is subject to considerable volatility (Petersen, 2007).
- Complexity: 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). Multiple dimensions are a key feature of freight, which render both complexity and uncertainty to air cargo capacity management.
- Flexibility: Transhipment itineraries between an origin and destination (OD) pair for cargo transport benefit the airline more than 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.

Air freight is the fastest form of transportation in terms of distance divided by time travelled. However, given extra costs related to delivery time such as customs processing, security considerations, consolidation of loads at a hub, warehousing, etc. air freight is less suitable for short distances transport (less than 700 km, rail is a more efficient transport mode, less costly and less complex than transport by air). Since the key value-added by air transport is time, the quick delivery of goods results in a demand and high willingness to pay for specific types of items. 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 development of World Cargo and its impact in Schiphol

According to BOEING (BOEING 2016), the growth trend estimates that cargo will be doubled the next 20 years (in Revenue Tons Kilometres) as Figure 1 illustrates.

Figure 1. Cargo Trend Worldwide

Purchases of new high-capacity cargo aircraft saw a gradual slow-down between 2012 and 2015, moving from 42 to 25 annual deliveries. This steady downward trend looks set to continue for the next years with 19 deliveries in 2017.

Belly capacity in the passenger aircraft fleet continued to see strong growth thanks to the expansion in the fleet, the latter expected to see annual growth of 5% between 2011 and 2019. For the years to come, around 400 new aircraft (for the most part B777s, B787s and A350s) will be introduced each year with the phasing out of some 100 to 200 aircraft per year (mostly B747s, B767s and A340s). The introduction of new aircraft will have an important impact since the bellies of new aircrafts have more capacity than the older aircrafts. For instance, the belly of the B787-9 can handle 20 tons of cargo in comparison with the 747 used for passenger which is able to handle only 12.5 tons of cargo, or the A340-300 which has a capacity of 14 Tons. In view of this dynamic, several air freight carriers are following the Air France –KLM Group's example by gradually decreasing their full freighter fleets in favour of bellies.

1.2 Schiphol as important node in air-cargo networks

The cargo operations at Schiphol 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, increasing volumes, volatility and uncertainty of airfreight and logistics. Last but not least, changes in freight strategy of the hub carrier KLM cargo. The last one consists in reducing its full-freighter and increase cargo transport in the bellies of the passenger's aircrafts as the recent phasing out of some freighters indicate. However, this transition has several challenges such as synchronization of cargo operations with passenger ones, capacity of ground handlers for increasing the cargo operation in the passenger bellies, time slot coordination, schedule and punctuality among others. Schiphol is important for the logistics sector and economic growth of the Amsterdam metropolitan region economy as well as for the Dutch one. Airfreight operations are fully concentrated at Schiphol airport, with minimal cargo activities in other regional airports such as Maastricht or Eindhoven airports.

Schiphol is ranked third in Europe in term of airfreight aggregated volumes (2 million tons in 2015), behind Charles-de-Gaulle and Frankfurt airports. There exists strong competition between the three European airports, which all of them function as gateway to the European market. Also, there is increase in the number of European regional airports that focus on airfreight activities/operations, which attract mainly full-freighters (and almost no belly aircrafts). The top four regional airports have home carrier as the main airfreight carrier, such as Cargolux/Panalpina in Luxemburg, UPS in Köln, DHL and TNT in Liège/Belgium. 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 is 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 of 2015, 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. However, starting from 2010 and confronted with the crisis of the sector, the group adopted a new "priority to bellies and combis" strategy, aimed at optimizing the economics of passenger aircraft bellies. The full-freighter fleet then is used as a complement to cover the routes not served with passenger flights, products that cannot be carried in bellies and markets in which belly capacity is not adapted to demand.

Over the past four years, Air France – KLM Cargo implemented a transformation and adaptation program focused on revenues, costs, hub productivity and the quality of bellies and combis, to optimize the payload on its full-freighter fleet.

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 (111 at December 31, 2014), 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).

The current study approximates the consequence for KLM fleet at Schiphol and the knock-on effects that this decision might have. In a previous work (Mujica et al. 2017) we have analysed the impact of the phasing-out of the full freighters under deterministic scenarios. The current work analyses the impact of the variability of the load factors and the effect of replacing old aircraft from the fleet with new ones that have bigger capacity than the current fleet. As it has been mentioned, it is expected that the downsize of the fleet will continue, thus, for KLM and Schiphol group the understanding of the consequences of the fading-out of the remaining full freighters is key for improving the operational management of the airport system. Besides all the restrictions and limitations, the demand will continue with the collateral consequences in congestion, delays and capacity. In the next sections we present the study where some implications of phasing out the FF and replacing the old fleet are discussed.

2 METHODOLOGY: STOCHASTIC MODELLING OF CARGO OPS

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 different scenarios. We performed some assumptions based on different studies and reports and we came up with the numbers and the initial implications of the transition.

2.1 Base Case of Cargo Operation

The model considers different elements which interact with each other: layout, traffic, infrastructure, vehicles and cargo. The ratio between input/output is calculated from the reports of cargo from Schiphol Group in 2016 (Schiphol 2016). According to those reports, the number of tons transported to and from Schiphol are approximately 823 tons per year. Figure 2 illustrates the amounts that are imports, exports and road imports or transhipments.

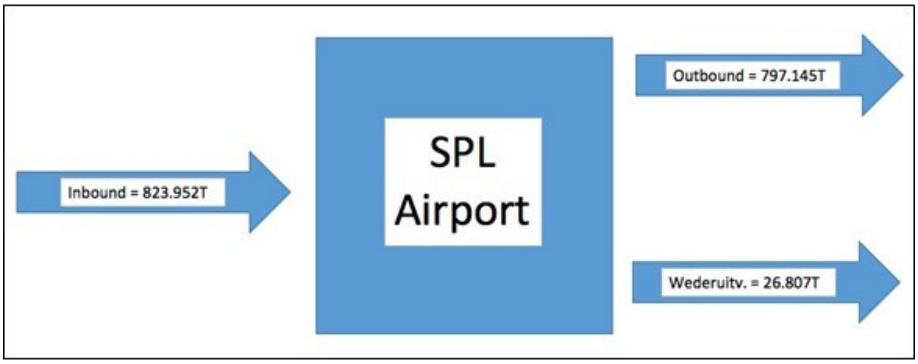


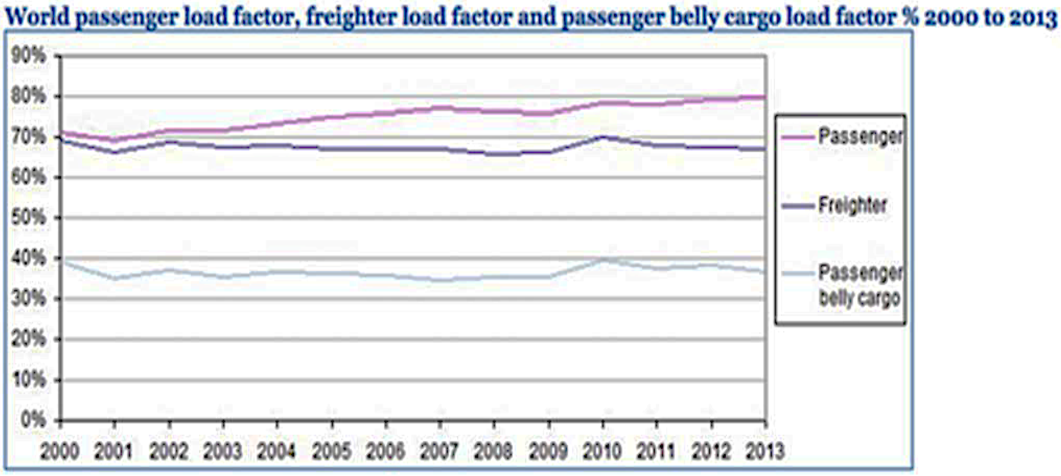
Figure 2. Flow model of Cargo at Schiphol

The inbound flux (Figure 2) is a combination of aircraft with cargo that arrive at Schiphol and ground cargo transported by trucks. The outbound flux is the combination of cargo that goes as export products and goes to a destination. The outbound flux – the inbound flux represents the accumulation of goods or the amount of cargo that is either non-reported (not found in the consulted reports) or stays in the warehouses in the surroundings of Schiphol. As it can be appreciated, the airport is just a stopover for the products. We considered these values for estimating the cargo load between the arrivals and departures. Furthermore, the load factors vary during the year, as Figure 3 illustrates. In our approach, we considered this variation for accounting the maximum values of cargo that are transported with the use of the A/C fleet of KLM+ Martinair.

In the model, we considered one day as the representative of the operation, the information of March 16th of 2015 was considered as the input for the model.

Figure 3 presents the variability of load factors of passenger traffic and cargo from the year 2000 until 2013 (CAPA, 2014). As mentioned, we considered these values for the base case which will include the variability of the load factors.

Figure 3. Evolution of load factors



It can be noticed that for the FF the load factor has a variability between 65% to 70% maximum, while for the belly operation the variability is between 35% to 40% maximum. In the variability values considered, we assumed that it was not possible to surpass the higher bounds of 70% for the cargo load factors. Therefore, for the different scenarios, we assumed that 70% load factor is a hard restriction or upper bound in the operation.

2.2 Stochastic Analysis

As initial analysis, the load factors for passenger flights and for the full freighters were modelled using variations of Beta Distribution as Table 2 illustrates. In addition, the table also presents the modifications of load factors of the different scenarios.

Table 1. Values for the uncertainty in A/C cargo

	Belly Load Factor				
Scenario	Mean	Min	Max	alpha1 = alpha2	Distribution
1	0.375	0.375	0.375	1	0.375
2	0.375	0.35	0.4	24	0.35+0.05*random.beta(24,24)
3	0.375	0.35	0.4	4	0.35+0.05*random.beta(4,4)
4	0.375	0.375	0.375	1	0.375
5	0.375	0.35	0.4	24	0.35+0.05*random.beta(24,24)
6	0.375	0.35	0.4	4	0.35+0.05*random.beta(4,4)
7	0.375	0.375	0.375	1	0.375
8	0.375	0.35	0.4	24	0.35+0.05*random.beta(24,24)
9	0.375	0.35	0.4	4	0.35+0.05*random.beta(4,4)
	Full Freighter Load Factor				
Scenario	Mean	Min	Max	alpha1 = alpha2	Distribution
1	0.675	0.675	0.675	1	0.675
2	0.675	0.675	0.675	1	0.675
3	0.675	0.675	0.675	1	0.675
4	0.675	0.65	0.7	24	0.65+0.05*random.beta(24,24)
5	0.675	0.65	0.7	24	0.65+0.05*random.beta(24,24)
6	0.675	0.65	0.7	24	0.65+0.05*random.beta(24,24)
7	0.675	0.65	0.7	4	0.65+0.05*random.beta(4,4)
8	0.675	0.65	0.7	4	0.65+0.05*random.beta(4,4)
9	0.675	0.65	0.7	4	0.65+0.05*random.beta(4,4)

A total of 9 scenarios were built to assess the impact that different levels of variability in the load factor will have on overall performance. Thus, we considered 3 levels of variability for both the “Belly Load Factor” and the “Full Freighter Load Factor”: zero variability, moderate variability and high variability. Zero variability was modelled by a constant load factor for each flight. Medium variability was modelled using a Beta distribution with alpha1 and alpha2 parameters equal to 24. High variability was modelled using a Beta distribution with alpha 1 and alpha2 parameters equal to 4.

All the distributions were centred around 0.375 and 0.675 load factors for Belly cargo and Full freighters, respectively. With the use of load factors we multiplied the capacity of each type of aircraft for the load factors to get the estimation of the amount of cargo transported by the flights and by following this approach we could estimate the impact of the variability in the total cargo transported via Schiphol. Table 3 provides the cargo capacities of the different types of aircraft within the fleet under study.

Table 2. Cargo Capacities of different Aircraft

A/C Type	Cargo Capacity (Kg)
B744	12500
B772	12700
B738	2000
A332	10900
E190	1000
B737	2000
A333	17400
F70	1000
B739	2000
RJ85	1000
B787-9	20000
B777-3	23700

Making the previous assumptions we were able to construct different scenarios where we could give light to the impact of variability in the operation. Once we identified the impact of it, by performing simulations with different scenarios, we could propose solutions for rebalancing the input flow if, for example, one or more full freighters are phased out.

3 RESULTS

For the following scenarios, we included the variability of the load factors in the scenario that has one full freighter less. The purpose of this was for addressing what is the maximum cargo that can be transported assuming a natural variation of the load factors in the aircraft.

For the different scenarios developed, we assumed the traffic mix is kept constant. Thus, the variation in the cargo numbers of the simulations is due only to the different parameters: phasing out of FF and replacement of old 747s and 772s with B787s and B777s.

Regarding the FF, Martinair currently have only 4 aircraft in operation. Some scenarios will evaluate the situation that Martinair will fade out the fleet from 4 to 3 full freighters. If we calculate the implication of that action, we end up with a deficit of 28 k tons annually. We assumed the following fleet flies every day:

- 3 McDonnell Douglas MD11F with capacity of 95 tons of cargo
- 1 Boeing 747 ERF with capacity of 112 tons of cargo

3.1 Base Scenario: Variability in place

Table 3 shows the average flow of cargo based on flight arrivals separated by inbound (input) and outbound (output) flows from and to the airport for a total of 100 simulation replications for each scenario. Results show that Scenario 9, which considers the highest amount of variability in the load factor of both bellies and FF, is the one that produced the highest total average input and output flows of all the scenarios. These results show that, even though all scenarios had the same mean load factor and a non-skewed distribution, a higher variability in the load factor tended to produce more flow of cargo. Because of Scenario 9 presented the highest values in terms of total flow, it was used as a comparison the Scenarios 10 and 11, where FF capacity was reduced.

Table 3. Results from the stochastic analysis (average annual kg.)

Scenario	Input Belly	Input FF	Input Total	Output Belly	Output FF	Output Total
1	104,187,334	97,810,875	201,998,209	100,639,427	94,583,116	195,222,543
2	102,754,139	97,810,875	200,565,014	99,177,335	94,583,116	193,760,451
3	103,177,257	97,810,875	200,988,132	99,599,022	94,583,116	194,182,138
4	102,690,195	97,822,396	200,512,591	99,260,388	94,594,256	193,854,644
5	105,120,173	97,822,396	202,942,569	101,536,972	94,594,256	196,131,228
6	105,830,683	97,822,396	203,653,078	102,258,821	94,594,256	196,853,077
7	102,442,588	97,842,173	200,284,761	99,001,098	94,613,381	193,614,479
8	105,060,903	97,842,173	202,903,075	101,479,658	94,613,381	196,093,039
9	105,946,896	97,842,173	203,789,069	102,408,936	94,613,381	197,022,317

3.2 Scenarios 10 and 11

In these scenarios, we removed one FF and assumed that part of the fleet was replaced with new models of aircraft. Table 4Error! Reference source not found. presents the new cargo values once the fleet is reduced to 3 full freighters.

Table 4. Capacity numbers for reduction of 25% FF Capacity

(ARR) 25% Less FF	
Cargo Capacity Annually bellies	114,084,400
Cargo Capacity Full Freighters	72,817,500
Total Capacity (Annually)	186,901,900
Missing Capacity (Daily)	-78,400
Missing Capacity (Annually)	-28,616,000

Scenario 10: Replacing all 747s for B777s and 787s aircraft

For the first additional scenario we assumed that all Boeing 747s were replaced from the fleet to evaluate if it is possible to absorb the cargo capacity of the removed full freighter. This fleet was chosen because it is one of the oldest aircraft in the fleet of KLM, according to Planespotters (www.planespotters.net). Thus, to compensate for the full capacity of FF, a total of thirteen 747s would be replaced by six 787-9 and seven 777-3. This change of fleet from B747s to aircraft with more capacity will resulted in an added annual capacity of 18k tons, which is still short for absorbing the missing capacity of 28k tons as Error! Reference source not found. shows.

Scenario 11: Replacing all 777-2 with 777-3

Owing to the fact that the proposal of Scenario10 could probably come short of capacity, as it only adds 18k tons of capacity in comparison with the 28k tons that are needed, the second additional scenario considers a change of all 777-2 in the fleet (nine aircraft) to 777-3 aircraft as it has more cargo capacity and 777-2 are the second oldest aircraft in the fleet (www.planespotters.net). This will result in an additional annual capacity of 14k tons, which added to the previous 18k tons, will result in a total of 32k additional capacity.

Table 5. Cargo flow for base scenario compared with scenarios where one FF was phased out (annual kg.)

Scenario	Measure	Input Belly	Input FF	Input Total	Output Belly	Output FF	Output Total
Scenario 9	Average	105,946,896	97,842,173	203,789,069	102,408,936	94,613,381	197,022,317
Scenario 10	Average	120,292,263	74,414,857	194,707,120	116,279,296	71,959,167	188,238,463
Scenario 11	Average	133,485,761	74,414,857	207,900,618	129,037,408	71,959,167	200,996,575
Scenario 9	Percentile 95	107,276,044	98,628,231	205,904,275	103,735,934	95,373,499	199,109,434

To assess the impact of phasing out one FF, Error! Reference source not found. compares the average inbound and outbound flows for Scenario 9 (baseline with high variability but full fleet of FF) with Scenarios 10 and 11 (where one FF has been removed). Results from Error! Reference source not found. show that removing one FF and substituting all 747s with B777s and 787s aircraft (Scenario 10) results in a reduction in capacity when compared with the baseline scenario (Scenario 9). It is only when all 777-2 fleet is replaced by the bigger 777-3 that the lost average capacity from phasing out one FF is recovered by the additional belly capacity.

In addition, as simulation results vary among replications because of the stochasticity modelled in the load factors. Table 5 presents the results of the 95th percentile of the total inbound and outbound flow for the baseline scenario to perform a risk assessment. In this manner, the 95th percentile of Scenario 9 shows that at most 95% of the times the total inbound cargo needed to be transported is 206k tons per year, instead of an average of 204k tons per year. If we compare this 95th percentile of Scenario 9 with the results from Scenario 11, we can see that, on average, removing one FF and replacing its capacity with bigger belly capacity results in a higher total capacity than what would be needed to be carried the 95% of times in the baseline scenario.

3.3 Discussion

Results from this simulation study show that the total cargo capacity lost, irrespective of origin and destination, by removing even one FF is very difficult to overcome by increasing the capacity in passenger flight's bellies by just replacing old aircraft with new model versions, as a total of 22 aircraft would need to be replaced. Furthermore, results also show that by incorporating variability into the load factor of both the bellies and FF, the fleet would need to transport a bigger quantity of cargo and more cargo capacity will be needed.

Further analysis is needed to investigate the impact in financial terms that removing one FF and replacing it with bigger capacity passenger aircraft will produce in the operations of the airline. Moreover, future research should also consider the actual flows from and to different destinations to Schiphol to assess the real impact of phasing out an FF flight and the impact of increasing the capacity of a passenger flight.

4 CONCLUSIONS AND FUTURE WORK

In the paper we analysed the implications of replacing old aircraft with new models (with bigger cargo capacity) of KLM and Martinair. The objective of this study was to assess whether, in the presence of variability, the replacement of aircraft is enough for absorbing the missing capacity if one of the four full freighters is retired from the cargo fleet. The simulations show that by replacing the old models with new ones the increase in capacity is just barely enough to absorb the capacity missed. Therefore, the results suggest that in addition to the renovation of fleet it is necessary that the load factors (in the bellies) should be increased so that it is possible to absorb the missing capacity if more than one full freighter is planned to be retired. This action implies a better coordination than the current one for ground handlers and the fleet; since due to the punctuality policies of commercial airlines, it is not possible to absorb delay due to the increase of cargo loading operations. Furthermore, if the airline is not willing to quit some routes, because of the lack of capacity, the airline should face the challenge making use of novel techniques mainly from the IT and OR realm to improve the coordination of the cargo operation. As a future work, the authors will investigate what the optimal balance between fleet replacement and increase of load factor will be assuming it is possible to increase the load factors in the bellies by improving the coordination of the cargo operations.

References

IATA, 2016,"Another Strong Year for Airline Profits in 2017", press release 76

Amaruchkul, K., Cooper,W.L., & Gupta, D. (2011). A note on air-cargo capacity contracts, Production and Operations Management, 20(1), 152-162

Bartodziej, P., Derigs, U., Malcherek, D., & Vogel, U. (2009). Models and algorithms for solving combined vehicle and crew scheduling problems with rest constraints: an application to road feeder service planning in air cargo transportation. Operation research-spektrum, 31(2), 405-429

BOEING, (2016), "World Air Cargo Forecast 2016-2017", Technical Report

Bronsing, M. (2013). KLM Cargo Flow Allocation Optimization at Schiphol. <http://repository.tudelft.nl/islandora/object/uuid:7bff00c1-895a-47be-9a4a-cd65650c7652/datastream/OBJ/download)>

CAPA. (2014). Air Cargo: few other industries would tolerate its structural overcapacity <http://centreforaviation.com/analysis/air-cargo-few-other-industries-would-tolerate-its-structural- overcapacity-192139>

Damme, van. D., Radstaak, B., & Santbulte, W. (2014). Luchtvrachtlogistriek een dynamische keten in perspectief. SDU, Den Haag.

Feng, B. et al. (2015). Air cargo operations: Literature review and comparison with practices

KLM. (2016). Our Fleet <https://afklcargo.com/NL/en/common/about_us/fleet.jsp>

Leung, L.C., van Hui, Y., Wang, Y., Chen, G., 2009. A 0–1 LP model for the integration and consolidation of air cargo shipments. Operational Research. 57 (2), 402–412

Li, Y., Tao, Y., & Wang, F. (2009). A Compromised large-scale neighbourhood search heuristic for capacitated air cargo loading planning. European Journal of Operational Research, 199(2), 533-560

Mujica Mota M., Makhloufi A., Boosten, G., Van Damme, D., Hunt, E., (2017). Is your belly empty?: the analysis of the transition from full freighters to belly cargo of klm. In Proc. of ATRS 2017, Antwerp, Belgium

Planespotters (2018). https://www.planespotters.net/airline/KLM-Royal-Dutch-Airlines. Updated March 30th 2018. Accessed May 1st 2018.

Petersen, J. (2007). Air Freight Industry—White Paper. Georgia Institute of Technology, Supply Chain and Logistics Institute, H. Milton Stewart School of Industrial and Systems Engineering. April 1, 2007. www.scl.gatech.edu/industry/industry- studies/AirFreight.pdf. Accessed December 12, 2016. Schiphol Group. (2016). Transport and Traffic Statistics. https://www.schiphol.nl/en/schiphol-group/page/transport-and-traffic-statistics/

Wang, Y.J., & Kao, C.S. (2008). An Application of a fuzzy knowledge system for air cargo overbooking under uncertain capacity. Computer & Mathematics with Applications, 56(10), 2666-2675.