Team „Forest Tokyo“

from JAPAN

„Eco-Share“

The Innovative Green Flight Distribution System

Eco-efficiency Area: ***Reduction of Carbon Footprint***

A Proposal for the

Airbus - Fly Your Ideas Challenge 2009

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EXECUTIVE SUMMARY

We propose a system in which major Japanese airlines cooperate and apply eco-optimized flight schedules which reduces CO_2 emissions by **870 kilotons** annually on the four major domestic routes in Japan.

The key findings on the current situation are:

- High CO_2 emissions per passenger due to eco-inefficient scheduled aircraft operations and low load factors
- Below industry average **load factors of only 64%** (industry average of **76%**) due to high seasonal fluctuations over the year

Our optimization calculations confirmed achievements of an average of **20%** or **870 kilotons CO_2 emission** reduction which equals **275 kiloton fuel** per year resulting in **$130 Million** both fuel and emission trading rights as well as a reduction of aircraft movements resulting in less noise impact.

We recommend the following "Eco-Share" proposal:

- Incorporating an Airbus-Airline joint venture, implementing a more eco-efficient fleet, operating our eco-optimized demand-driven schedules with partly code-shared flights to dramatically increase load factors
- Global distribution of a certain part of the "Eco-Share" fleet to transfer seat capacity from Japan in times of seasonally low demand to other areas with seasonally high demand

Team "Forest Tokyo"
from JAPAN

(alphabetical)

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Tokyo, the 31st of March 2009, GMT 12:00

1. INTRODUCTION

1.1 The ISSUE to solve – Current situation

Flying domestically in Japan today, we can observe that many seats are left vacant. Considering the fact that Japan, the world's third largest domestic airline market with 91 Million passengers a year after the USA and China (see Table 1), is operating its flights with only about 63.9% of the seats in use (calculated from [5,6,7]), this is definitely a problem that should be addressed.

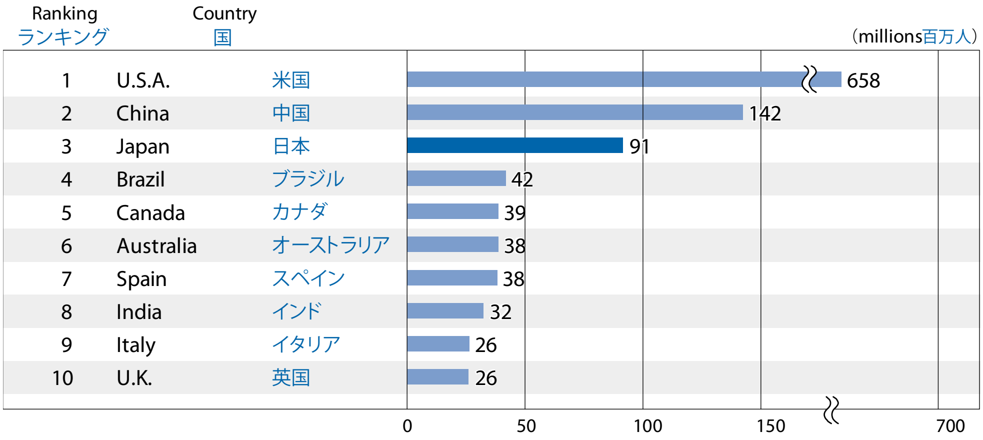


Table 1 Number of Passengers on Domestic Routes by Country
(Source: IATA [1])

The scientific term describing the percentage of seats occupied is the *load factor* of an aircraft. To measure the efficiency of air transport the load factor is the key parameter as it stands for fuel efficiency and therefore CO_2 and noise emissions per passenger and thus for the financial as well as ecological costs of air transport.
Just like operating a supercomputer to calculate the sum of 1 and 1, operating an almost half empty aircraft is inefficient: even worse, it's eco-unfriendly and therefore damaging our planet. Table 2 gives an overview of typical load factors of various regions and airlines.

Load Factors 2007			
	domestic	international	Total %
IATA statistics			
Africa			70.2
Asia/Pacific			73.9
Europe			76.6
Latin America			74.0
Middle East			74.9
North America			79.8
Industry Average			75.9
JAL	63.4	71.8	65.2
ANA	63.6	74.7	64.4
Lufthansa			77.4
United Airlines			82.7
Singapore Airlines			80.3

Table 2 Load Factors of Japan Airlines (JAL) and All Nippon Airways (ANA), of different world regions and of further airlines (Source: IATA [2], Annual Reports of Airlines [3, 4])

1.1.2 Reasons for Low Load Factors in Japan

Two major reasons for the comparatively low load factors on Japanese domestic routes are the large number of large aircraft (B747 and B777) used on the domestic routes and the large seasonal fluctuations in the demand for air tickets. Actually, Japan is one of the few countries operating big aircraft like the Boeing 747 and the Boeing 777 on domestic routes.

The real reason becomes clear when considering the high seasonal fluctuation in the demand for air travel (Figure 1) due to the high compliance in “the nation’s” common vacation schedule (like the “Golden Week” in May - a week full of holidays which many Japanese use to travel). At these peak times, big aircraft are needed, resulting in a fleet that has overcapacity in the low season.

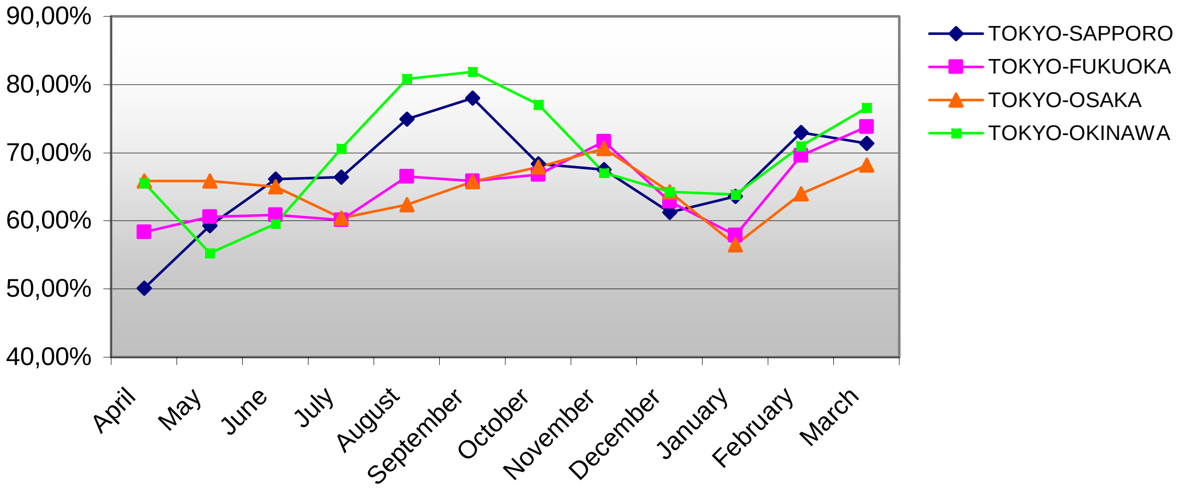
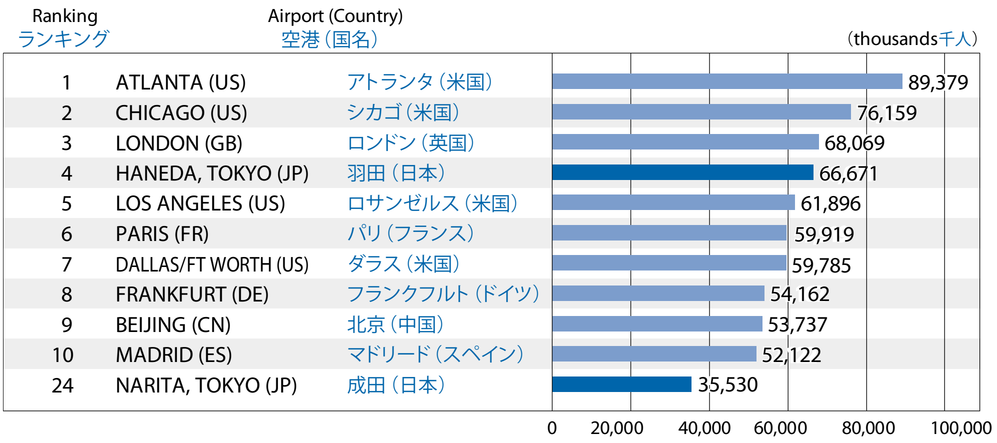


Figure 1 “Seasonal load factors in Japan”; major airline average on four major routes from 2007/04 to 2008/03 (Compiled from airline released data [5, 6, 7])

Why don’t the airlines just reduce the frequency of flights?

The airlines’ theory is that, if the frequency of flights is kept as high as always, more passengers will actually board, since the flight departure times match with more people’s personal schedules. Instead of having one flight with a load factor of 80% on an aircraft with 100 seats, the airline can make more money having two flights with the same aircraft with an average load factor of 55% that would in total result in 110 instead of 80 passengers. Additionally, the operating cost per flight are reduced because the purchase price of the aircraft can be amortized over more flights; the aircraft gets “cheaper”. And there is always the competitor who may be offering an even higher frequency of flights, thus spreading its image as the more “convenient” airline.

On the route Tokyo – Osaka there is a strong competition with the “bullet train” (“Shinkansen”), which requires a frequent schedule and the possibility for last minute tickets on the airline side. Therefore, overbooking is not largely being applied to these routes.



Ranking ランキング	Airport (Country)	空港（国名）	(thousands千人)
1	ATLANTA (US)	アトランタ（米国）	89,379
2	CHICAGO (US)	シカゴ（米国）	76,159
3	LONDON (GB)	ロンドン（英国）	68,069
4	HANEDA, TOKYO (JP)	羽田（日本）	66,671
5	LOS ANGELES (US)	ロサンゼルス（米国）	61,896
6	PARIS (FR)	パリ（フランス）	59,919
7	DALLAS/FT WORTH (US)	ダラス（米国）	59,785
8	FRANKFURT (DE)	フランクフルト（ドイツ）	54,162
9	BEIJING (CN)	北京（中国）	53,737
10	MADRID (ES)	マドリード（スペイン）	52,122
24	NARITA, TOKYO (JP)	成田（日本）	35,530

Table 3 Tokyo Haneda airport – the fourth largest airport world wide; (Source: Airports Council [8])

1.2 Our Proposal - "WHAT you need, WHEN you need it!"

To reduce the amount of CO_2 and noise emissions which result from eco-inefficient use of aircraft due to low load factors, we

- developed a flight distribution system that will distribute passengers more efficiently over aircraft to increase load factors and therefore reduce the CO_2 emissions on the four major domestic routes in Japan.

- suggest that, to implement our concept in the real world, a business model should be adopted that will apply our distribution system to these four routes and additionally provide a flexible global seasonal distribution system for aircraft to take eco-efficient advantage of relatively strong seasonal demand fluctuations in Japan.

"WHAT you need, WHEN you need it!" Unlike an automobile, an aircraft is a long-term investment that requires careful planning and research. Even in the case of cars, the need for flexibility has resulted in a flourishing rent-a-car industry. To meet the various needs of its customers, a rent-a-car company offers one-day leasing of a wide range of vehicles. To a certain extent, a similar system can be applied to air transport.

1.2.1 The Innovation of our Proposal

We believe that our proposal is a new and innovative approach to reduce the carbon footprint of the airline industry because

- the innovative flight distribution optimization system ***focuses on eco-efficienc.***
- the system considers the **seasonal fluctuations in demand for air tickets** in Japan and other countries by flexible distribution of parts of the "Eco-Share" fleet **globally**.
- in contrast to many other eco-efficiency projects and measures, our proposal will not be of any disadvantage to anybody, but **creates benefits for all parties through cost and emission reduction.**

Refer to chapter 3.4 for details on the business model as well as the global distribution system.

2. OBJECTIVES

2.1 Market Analysis and Business Model

We performed a market analysis of the Japanese airline market in general as well as for the two major airlines in Japan - Japan Airlines (JAL) and All Nippon Airlines (ANA) - to evaluate if our idea would fit into their business plans. Based on this information we developed a business model incorporating major Japanese airlines. This model was then discussed with Airbus Japan KK to receive comments from experts.
Refer to chapter 3.4 and chapter 5.1 for details.

2.2 Booking Data and Optimization

To further elaborate on the core of our proposal, we acquired booking data from the booking websites of airlines and applied a self-made computer program to increase the level of detail of the rough load factors on each flight. We ran optimizations on this data with another self-created program and obtained results on the CO_2 emission reduction by rescheduling flights and proposing more suitable aircraft types for flights.
Refer to chapters 3.1 and 3.2 for details.

2.3 Strengths, Weaknesses, Opportunities and Threats Analysis (SWOT)

The feasibility of our initial “ECO Share” idea was analyzed by performing a SWOT (**S**trengths, **W**eaknesses, **O**pportunities, **T**hreats) analysis. A short summary of the SWOT analysis is presented in chapter 3.5, the full SWOT analysis can be found in Appendix B.3.

3. DESCRIPTION

3.1 Data Acquisition

3.1.1 Obtaining actual Load Factor Data

We chose the four main Japanese domestic routes for closer analysis. These routes (“Tokyo-Sapporo”, “Tokyo-Fukuoka”, “Tokyo-Osaka” and “Tokyo-Okinawa”) account for 30 % of all domestic passengers in Japan [9].

In order to optimize the load factors it required the number of passengers of each flight over a period of one month. However, this competition-sensitive data was not disclosed by the airlines. Consequently, we decided to predict these data using the airlines’ online reservation status.

A self-made computer program (Appendix C.1) extracted the seat availability from the 3 airlines’ websites and used a smart algorithm considering the availability of different ticket types (regular, discount, boarding classes) as well as monthly average load factors to estimate more detailed load factors.

Refer to Appendices A.1 and C.1 for details.

3.1.2 Fuel Burn and CO_2 emissions

CO_2 emissions are directly related to fuel burn [10]. With the help of Airbus, we managed to obtain a full list of fuel consumption of the aircraft types we investigated (Appendix C.5).

3.2 Optimization Process

The objective of this optimization was to create a new flight schedule with the highest possible load factors at the smallest possible CO_2 emissions and with minimal waiting time for the passengers. The independent parameters subject to optimization were the departure time and aircraft type for each flight.

A MATLAB® program was made to carry out this optimization (see Appendix C.2). Because of the high number of parameters like flights, departure times and possible aircraft types, too many schemes would have to be considered. Since this was not feasible and because gradient information was also not available, we chose the Genetic Algorithm (GA) as optimization strategy.

GAs are guided random search techniques that work analogous to biological evolution and incorporate principles of “genetic variation” and “natural selection”, often called “survival of the fittest”. The “gene” in this case is a parameter string containing departure times and aircraft types for all flights. An individual’s “fitness” is its performance with respect to the objectives, minimal CO_2 emissions and waiting time in this case. Assuming that a recombination of genetic material from fitter individuals creates favourable offspring, a GA uses selection and variation to solve the optimization problem iteratively, i.e. fitter individuals have a higher chance of passing their genetic material on to the next generation. Variation is accomplished by recombination of genetic material from selected individuals and occasional random changes in genes.

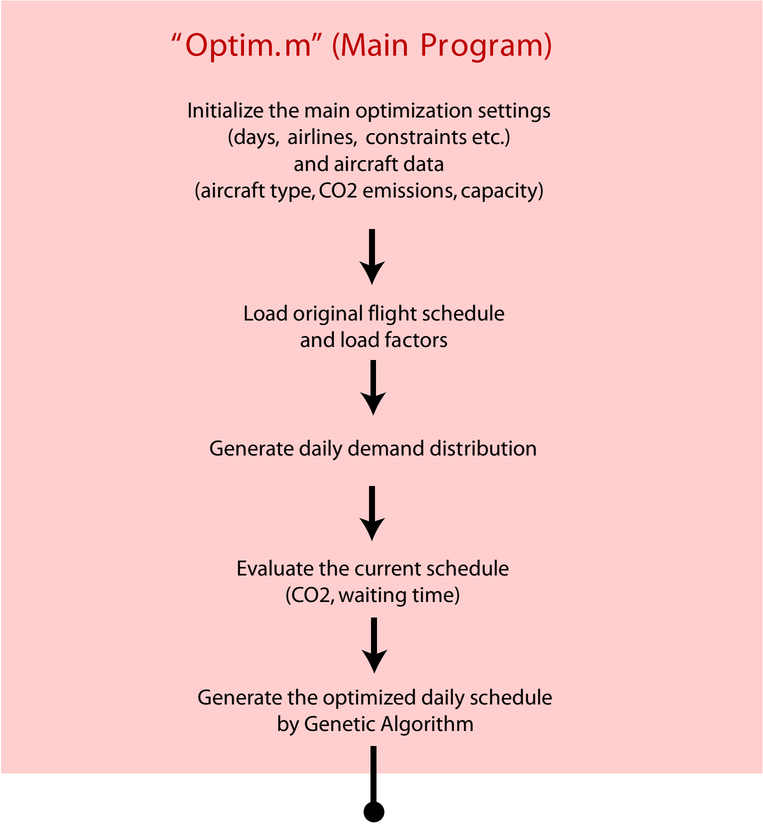

"Optim.m" (Main Program)
Initialize the main optimization settings (days, airlines, constraints etc.) and aircraft data (aircraft type, CO2 emissions, capacity)
Load original flight schedule and load factors
Generate daily demand distribution
Evaluate the current schedule (CO2, waiting time)
Generate the optimized daily schedule by Genetic Algorithm

Figure 2 Program Structure

Our program uses the GAOT toolbox [11] and can:

- optimize all flights (regardless of airline) or consider just one airline's flight schedule
- optimize several days at once, generating the same "base" schedule for all days and (if desired) an additional schedule which can vary per day
- limit the aircraft types available to the current fleet of the airline(s), or add additional aircraft types
- choose to operate less flights than in the original schedule

Assumptions had to be made to keep things manageable within the limited time available. Some that possibly have a significant impact are:

- No logistics constraints were imposed. This means that aircraft are always considered available at the place where they are needed.
- "TO" and "FROM" routes are optimized separately, so the idea that the same aircraft that did the "TO"-flight will do a return flight later is not implemented. Therefore also turnaround times etc are not considered.

Further assumptions can be found in Appendix A.2.

The input is the current daily demand distribution derived from the estimated load factors. The optimized departure times and aircraft types are compared with the current ones.

3.3 Optimization Results

The results of the optimization are dependent on the constraints. Generally **15-20% reduction of CO_2 emissions** can be achieved on any flight schedule for the four routes without compromising (often even improving) passenger waiting time. **20% CO_2 or 870 kilotons reduction** equals **275 kilotons fuel recution** per year, a total equivalent of **$130 Million** in fuel savings and CO_2 emission rights. (See Appendix A.4 for calculations.)

We will discuss some general findings and highlight two cases giving an impression of the flexibility of the optimization and the power of our ECO-Share concept. A few more cases can be found in Appendix A.3.

3.3.1 General results

Typically the optimization has the option to use A320 and A380 aircraft additional to the existing airline fleet. The majority of the aircraft in the optimized schedules are the B777-200/-300 (regardless of the route). This indicates that the B747 currently widely used are oversized and inefficient. Including the A330-300 and A350-1000 in the optimization, results in a significant share of these types in the optimized schedule.
Allowing flexibility in the schedule (e.g. 1 extra flight per day, but not at the same time every day) the A320 pops up in the flexible schedule results.

It is often difficult to find a good trade-off between passenger waiting time and CO_2 reduction. If passenger waiting time increases, passengers will rather go for the competitor's more frequent schedule. We generally ran a batch of optimizations with several weighting settings to CO_2 and waiting time. The program then outputs a graph like in Figure 4, where we can see the trade off. The final decision on the best trade-off is to the marketing analyst and cannot be made automatically.

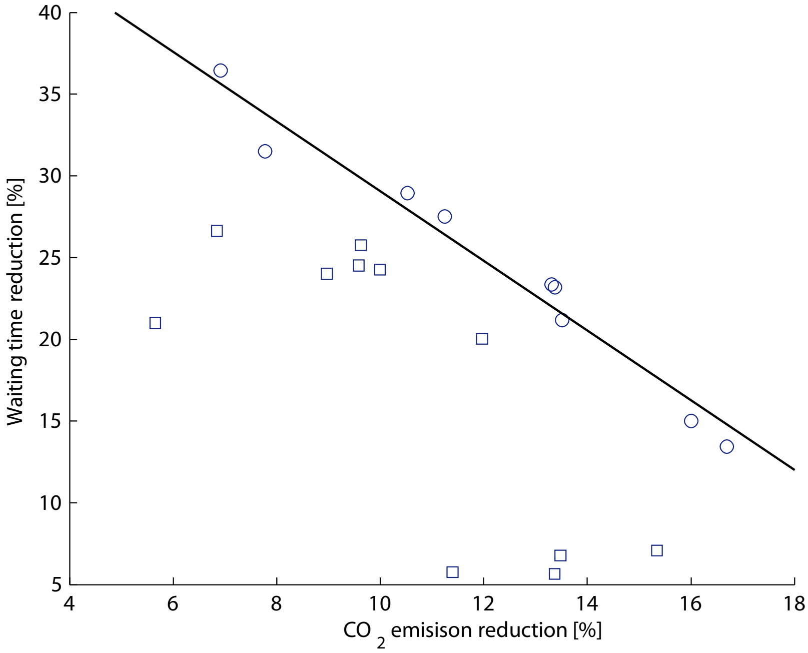


Figure 3 Multiple optimization results: different weights result in a trade-off, circles (optimal solutions).

3.3.2 Case Highlight 1: Tokyo → Sapporo (all airlines optimization)

With 52 flights a day, this is Japans busiest domestic route. Figure 5 shows a typical output of the optimization. It illustrates the overall daily demand on the Tokyo → Sapporo route for one week. Each vertical line represents a flight in the optimized schedule. The labels showing the aircraft types (e.g. 772=B777-200 etc.).

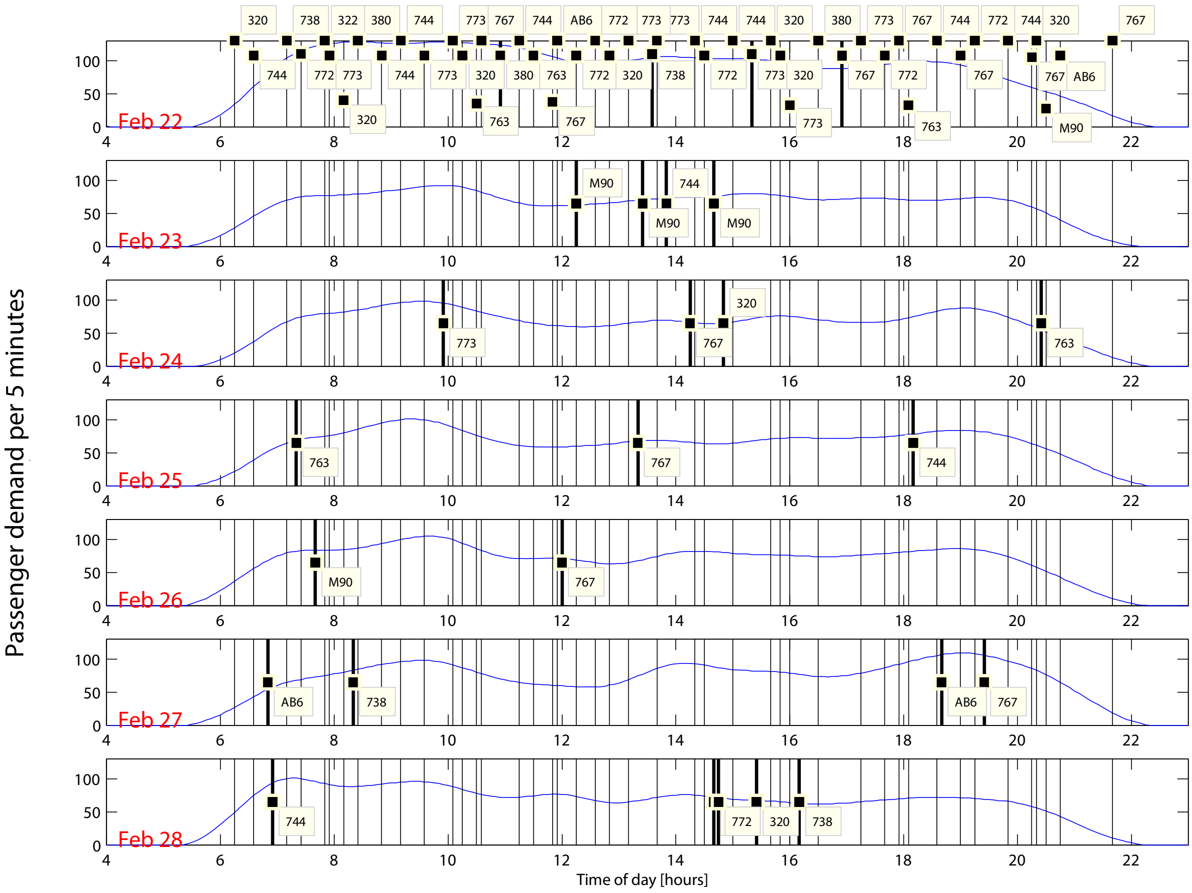


Figure 4 Daily demand and optimized schedule for Tokyo → Sapporo

The optimization resulted in a yearly **CO_2 reduction of almost 100.000 tons** and **a reduction of the average passenger waiting time from 7 to 6 minutes** (note: “waiting time” is defined as the difference between a person’s desired departure time and the actual departure time of the flight). On top of these, the total number of flights this week was reduced by 31 flights compared to the current schedules, resulting **in less operational and maintenance costs** and **lower noise impact** on the ground.

These results illustrate the high increase of eco-efficiency if airlines cooperate, adjust their flight schedules to each other and to passenger demand, and merge half empty flights.

3.3.3 Case Highlight 2: Tokyo → Okinawa (single airline optimization)

As a full cooperation of airlines might be unrealistic in the near future we also carried out optimizations within single airlines.

We optimized the weekly schedule of ANA on the Tokyo → Okinawa route (Table 4).

Original Schedule		**Optimized Schedule**	
departure	type	departure	type
Base Schedule			
06:25	B737-500	06:55	B777-200
06:35	B767-300	08:10	B747-400
07:55	B747-400	09:35	B777-300
08:40	B747-400	11:20	A380-800
10:05	B777-300	12:40	B777-200
11:45	B747-400	14:40	B777-200
13:00	B747-400	17:00	A320-200
15:30	B747-400	18:05	A320-200
20:00	B747-400	20:10	A320-200
Flex (Sunday 22feb)			
10:20	B777-200	-	-
Flex (Friday 27feb)			
10:20	A320-200	20:45	A320-200
Flex (Saturday 28feb)			
10:20	A320-200	21:00	A320-200

Table 4 Original and Optimized Schedule

It is interesting to see that the optimized schedule is more balanced over the day, which actually resulted in a **"waiting time" reduction of 24% (average of 10 minutes)**. Furthermore, the fact that the aircraft capacities better match the demand, results in a **23.6% reduction of CO_2 emissions**, almost **50.000 tons of CO_2** a year for only one airline! This carbon emission would require a forest of almost 4000 hectares to be set-off. (Refer to Appendix A.4)

Figure 6, another output of the optimization program, visualizes the daily demand and the optimized schedule. There is a peak in the demand for flights to Okinawa in the morning. Practically all optimization results for Tokyo→Okinawa contain one **A380 flight in the morning** to accommodate this enormous demand and as a matter of fact, the optimized Okinawa→Tokyo schedules show an **A380 flight in the evening**, making Tokyo-Okinawa a very good option for actual implementation of the A380.

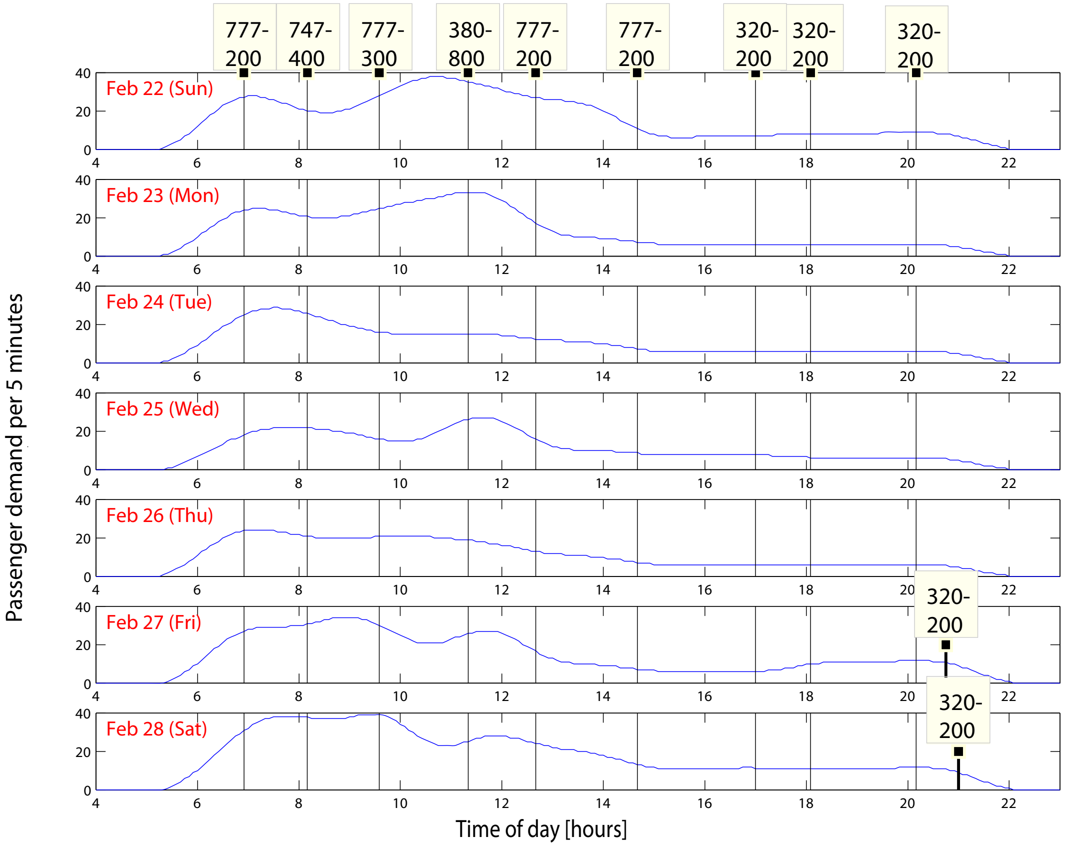


Figure 5 Daily demand and optimized schedule for Tokyo → Okinawa for ANA

3.4 The Business Model or “How to implement our Idea in the Real World.”

The main objective of our proposal is the reduction of the carbon footprint on Japan’s most busy domestic routes by increasing the load factors of aircraft through applying a route dependent cooperation between major airlines and Airbus and applying a new adaptive flight distribution system.

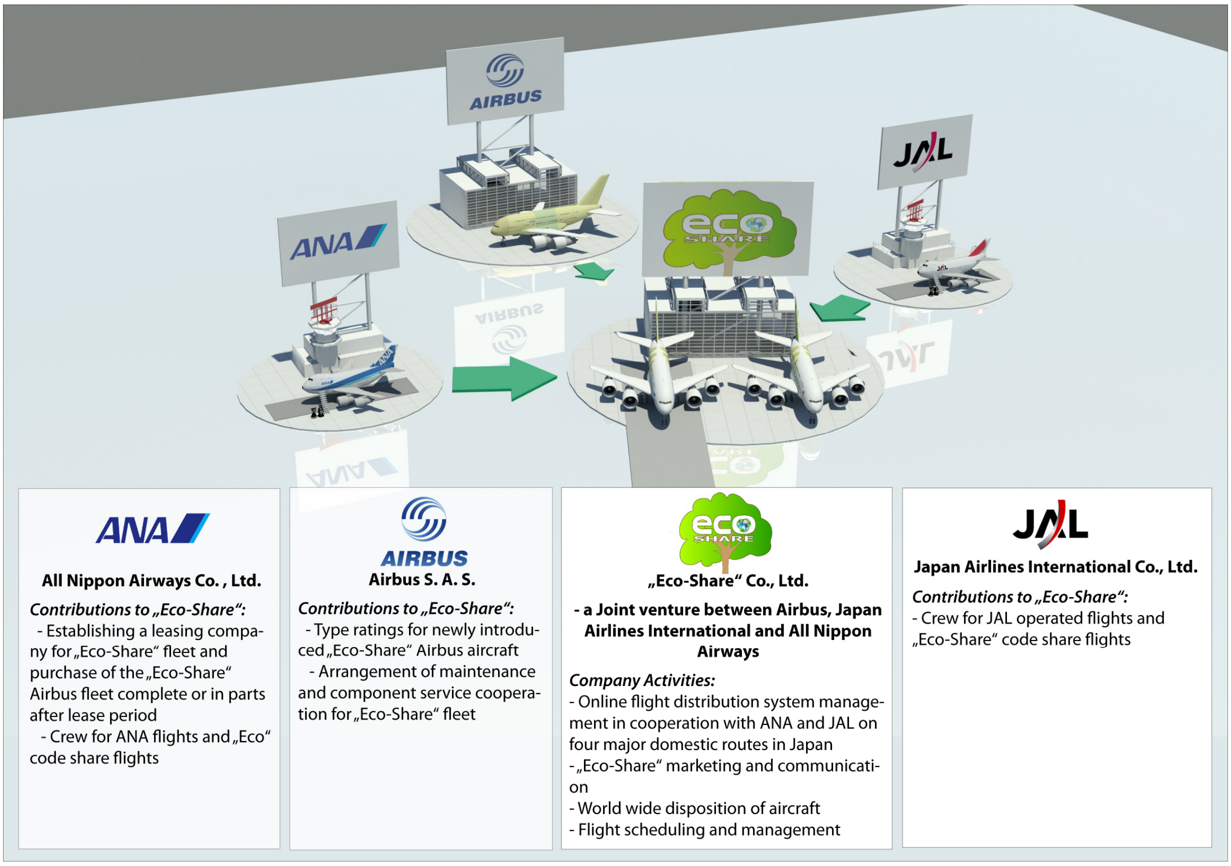
Main objectives:

- **Increasing passenger load factors on major Japanese air routes** by implementing an innovative flight distribution system, introducing large fuel-efficient aircraft (A380) and introducing route-dependent co-operations between major Japanese airlines
- **Reduction of CO_2 and noise emissions** by increasing eco-efficiency trough implementation of our “Eco-Share” concept

Further objectives:

- **Implementation of a global seasonal demand related aircraft distribution** system to increase efficient usage of aircraft and further increase of passenger load factors by international cooperation of major airlines for the domestic market
- **Increase Airbus’ market share** in the world’s third largest domestic airline market
- **Increase the eco-awareness** of Japanese airline passengers by introducing an eco-related campaign, painting aircraft with a recognizable design and providing videos on the in-flight infotainment system of all “Eco-Share” flights

3.4.1 “Eco-Share” Business Concept Implementation



ANA

All Nippon Airways Co., Ltd.

Contributions to „Eco-Share“:
- Establishing a leasing company for „Eco-Share“ fleet and purchase of the „Eco-Share“ Airbus fleet complete or in parts after lease period
- Crew for ANA flights and „Eco“ code share flights

AIRBUS

Airbus S. A. S.

Contributions to „Eco-Share“:
- Type ratings for newly introduced „Eco-Share“ Airbus aircraft
- Arrangement of maintenance and component service cooperation for „Eco-Share“ fleet

„Eco-Share“ Co., Ltd.

- a Joint venture between Airbus, Japan Airlines International and All Nippon Airways

Company Activities:
- Online flight distribution system management in cooperation with ANA and JAL on four major domestic routes in Japan
- „Eco-Share“ marketing and communication
- World wide disposition of aircraft
- Flight scheduling and management

JAL

Japan Airlines International Co., Ltd.

Contributions to „Eco-Share“:
- Crew for JAL operated flights and „Eco-Share“ code share flights

Figure 6 Business Model of the „Eco-Share“- Joint Venture

We propose to form a joint venture between Airbus on the one hand and the airlines All Nippon Airways and Japan Airlines on the other hand (Figure 7). This joint venture, especially the cooperation between the two major Japanese airlines, will be strictly limited to the four major domestic routes:

- Haneda (Tokyo) – Chitose (Sapporo)
- Haneda (Tokyo) – Itami (Osaka)
- Haneda (Tokyo) – Fukuoka
- Haneda (Tokyo) – Naha (Okinawa)

ANA will hold the largest share of the joint venture. After analysis of the economic situation of All Nippon Airways from the Annual Report of 2008 [3], their business plan until 2010 [12] and their company structure [3], we inferred that ANA could host and manage the leasing of the “Eco-Share” fleet. ANA would take advantage of their existing in-house leasing company to purchase the “Eco-Share” fleet and lease them internally to themselves and externally to JAL. Airbus would contribute in terms of type ratings for the new aircraft types as well as arranging the maintenance. As a counter value, Airbus would print its lettering or its logo on every “Eco-Share” aircraft.

The fleet of the joint venture will appear with a specific “Eco-Share” corporate design which is further described in Chapter 3.4.3. Each airline would individually operate their carbon footprint optimized schedules (using our flight distribution system) with their own “Eco-Share” fleet (airline logos will be printed on the aircraft as part of the “Eco-Share” design concept”). As the ultimate goal we would like to have both airlines operate additional code-share flights to even further increase eco-efficiency. This would work similar a shuttle service.

3.1.4.1 Company Activities of “Eco-Share”

The main activity of “Eco-Share” would consist of the management of the online flight distribution system in cooperation with ANA and JAL. Further activities would concern the marketing and communication of “Eco-Share” and the management of the worldwide disposition of aircraft.
Refer to chapter 3.4.2.1 and 3.4.2.2 for details.

3.1.4.2 Benefits for each party

Airbus will benefit by increasing their market share in Japan. The airlines will benefit by reducing their operational costs as well as those linked to CO_2 and noise, and by communicating their “green” image to the public. Last but not least the passengers benefit, because besides evoking their eco-awareness by the “Eco-Share” campaign introduced on the in-flight infotainment system, they will also financially benefit by cheaper ticket prices. Therefore, each passenger will save money and contribute to our environment.

3.4.2 The “Eco-Share” fleet

The “Eco-Share” fleet will consist of two types of aircraft:

- A380 fleet with a cabin layout for the Japanese domestic market (high capacity)
- A320 family additional fleet to accommodate seasonal fluctuations. This fleet will be globally distributed in times with a seasonally low demand in Japan.

3.4.2.1 “Eco-Share” A380 fleet

This fleet would serve to fit the basic demand. As generally applying to all “Eco-Share” flights, the schedule for the A380 fleet would be based on the eco-efficient optimized schedule but fixed to a certain high percentage so that there are almost no aircraft resting on the ground and “skipping” a scheduled flight. The A380 fleet would be based in Japan and not be used to serve anywhere else in the world. Therefore, the cabin layout can be decided by the major airline owning this aircraft. Typical seating layout will include between 800 and 850 seats in total and an economy class seats percentage between 85% and 95%.

3.4.2.2 “Eco-Share” A320 family fleet

This additional fleet would fill the capacity gaps to cope with the seasonal increase in the demand of domestic flights at special holidays in Japan. This fleet would be transferred to another place in the world to decrease the aircraft capacity for Japan in times with seasonally low demand and increase the capacity in places of the world “WHEN they need it”. A possible example: transfer to Europe at times with high seasonal demands in there, like the Christmas and Easter seasons. The transfer flights from Japan to Europe and back could be undertaken with one or two stops on the way. (Flight ranges of A319 = 3600nm, A320/21 = 3000nm; Tokyo to Paris = 6050nm [13]). Tickets for the transfer flights could be sold as “Eco-Share-Adventure Tour to Europe” for discount prices to promote “ECO-Share”.
The seating and interior design of this fleet may have to be different from the Japan based “Eco-Share” fleet to fit European customer taste.

3.4.2.3 “Eco-Share” benefit for passengers

Passengers on “Eco-Share” flights will be provided with information on environmental issues and monthly changing topics and campaigns through the in-flight infotainment system. This should make each passenger conscious about the preciousness of our planet and the issue of global warming and how each person could contribute their part in energy saving like they already did by choosing an “Eco-Share” flight.

3.4.3 The Design and the Name “Eco-Share”

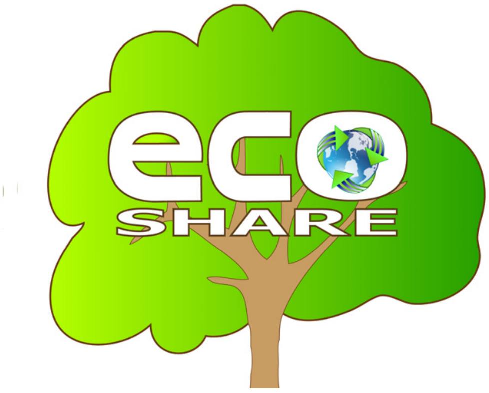
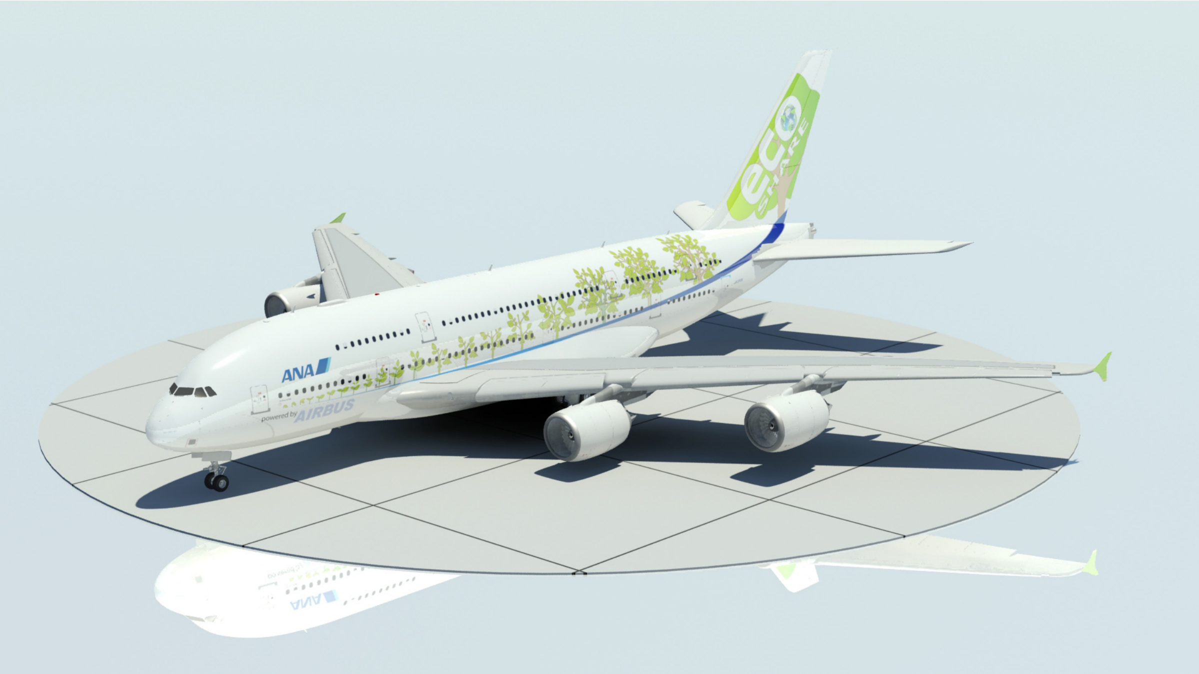
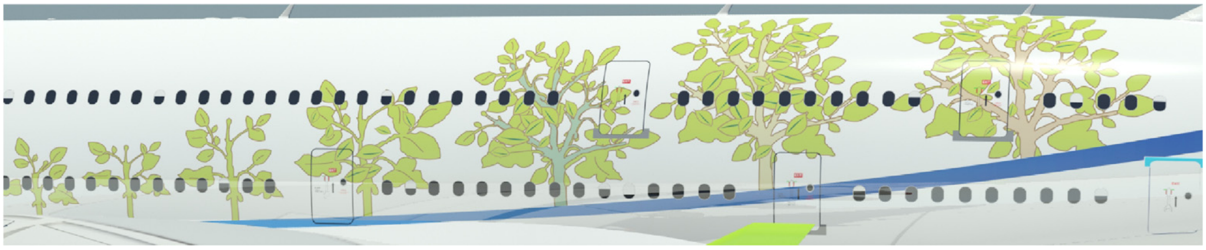


Figure 7 „Eco-Share“ logo

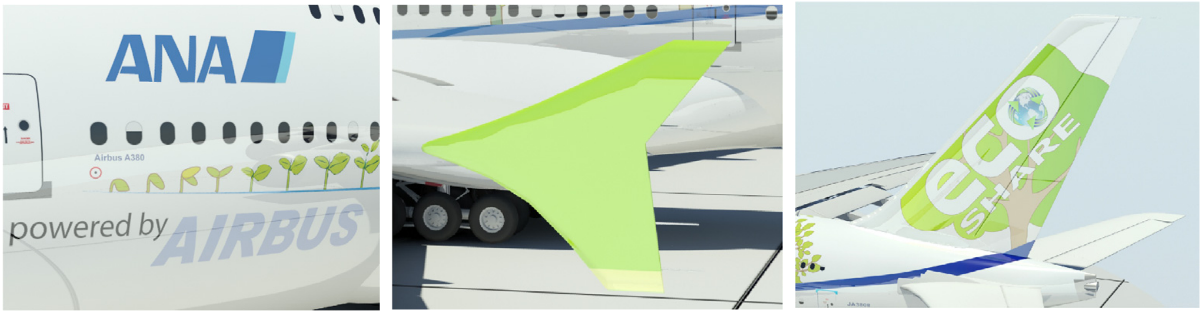
The “Eco-Share“ logo (figure 8) consist of a tree with the text “Eco-Share” on it having the globe centered in the “o” of “Eco”. Three arrows resemble “caring for our future, protecting our planet” and a part of the AIRBUS corporate design. Figure 9 displays the livery of an A380 “Eco-Share” operated by ANA.


ANA
powered by AIRBUS
eco SHARE

The A380-800 in „Eco-Share“ livery.



The growing plant sequence as a symbol of nature and the future of our planet.


ANA
Airbus A380
powered by AIRBUS
eco SHARE

The logo of the airline operating the aircraft (ANA) is placed close to the cockpit. At the lower fuselage „powered by AIRBUS“ will be printed.

The winglets will be painted green with a yellow underline to resemble the color of the leaves of the growing plant sequence.

The logo of„Eco Share“ on the vertical tail plane. The earth surrounded by three arrows which are representing the fact that this aircraft operation concept is a commitment to the future of our planet.

Figure 8 A380 in „Eco-Share“ livery operated by ANA

3.5 The SWOT analysis

3.5.1 Main Strengths

Environmental Benefits
Optimized load factors and smart aircraft distribution leads to reduced fuel burn per passenger and consequently CO_2 emission abatement. The same number of passengers can be transported with fewer aircraft, resulting in fewer aircraft movements and thus less noise.

“WHAT you need, WHEN you need it”
Every airline has a limited number of aircraft types in its fleet and is forced to choose available ones for each route. Seasonal adjustments can be made to a certain extent, but they are subject to long term planning and are generally not very flexible. The “Eco share” proposal removes this obstacle offering additional types of aircraft to meet the airlines’ acute needs.

Minimal financial risk
By and large, providing a new aircraft is associated with high risk, which can be unaffordable for the airlines in a state of recession or fluctuating economy. The “ECO share” fleet is a superb no-purchase-bound solution.

3.5.2 Main Weaknesses

Profits and responsibilities distribution
The joint operation of flights might cause confusion in the profits and responsibilities distribution. In particular, the issue of responsibilities and financial compensations in the case of an accident might be difficult to solve.

Reduced competition
Having at least two major airlines working together can lead to reduced competition and lack of interest in further improvements. Competition is an effective stimulus for each company and is crucial from the passengers’ perspective.

3.5.3 Main Opportunities

Reduced R&D costs
Aircraft are developed in close collaboration with the airlines because the aircraft industry has shifted towards need-based production [14]. The joint venture offers Airbus an opportunity to get a first-hand view of the market.

Increased share in Japan
At present, there is severe competition in the market of domestic flights in Japan. Through a brand new leasing scheme and unique aircraft promotion, Airbus will be able to increase its market share and strengthen its presence in Japan.

3.5.4 Main Threat

Lack of cooperation
For the “ECO Share” concept to work, cooperation of major airlines is absolutely necessary. If the airlines refuse to work together with their “rival”, the idea cannot be implemented.

3.5.5 Conclusion of the SWOT analysis

What we can do to use our strengths, stop our weaknesses, exploit out opportunities and defend against threats is discussed in detail in Appendix B.3. That extensive analysis showed that the weaknesses and threats can probably be dealt with accordingly. Our proposal and the detailed solutions therefore considered are feasible.

4. OUTCOMES

4.1 Key Outcomes

Our “Eco-Share” proposal incorporating an Airbus–Airline joint venture implementing a more eco-efficient fleet and operating eco-optimized demand-driven schedules with increased load factors was shown to be feasible by a detailed SWOT and market analysis.

By globally distributing the part of the “Eco-Share” fleet (A320 family fleet) for the seasonal demand fluctuation, we showed that it would easily be possible to reduce seat capacity in Japan in times of seasonally low demand.

Findings on our proposal:

- Today’s situation of Japan’s major airlines JAL and ANA including their future plans are fully compatible with our “Eco-Share” business model implementation [15], [16].

- Unlike other measures increasing eco-efficiency, our “Eco-Share” proposal is beneficial not only to the environment, but also to all stakeholders.

Further recommendations:

- A380 is pre-destined for Japanese domestic market
- Excellent current conditions for Airbus to increase its market share in Japan

4.2 Eco-Efficiency benefits in hard numbers

We validated that by incorporating above mentioned measures and allowing partly flexible schedules, we could achieve an average of **20 %** or **870 kilotons CO_2 emission reduction** resulting in **$130 Million** fuel and emission trading rights as well as a reduction in airline movements per day resulting less noise impact per year.

5. RECOMMENDATIONS

This chapter provides an evaluation of the feasibility of our idea. Additionally this chapter provides information on today’s unique situation of AIRBUS on the Japanese market.

5.1 How feasible is this idea?

Future aviation will be facing both economic and environmental challenges. According to ANA’s Annual Report 2008 [3], ANA was the first among the world’s airlines to set CO_2 emission target reduction from 4.9 million tons to an annual average of 4.7 million tons till March 2012. JAL plans to renew its fleet retiring 46 of their B747 fleet no later than 2010 and substitute them with more fuel-efficient aircraft [15]. Furthermore, JAL is planning to concentrate on high-profit routes with large carriers [15]. Due to the high demand on the main domestic routes, a significant number of large carriers are operated in Japan.

5.1.1 Excellent conditions to increase the market share of Airbus in Japan

The A380, being the largest passenger carrier in the world, it is pre-destined to be a part of the unique Japanese market. In the summer of 2008, ANA started to communicate their plans for a possible purchase of the A380 to the public. Due to the impact of the financial crisis this plans were postponed. However, today, there are excellent conditions like increasing landing fees for eco-inefficient aircraft and the still growing demand for high capacity on major routes, for the implementation of this environmentally-friendly aircraft

Our proposal gives the airlines a chance to make the most of such aircraft without taking a high risk.

5.2 Future Work - What are the next steps to be undertaken?

At present, due to the limited time we had available for the completion of the project, we had to disregard certain constraints such as logistic issues on the airline's side and airline preferences on the passenger's side. In order to obtain more realistic results and have the optimal schedules implemented more constraints need to be introduced.

Furthermore, negotiations with JAL, ANA and the other airlines operating aircraft on these four main routes are needed. Cooperation of Tokyo Haneda airport will also be crucial. In order to work on the details of the joint venture, the fleet that will be available and the terms of delivery of the aircraft, negotiations with Airbus International and Airbus Japan KK have to be initiated.

5.3 Closing Argument

"Eco-Share" – For the Eco-efficient Future of Our Planet and the Future of AIRBUS in Japan

Achieving an average of 20 % reduction of CO_2 emissions resulting in 870 kilotons reduction of CO_2 per year is a huge contribution to a greener future of the world third largest domestic airline market. Although we performed just a case study for the Japanese market, this is a significant part of the world market. Our proposed system could be extended to other countries in future.

The current situation is excellent for Airbus to increase its share in the second biggest economy of the world and home of the airline owning the most Jumbo-Jets. We believe that Airbus should take this chance to introduce especially the A380 to the Japanese market and our proposal would be the best start to this goal.

For the future our only green planet and the future of Airbus in Japan – "Eco-Share".

Tokyo, the 31st of March 2009, GMT 12:00

APPENDIX A

A.1 Data Acquisition

This section describes how we obtained the data needed for the optimization. Subsection A.1.1 describes how we obtained the daily passenger demand (and load factor) data for Japanese domestic flights. Subsection A.1.2 deals with the fuel burn and CO2 emission data we used.

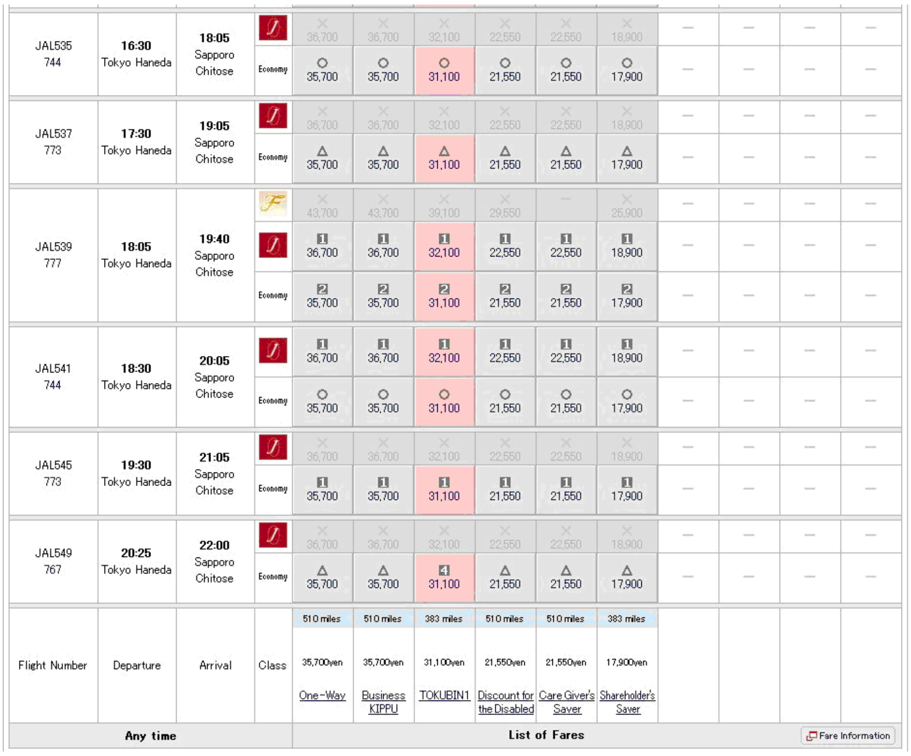
A.1.1 Passenger Demand

First of all, we chose to do a case-study with only a few routes to be optimized. When the “ECO-Share” system is operational, the passengers’ convenience should also be considered. If our project is used for routes which have only a few flights per day, a reduction of one flight can cause a big effect. On the other hand, a few flights reduction for main routes which have 30-50 flights per day, does not affect the convenience so much. In Japan, the 4 main routes (“Tokyo-Sapporo”, “Tokyo-Fukuoka”, “Tokyo-Osaka” and “Tokyo-Okinawa”) account for 30 % of the passengers of total domestic route [9]. If these routes can be made more efficient, a large benefit can be obtained easily. Therefore, the flight schedules of these routes are optimized in our current investigation.

In order to optimize the load factor, we planed to obtain the time distribution of the number of passengers for the four main routes over a one month period. However, this data is not disclosed by the airline companies, and it is rather difficult to obtain such data via other channels because of its competition-sensitive nature. Consequently, we decided to predict these data using the airline online reservation status [17], [19], [21].

Recently, the airline companies developed online reservation systems which show the seat availability depending on the fare basis at any time for any flight. Although this data does not show the exact number of seats available, it gives a rough indication for each fare basis. Additional knowledge of the difference between the fare bases is used to predict the load factor. For example, on the Japanese domestic routes, upper grade seats are also provided. Using this data, the load factor is assumed to be high if the upper grade seats are relatively full. Moreover, not only normal fare tickets but also discount tickets are sold by the airline; sometimes only the discount ticket is (nearly) sold out. We think this means that the flight for which the discount tickets are sold out has relatively less overall seat availability. Using such data, the load factor is predicted for each flight.

In order to predict the load factors per flight, first of all, the online reservation status has to be obtained. We collected the booking status data of the next day's flights on a daily basis throughout February 2009. However, this data is a huge volume. The routes we chose (especially Tokyo-Sapporo & Tokyo-Fukuoka) have about 40-50 flights per day and are operated by four airlines (Japan Airlines, All Nippon Airways, Air Do, and Skymark Airlines). Therefore, we developed a computer program to obtain the data automatically. This program gets the html source of the page where the reservation status is displayed (one example is shown in Fig. 10), and the information we need is extracted using the website's typical markup elements. Additional information could be obtained from the airline websites; the seat map for each aircraft model and the monthly average load factors per route for 2008 [5], [6], [7]. From the seat map, the number of seats provided in each aircraft (capacity) is obtained [18], [20]. Moreover, the load factor is different depending on the seasons, so the monthly average load factor data is also used to calibrate the prediction. Of course the data for this year cannot be obtained, so the monthly data for the last year is used instead of this year's.



JAL535 744	**16:30** Tokyo Haneda	**18:05** Sapporo Chitose	J	× 36,700	× 36,700	× 32,100	× 22,550	× 22,550	× 18,900	—	—	—	—
			Economy	○ 35,700	○ 35,700	○ 31,100	○ 21,550	○ 21,550	○ 17,900	—	—	—	—
JAL537 773	**17:30** Tokyo Haneda	**19:05** Sapporo Chitose	J	× 36,700	× 36,700	× 32,100	× 22,550	× 22,550	× 18,900	—	—	—	—
			Economy	△ 35,700	△ 35,700	△ 31,100	△ 21,550	△ 21,550	△ 17,900	—	—	—	—
JAL539 777	**18:05** Tokyo Haneda	**19:40** Sapporo Chitose	F	× 43,700	× 43,700	× 39,100	× 29,550	—	× 25,900	—	—	—	—
			J	1 36,700	1 36,700	1 32,100	1 22,550	1 22,550	1 18,900	—	—	—	—
			Economy	2 35,700	2 35,700	2 31,100	2 21,550	2 21,550	2 17,900	—	—	—	—
JAL541 744	**18:30** Tokyo Haneda	**20:05** Sapporo Chitose	J	1 36,700	1 36,700	1 32,100	1 22,550	1 22,550	1 18,900	—	—	—	—
			Economy	○ 35,700	○ 35,700	○ 31,100	○ 21,550	○ 21,550	○ 17,900	—	—	—	—
JAL545 773	**19:30** Tokyo Haneda	**21:05** Sapporo Chitose	J	× 36,700	× 36,700	× 32,100	× 22,550	× 22,550	× 18,900	—	—	—	—
			Economy	1 35,700	1 35,700	1 31,100	1 21,550	1 21,550	1 17,900	—	—	—	—
JAL549 767	**20:25** Tokyo Haneda	**22:00** Sapporo Chitose	J	× 36,700	× 36,700	× 32,100	× 22,550	× 22,550	× 18,900	—	—	—	—
			Economy	△ 35,700	△ 35,700	4 31,100	△ 21,550	△ 21,550	△ 17,900	—	—	—	—
Flight Number	Departure	Arrival	Class	510 miles 35,700yen One-Way	510 miles 35,700yen Business KIPPU	383 miles 31,100yen TOKUBIN1	510 miles 21,550yen Discount for the Disabled	510 miles 21,550yen Care Giver's Saver	383 miles 17,900yen Shareholder's Saver				
Any time				**List of Fares**									Fare Information

Figure 10 Snapshot of JAL's Booking Page

Using this data, the load factor of each flight is predicted (this will be discussed in detail shortly). In Japan, the ticket price and the ticket selling conditions (reservation class) are fixed in advance (see Fig. 10). "One-way" ticket is a normal ticket, and "Tokubin 1" ticket is a discount ticket which is sold until one day before the departure. "J" means the upper class seat. This time, only these three tickets availabilities are considered. As shown in this figure, each ticket has a separate availability. For example, for flight JAL 549, there are 10-29 “One-way” tickets, 4 “Tokubin” tickets, and no upper class seat available. The other airlines apply a similar ticket selling system, and the same prediction method, which is explained from now, can be used.

1) The preliminary availability is predicted from the “One-way” ticket availability.
On the website, “One-way” ticket availability is divided into three categories: over 30 seats, 10-29 seats, and 0-9 seats. Actually, in case of 0-9 seats, the exact number of seats is shown. “10-29 seats” is assumed to be 15 seats left. However, “over 30 seats” can mean either 40 seats available or 200 seats available, but we cannot distinguish this difference. Therefore, as a preliminary availability, it is assumed that “over 30 seats” has the same percentage of the availability as the monthly average load factor.

2) Upper class & discount ticket status are considered to better predict the seat availability.
As mentioned before, the upper class and discount ticket availability is used to improve the predictability. Actually, if the upper class and discount ticket seats are relatively more vacant than other flights, the availability is decreased with respect to the preliminary one. It is important how to decide the weight of the additional information, and the minimum load factor is arranged to be about 40 %.

3) Finally the whole month’s data was normalized so the average load factor matches the one reported by the airlines over Feb 2008 for each route.

Table 4 shows one example of the prediction results. (5 February 2009, Tokyo-Sapporo, Japan Airlines)

Table 4 Prediction Results for 5 February 2009, Tokyo-Sapporo, Japan Airlines

Flight	Departure	Seats Provided	Predicted Passengers	Load Factor
JAL503	6:35	500	381	76.2%
JAL507	7:25	546	546	100.0%
JAL509	8:15	500	377	75.4%
JAL513	9:00	546	425	77.9%
JAL4503	9:20	290	229	78.8%
JAL515	9:45	546	421	77.1%
JAL517	10:15	361	335	92.9%
JAL521	11:05	361	246	68.2%
JAL523	12:00	500	499	99.8%
JAL525	12:45	361	228	63.3%
JAL527	13:15	261	198	75.7%
JAL529	14:15	500	343	68.6%
JAL531	14:50	361	178	49.4%
JAL533	15:35	546	379	69.4%
JAL535	16:30	546	416	76.2%
JAL537	17:30	500	381	76.2%
JAL539	18:05	361	246	68.2%
JAL541	18:30	546	379	69.4%
JAL545	19:30	500	385	77.1%

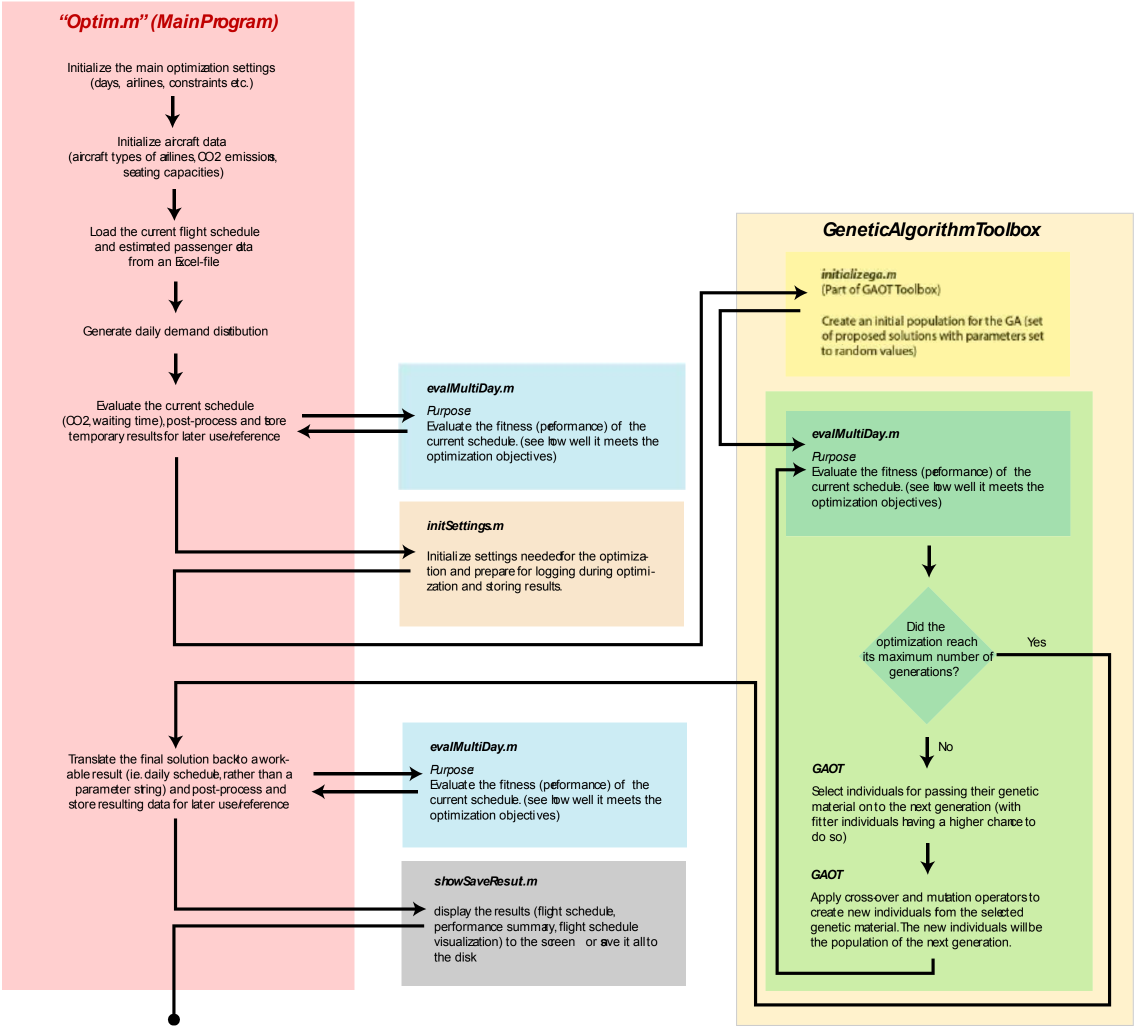
A.1.2 Fuel Burn and CO2 Data

CO2 emissions are directly proportional to the amount of fuel burnt during a trip [10]. It was therefore important for us to get data about the amount of fuel different aircraft types need to fly the routes we investigate. Although such information is publicly available [22], data for recent aircraft such as the B737-800 and the A380 are missing and several very different aircraft are considered “similar”. From a carbon offset point of view this may be acceptable, but for our optimization the difference between a A300-600, a B767-200 and a B767-300 is significant. Therefore our campus contact has provided us with more detailed data. A full table of the fuel burn data can be found in Appendix 3, Section 3.

A.2 Program Description

As discussed in the main report, we implemented the Genetic Algorithm in our optimization.

A flow chart of the complete program is shown in Fig. 11. The evaluation function, which estimates how good a result is every step of the way is shown in Fig. 12.



"Optim.m" (MainProgram)
Initialize the main optimization settings (days, airlines, constraints etc.)
Initialize aircraft data (aircraft types of airlines, CO2 emissions, seating capacities)
Load the current flight schedule and estimated passenger data from an Excel-file
Generate daily demand distribution
Evaluate the current schedule (CO2, waiting time), post-process and store temporary results for later use/reference
evalMultiDay.m
Purpose
Evaluate the fitness (performance) of the current schedule. (see how well it meets the optimization objectives)
initSettings.m
Initialize settings needed for the optimization and prepare for logging during optimization and storing results.
Translate the final solution back to a workable result (ie. daily schedule, rather than a parameter string) and post-process and store resulting data for later use/reference
evalMultiDay.m
Purpose
Evaluate the fitness (performance) of the current schedule. (see how well it meets the optimization objectives)
showSaveResult.m
display the results (flight schedule, performance summary, flight schedule visualization) to the screen or save it all to the disk
GeneticAlgorithmToolbox
initializega.m
(Part of GAOT Toolbox)
Create an initial population for the GA (set of proposed solutions with parameters set to random values)
evalMultiDay.m
Purpose
Evaluate the fitness (performance) of the current schedule. (see how well it meets the optimization objectives)
Did the optimization reach its maximum number of generations?
Yes
No
GAOT
Select individuals for passing their genetic material onto the next generation (with fitter individuals having a higher chance to do so)
GAOT
Apply cross-over and mutation operators to create new individuals from the selected genetic material. The new individuals will be the population of the next generation.

Figure 11 Flow Chart of the Optimization Program

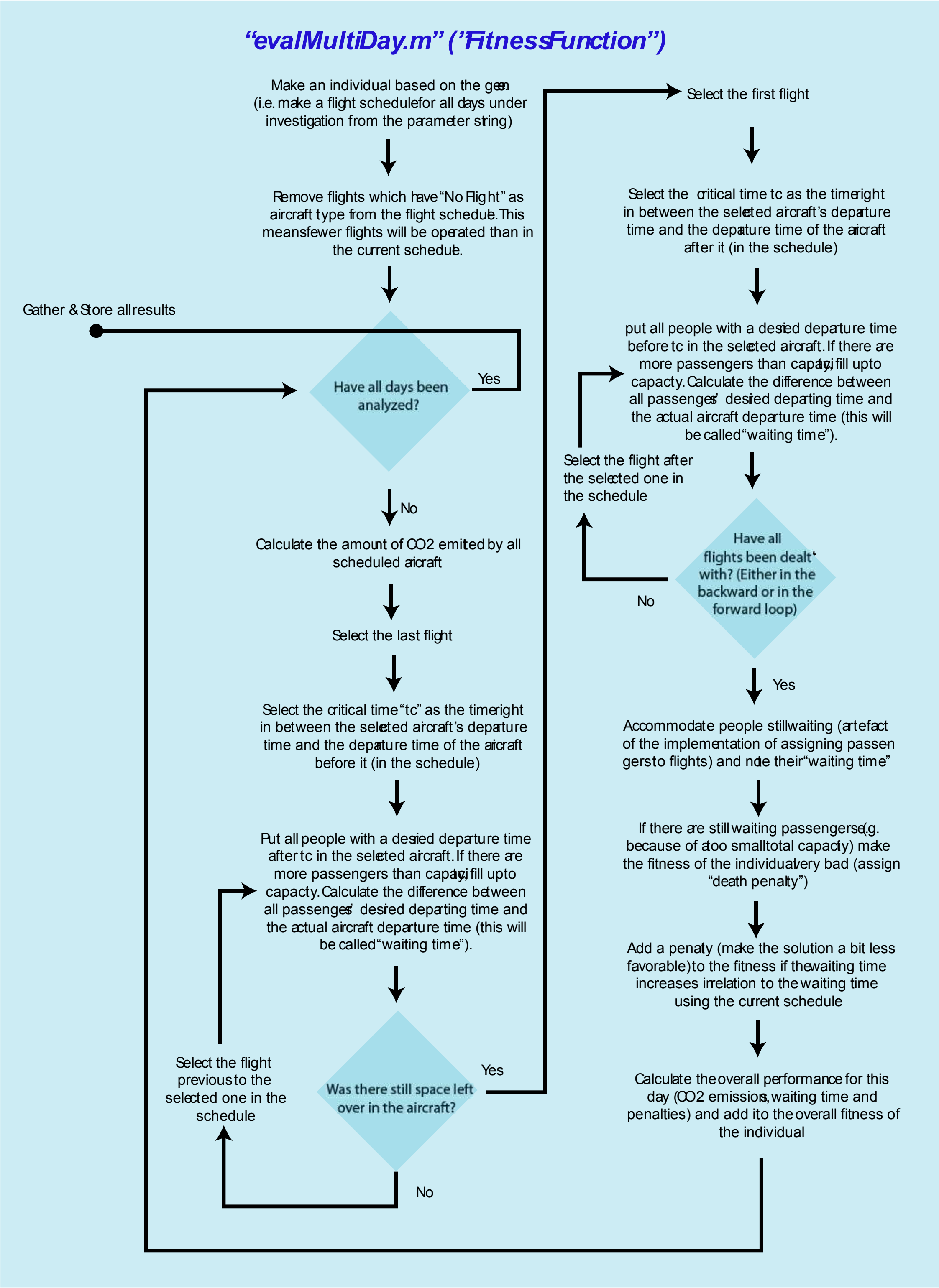

"evalMultiDay.m" ('FitnessFunction")
Make an individual based on the gene (i.e. make a flight schedule for all days under investigation from the parameter string)
Remove flights which have "No Flight" as aircraft type from the flight schedule. This means fewer flights will be operated than in the current schedule.
Gather & Store all results
Have all days been analyzed?
Yes
No
Calculate the amount of CO2 emitted by all scheduled aircraft
Select the last flight
Select the critical time "tc" as the time right in between the selected aircraft's departure time and the departure time of the aircraft before it (in the schedule)
Put all people with a desired departure time after tc in the selected aircraft. If there are more passengers than capacity, fill upto capacity. Calculate the difference between all passengers' desired departing time and the actual aircraft departure time (this will be called "waiting time").
Select the flight previous to the selected one in the schedule
Was there still space left over in the aircraft?
Yes
No
Select the first flight
Select the critical time tc as the time right in between the selected aircraft's departure time and the departure time of the aircraft after it (in the schedule)
put all people with a desired departure time before tc in the selected aircraft. If there are more passengers than capacity, fill upto capacity. Calculate the difference between all passengers' desired departing time and the actual aircraft departure time (this will be called "waiting time").
Select the flight after the selected one in the schedule
Have all flights been dealt with? (Either in the backward or in the forward loop)
No
Yes
Accommodate people still waiting (artefact of the implementation of assigning passengers to flights) and note their "waiting time"
If there are still waiting passengers (e.g. because of a too small total capacity) make the fitness of the individual very bad (assign "death penalty")
Add a penalty (make the solution a bit less favorable) to the fitness if the waiting time increases in relation to the waiting time using the current schedule
Calculate the overall performance for this day (CO2 emissions, waiting time and penalties) and add it to the overall fitness of the individual

Figure 12 The Fitness Function

Assumptions with minor or no impact:

- Aircraft departure times are limited to 5min slots (this is already current practice)
- Environment friendliness is entirely decided by CO_2 emissions, which are in turn linearly related to fuel burn. (Other factors such as noise impact reduction resulting from fewer flights could easily be added)
- The amount of fuel used for a flight depends on the aircraft type/subtype and flight distance only. (i.e., it is independent of the number of passengers boarding and independent of the (class) layout)

A.3 Additional Results from the Optimization

A.3.1 But What If There Was No 777?

But what if there was no 777? We ran some optimizations to see what the world would look like then…

As discussed in the main test of the report, the Boeing 777 aircraft often appears in the optimized flight schedules. Apparently this capacity is very suitable for the frequent flight schedule in combination with the high passenger demand. Also the fact that this is a very recent and thus relatively eco-efficient aircraft will have added to its success in the optimization.

The reason that no similar Airbus aircraft, such as the A330-300, the A340-600 or the A350-1000 are found, is because they were not included in the optimization. This was for a good reason: the Japanese airlines currently don't own these aircraft types. As acceptance of our ECO-Share idea by the airlines is of vital importance for its functioning, we considered it would be better to take the airlines' current fleets as a starting point.

Here, one example of the optimization results (Tokyo to Sapporo for ANA) is considered (see Table 5). This optimization achieves 12.1 % waiting time reduction and 10% CO2 emission abatement. This schedule consists of 15 Airbus aircraft out of 24 aircraft, and 2 A380s also appear. Generally speaking, the use of big aircraft leads to increase the waiting of time, but this result implies that big aircraft such as A380 can still be practical on such a crowded route. It can also be seen that the A350-1000 and A330-300 often appear in the schedule, thus forming a very feasible alternative to the 777. There is possibly still some room for further optimization of the schedule, for instance by merging the 14:35 and 14:45 flights.

A similar optimization for the JAL flights between Tokyo and Sapporo results in a 16% CO2 reduction with 4% waiting time reduction over 19 flights a day. For SKYmark airlines a 10% CO2 and 2% waiting time reduction is found when optimizing their 8 flights daily schedule.

Table 5 Optimization result for Tokyo to Sapporo for ANA (No 777 as option)

```
BASE Schedule:
   6:20   322   (A320-200          )
   7:15   346   (A340-600          )
   7:50   351   (A350-1000 XWB    )
   8:55   380   (A380              )
   9:40   351   (A350-1000 XWB    )
  10:20   351   (A350-1000 XWB    )
  10:45   744   (ANA B747-400     )
  11:40   763   (ANA B767-300(P))
  12:15   744   (ANA B747-400     )
  13:15   380   (A380              )
  13:50   333   (A330-300          )
  14:35   767   (ADO 767           )
  14:45   333   (A330-300          )
  15:20   767   (ADO 767           )
  15:50   333   (A330-300          )
  16:55   351   (A350-1000 XWB    )
  17:25   322   (A320-200          )
  17:50   738   (ANA B737-800     )
  18:25   744   (ANA B747-400(P))
  18:50   322   (A320-200          )
  19:10   321   (A321-200          )
  19:45   763   (ANA B767-300(P))
  20:15   763   (ANA B767-300(P))
  21:05   351   (A350-1000 XWB    )
FLEX Schedule (day 22):
  16:05   763   (ANA B767-300(P))
FLEX Schedule (day 23):
  8:10   320   (ANA A320)
FLEX Schedule (day 24):
  8:30   767   (ADO 767)
FLEX Schedule (day 25):
  21:40   767   (ADO 767)
FLEX Schedule (day 26):
  8:20   738   (ANA B737-800)
```

```
FLEX Schedule (day 27):
  19:35   351   (A350-1000 XWB)
FLEX Schedule (day 28):
  16:20   321   (A321-200)
  20:45   767   (ADO 767 )
--------------------------------------------------------------
            OPTIMIZATION    RESULTS
--------------------------------------------------------------
SETTINGS:
     Route:                    HND-CTS
     Airline(s):               ANA
     Day(s):                   22,23,24,25,26,27,28
     Existing fleet only: No
     Allow fewer flights: Yes
     Decrease capacities: No
     # of flights (base): 24
     # of flights (flex):   1
     # of flights (flex):   1
     # of flights (flex):   1
     # of flights (flex):   1
     # of flights (flex):   1
     # of flights (flex):   1
     # of flights (flex):   2
RESULTS:
     Waiting time reduction:          12.1%
     CO2 emission reduction:           10.1%
     Original   Load Factor:           66.5%
     Optimized Load Factor:            70.6%
     Improvement (% points):            4.0%
     Decrease of number of flights: 0
DETAILS:
     Avg waiting time (current):      11.6
     Avg waiting time (optimized):   10.1
     CO2 emissions (current):       5078156 kg
     CO2 emissions (optimized):   4562955 kg
```

A.3.2 What If We Optimized Over a Long Time?

Most of the schedules discussed consider one week as the period of optimization. This was done because analyzing many days in the optimization takes a lot of time, and we don’t want to wait too long to get results to show you…

However, to see whether it actually makes a difference whether we check a week, or fix a schedule over a much longer period, we did several runs for all data we have. For 24 days we have all data complete, and we used all these daily demand data to check if we could still get the high CO2 reductions of 15-20% we generally got.

In Table 6 we present one example: optimization of the JAL schedule for Tokyo-Osaka. The base schedule is operated every day and additionally a flexible schedule (departure time and aircraft type can vary among days) of maximum 1 flight per day is operated.

It can be seen that with 15% CO2 reduction and still 8% waiting time reduction, even a schedule fixed for more than 3 weeks can be improved a great deal by our ECO-Share optimization.

Table 6 Optimization result for Tokyo to Itami (Osaka) for JAL

```
BASE Schedule:
   9:30   772   (JAL B777-200(J2))
  14:25   AB6   (JAL A300-600       )
  16:45   773   (JAL B777-300       )
  18:00   AB6   (JAL A300-600       )
   6:35   772   (JAL B777-200(J2))
  18:40   773   (JAL B777-300       )
   8:40   322   (A320-200           )
  12:05   773   (JAL B777-300       )
  10:50   AB6   (JAL A300-600       )
  13:20   772   (JAL B777(200)      )
  15:35   767   (JAL B767           )
   7:45   772   (JAL B777(200)      )
  19:15   322   (A320-200           )
  20:10   AB6   (JAL A300-600       )

FLEX Schedule (day 5):
FLEX Schedule (day 6):
FLEX Schedule (day 7):   9:10   772   (JAL B777(200))
FLEX Schedule (day 8):   12:30   322   (A320-200)
FLEX Schedule (day 9):   9:40   772   (JAL B777(200))
FLEX Schedule (day 12):   10:20   322   (A320-200)
FLEX Schedule (day 13):   17:05   767   (JAL B767)
FLEX Schedule (day 15):   17:25   322   (A320-200)
FLEX Schedule (day 16):   20:35   322   (A320-200)
FLEX Schedule (day 17):   10:05   M90   (JAL MD-90)
FLEX Schedule (day 18):   21:40   322   (A320-200)
FLEX Schedule (day 19):   7:55   322   (A320-200)
FLEXSchedule (day20): 15:50   772   (JAL B777-200(J2))
FLEX Schedule (day 21):   10:15   322   (A320-200)
FLEX Schedule (day 22):   13:50   AB6   (JAL A300-600)
FLEX Schedule (day 23):   21:15   M90   (JAL MD-90)
FLEX Schedule (day 24):   8:00   767   (JAL B767)
FLEX Schedule (day 25):   15:45   773   (JAL B777-300)
FLEX Schedule (day 26):   14:55   AB6   (JAL A300-600)
```

```
FLEX Schedule (day 27):   17:35   322   (A320-200)
FLEX Schedule (day 28):   20:25   322   (A320-200)
FLEX Schedule (day 29):   17:35   772   (JAL B777(200))
FLEX Schedule (day 30):   21:00   M90   (JAL MD-90)
FLEX Schedule (day 31):   17:15   M90   (JAL MD-90)


-------------------------------------------------------------
              OPTIMIZATION     RESULTS
-------------------------------------------------------------
SETTINGS:
    Route:                     HND-ITM
    Airline(s):                JAL
    Day(s):    5,6,7,8,9,12,13,15,16,17,18,19,20,
                     21,22,23,24,25,26,27,28,29,30,31
    Existing fleet only: No
    Allow fewer flights: Yes
    Decrease capacities: No
    # of flights (base): 14
    # of flights (flex):    1 (for each day)
RESULTS:
    Waiting time reduction:            8.5%
    CO2 emission reduction:            15.7%
    Original    Load Factor:           66.3%
    Optimized Load Factor:             72.8%
    Improvement (% points):            6.6%
    Decrease of number of flights: 2
DETAILS:
    Avg waiting time (current):       17.4
    Avg waiting time (optimized):    15.9
    CO2 emissionsion (current):       6409686 kg
    CO2 emissionsion (optimized):    5404912 kg
```

A.4 Calculations of financial and environment impact

We assume that

- If we burn 1 kg fuel, 3.15 kg CO2 is emitted [10]
- 1 barrel of kerosene (fuel) costs USD60.00 [23].
- 1 barrel = 139 kg kerosene
- Emission of 1000 kg CO2 (CER: Certified Emission Reductions) are worth EUR10.00 = USD13.00 [24].
- One Japanese cedar absorbs 14 kg CO2 per year [25].
- 920 Japanese cedars can be planted on 1 ha. [26].

We will calculate the impact to reduce 1 kg fuel (kerosene):

- Fuel reduction

$$1[\text{kg fuel}]\times\frac{1}{139}[\text{barrel/kg fuel}]\times 60[\$/\text{barrel}]=\$0.432$$

- CO2 reduction

$$1[\text{kg fuel}]=3.15[\text{kg CO}_2]\times 0.013[\$/\text{kg CO}_2]=\$0.041$$

Total

$$\$0.432+\$0.041=\$0.473/1\ \text{kg fuel}$$

Total forest size needed to absorb CO2:

14x920=12.88ton CO2 is absorbed by 1ha of forest per year

APPENDIX B

B.1 Seasonality Of the Demand For Flights In Japan

As mentioned previously the demand for air tickets is not the same throughout the whole year. There are certain times and periods when people do more likely fly somewhere than in other times. The reasons are mainly related to important cultural festivals, like Christmas in Europe, when many people fly home to spend the time with their families. Since the whole country is kind of living on the same pace, the seasonal changes in demand, especially of holiday travellers, are quite high. The following important seasons have a strong impact on the demand for air travel:

Period: December 26th to January 5th

At the change of the year, most of the Japanese go to their hometown to spend the most important festival of the year with their families at their birthplace. This is a Japanese tradition.

Period: February

Since it's close to the end of the fiscal year (please refer to the period of March), many people starting to travel abroad.

Period: March

School children are having their spring break in March and March is also known as the end of the school, university and business (fiscal) year in Japan. That's why many families and a lot of businessman use this chance to travel.

Period: April

This month is the beginning of the school, university and business year in Japan. Many business men are busy at their company. Almost nobody travels.

Period: mid of July to end of August

In Japan, the school holiday in summer lasts as long as 40 days. Mainly families and university students travel abroad.

Period: September

There are two national holidays in September, and two "three days holidays" in Japan. In addition, the tickets are relatively cheap compared to August. Many businessmen take their holiday in this month, because they are not so busy and it is relatively easy to go on vacation.

B.2 The Name "Eco-Share"

The trade mark of our concept would not only be painted on aircraft in form of the recognizable logo but also be the name of the joint venture to form. The naming would have to be unmistakably linked to eco-efficiency, eco-friendliness, CO_2 reduction etc. by Japanese as well as people world-wide. Furthermore, the naming would have to be accepted from the airline side in terms of raising there "green" image in the public.

The word "eco" as the English abbreviation for ecology has been taken over in to modern Japanese as "エコ" and has become a kind of trade mark when it comes to eco-friendliness. Within the last 5 years the number of campaigns concerning improvements of the eco-efficiency of daily life products has remarkably increased. Japan airlines has introduced a campaign flight testing an aircraft using 10% of its fuel from regenerative sources (Fig. 13).

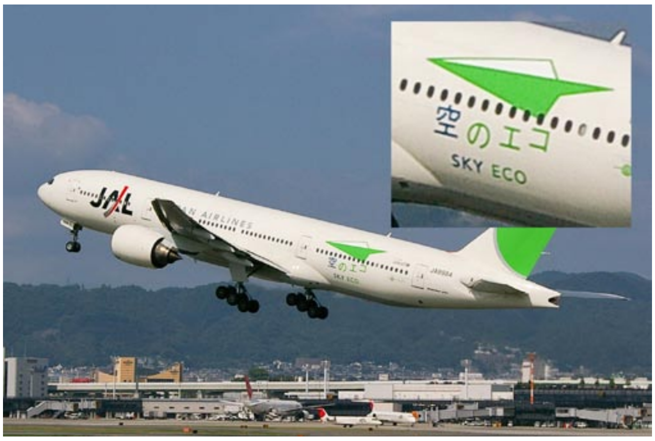


Figure 13 Japan Airlines „SKY ECO" jet flying with fuel including 10% regenerative sources (bio-fuel)

"ECO" or in Katakana "エコ" has developed into a well-known word which associates with eco-efficiency and has a very positive image „環境に優しい" (good for our environment).

The word "share" as the English abbreviation for sharing シェア has been introduced into the Japanese language through words like "apartment sharing" and has the very social and very positive meaning. Sharing by using "Eco-Share" and contributing to a greener future.

B.3 SWOT Analysis

Why SWOT?

In order to evaluate how practical “ECO Share” is, we performed a detailed SWOT (**S**trengths, **W**eaknesses, **O**pportunities and **T**hreats) analysis. We elaborated further and considered possible strategies to benefit the most from our proposal. To do that, we asked ourselves the following questions: “How do we use our strengths? How do we stop our weaknesses? How do we exploit out opportunities? How do we defend against threats?” Since a SWOT analysis concentrates in general on issues which have potentially the most impact, it is believed to be useful when a limited time is available to assess a complicated or a brand new strategic situation. Therefore, we opted for this tool when evaluating the pros and cons of our proposal.

We considered the project from the perspective of all stakeholders to obtain a thorough and comprehensive view. These stakeholders are Airbus, the airlines, the joint venture and the passengers. The results are summarised in the Table 7.

STRENGTHS

Strengths from the airline’s perspective

Unique Selling Point

First, we looked at the strengths of the project. Our unique selling point is simple and straightforward: “what you need, when you need it”. Unlike an automobile, an aircraft is a long-term investment which requires careful planning and research. However, even in the case of cars, the need for flexibility and reduced obligations has resulted in the development of the rent-a-car industry which is currently flourishing in Tokyo. When you need a small vehicle to go on a drive in the countryside you do not rent a big van because you want to keep your fuel consumption, and thus costs, as low as possible without causing yourself an inconvenience. On the other hand, when you need to move to a new apartment, you rent a small truck which can carry all the things you have. To meet the various needs of its customers, a rent-a-car company offers one-day leasing of a wide range of vehicles. To a certain extent, a similar system can be implemented to air transport.

Financial Aspects of Becoming Eco

Making the airline “ECO” is one of the most important strengths of “ECO Share” and it has the potential to lead to governmental subsidies. Since environmental issues have been in the spotlight for a long time now, various measures have already been introduced to reduce the harmful effects of human activity on our environment. For aviation, these include technological advances such as lightweight materials and new combustion systems, simulator training and optimized flight trajectories to minimize fuel burn [27]. Unlike many other industries, emissions from aviation are relatively easily calculated and are therefore subject to careful analysis. The current emissions are likely to become the base for emission trading. Emission trading is a system which was first introduced in Europe that provides financial incentives to companies which achieve greenhouse gas emission abatement while having the countries which fail to comply with the requirements incur financial losses [28]. When an airline reduces its carbon footprint substantially, it can rely on support and even subsidies from the government. We have come to a stage when being eco is no longer simply qualitative, but also a quantitative term which has clear financial dimensions.

Minimal financial risk

Our proposal allows an airline to lease an aircraft even when it does not have the financial resources or the will to purchase it at the time. Since a commercial aircraft is usually in service for about 30 years after it is bought, each airline makes sure that there will be sufficient demand not only in the short, but also in the long term. Therefore, some argue that buying a large aircraft can bring more profits but is inevitably associated with high risk. For example, “concerns of fall in a global demand resulting from the knock-off effect of the sub-prime loan crisis; and fierce competition expected in the air transportation business both in Japan and abroad” [15] have been forcing JAL, one of the major airlines in Japan, to downsize its fleet in terms of capacity and purchase only small and medium aircraft. As no purchase is necessary for the execution of “ECO Share”, it will prove to be an excellent solution for stable growth and profit generation in any environment in the time of a global financial crisis which we are witnessing at present.

Low market development costs

Another strength of the proposal is the fact that we are dealing with an existing market and therefore less development and advertising costs will be needed. Merging flights is done only on four major domestic routes which already have a significant number of passengers who are familiar with the booking system, services and benefits available to them by the airline. Our proposal does not require any drastic changes, which makes it easy to implement.

Common Strengths

Less fuel burn per passenger

Merging schedules and shared use of aircraft will result in less fuel burn per passenger. The reason for this is twofold: the objective of the “ECO Share” project is to maximize the load factor thus increase the flight efficiency and additionally, our scenarios of merging flights include the usage of bigger aircraft such as A380. As a rule, the bigger the aircraft is, the smaller the fuel burn and cost per person get. Therefore, the combined effect of maximized load factor and the usage of large aircraft will lead to a substantial decrease of the total fuel burn and thus CO_2 emissions needed to transport all passengers. Details about the optimization and numerical results for different cases are presented in the next chapter.

Timing

Another pro of our proposal is its timing. There is no doubt that eco awareness is at its top now. Even though a few years ago most people knew that Amazon rain forest was threatened and ice polar caps had been getting thinner and thinner, very few concrete measures were taken to actually deal with the problem. Luckily, this is not the case now. In Japan, companies from all fields have been promoting projects to help the environment. For instance, the famous mobile phone company AU announced to its customers that for every kilometer they run, the company will set aside 1 yen to plant a tree [29]. Yet another example is an air conditioning manufacturer DAIKIN who offered to increase the green on the planet on behalf of its customers who use the air conditioning system wisely and do not waste energy [30]. These projects are clearly communicated to the public and offer everyone to become of a part of them. They are concrete, personal and attractive. It is projects like these that have drawn the people's attention to the environmental issues and have started to make everyone feel they can make a change. Because of the perfect timing, there will be no need to waste financial resources to build up the eco conscience of the customers because it is already present. Through clear promotion and straightforward explanations supported by hard numbers we can reach people regardless of their occupation, background and interests.

Strengths from the joint venture's perspective

The eco fleet will require minimal changes of the aircraft upon a new lease. At present, every time an aircraft is leased, the full interior and exterior are renewed in order to switch the image from one airline to another. This is both time and cost consuming (on average, 3 million USD) [31]. By introducing a common and highly recognizable interior and exterior with just a few features explicitly showing the airline to which an aircraft belongs, we found a way to reduce these repaint and reform costs. Some might argue that all airlines would rather fly an aircraft bearing a visible logo, but we do not believe that is the case. Take for example the ANA Pokemon jet and the JAL Mickey jet [32], [33]. They enjoy a lot of popularity among all generations in Japan and contribute to the image of the airline. We are convinced that the situation will be similar with the eco jets we plan to introduce to the market.

Strengths from the passenger's perspective

Eco conscience

There are also numerous strengths from passengers' perspective. First of all, the reduced fuel burn can result in cheaper tickets and undoubtedly the price of the ticket is a main criterion for most passengers. Furthermore, by flying on an eco jet each and every passenger will be aware that they are eco, i.e. they will feel good about themselves because they are doing something for the future of the planet and their children. In order to further stress this point, we plan to have environment-related messages on the inflight video which can show the passengers just how unique and fragile the Earth is and what we can do to preserve it. We will also have special interior and exterior designs to remind the people on board that they are on a green "ECO Share" flight.

Minimal passenger inconvenience

Our proposal allows for merging of flight without any long waiting times, because the schedule adjustments, i.e. the optimization of the schedule considers the passengers' side as well. For this strength to be used, we focused on busy routes only where minimum inconvenience for the passenger will be caused - if any at all.

Strengths from Airbus' perspective

The main strength of the project from Airbus' point of view is the promotion of new aircraft. The financial crisis and uncertainties about the future have made a lot of airlines unwilling to take risks with a new aircraft because they feel unsure about its qualities and consider the cost versus return factor. We believe that the leasing model we suggest will encourage the companies to include new aircraft in their fleet as airlines can get accustomed to these new aircraft types through the "ECO Share" program with minimum risk and efforts.

WEAKNESSES

Having looked at the main strengths of our project, we need to take a look into the weaknesses and what we should do to stop them.

Weaknesses from the airline's perspective

"Resting" aircraft

The major issue can be that of resting aircraft, i.e. aircraft not in use. Our current optimization does not take into account any logistics. A way to deal with the problem will be to implement these constraints too. However, due to the limited time allowed within the Fly Your Ideas project, we cannot bring our numerical simulations to that level. In fact, the issue might turn out to be relatively easy to solve. On the busy routes we consider, more people tend to travel in one of the directions in the morning and return in the evening. This is related to the business trips which constitute a mayor part of the Japanese domestic air travel demand. Therefore, even though there is a time gap of a few hours, the aircraft are at the right places in most cases. Further research needs to be done to optimize the schedules with logistic constraints to obtain more realistic estimations of reachable fuel burn and emission savings though.

Profits and responsibilities distribution

A con of our proposal can be difficulties in distribution of the profits and responsibilities, both during routine operations and in the case of an incident or accident. As with every joint venture, distribution issues can be solved in the initial contract. We referred to numerous joint venture projects and our research showed that making the initial contract usually takes up to a year [31]. Even though this time might seem wasted, it is crucial that the distribution is made clear and that is why we believe this contract is the key to cope with the possible weakness.

Crew training

Not everything can be solved on paper, though. Issues, might arise with the introduction of a new aircraft type which is not present in the current fleet of an airline. The airline will have to provide training for the crew. In the long run, these training costs can pay off, as will be further discussed in the opportunities section.

Reduced competition

Our proposal includes the collaboration of at least two major airlines which fly on the same route. Unlike in the existing alliances, where rarely two partners operate aircraft on the same route, for our project to work successfully, we need obvious competitors to work hand-in-hand. This might be misinterpreted a monopoly, but in fact it is reduced competition at most. Even though the airlines are in a joint venture, each of them will still try to operate their own aircraft, which will keep the competition at a considerable level.

Weaknesses from the joint venture's perspective

Another weakness of the proposal is thought to be the leasing system implementation cost. However, this cost will pay off in the long run so all we need to do is consider this carefully in the initial contract stating the responsibilities and profit distribution among the stakeholders.

OPPORTUNITIES

So far we considered the internal factors which can determine the success or the failure of the project. Next we look into the external factors and take them into account to analyse our “ECO Share” proposal.

Opportunities for Airbus

Reduced R&D costs

Having a joint venture as proposed will be very helpful when a new aircraft is being designed. Unlike in the past, the current aircraft market is very customer oriented, i.e. aircraft manufacturers first do extensive research and then they plan the aircraft which is to be produced. Close collaboration with the airlines will result in a deeper understanding of the market and be an advantage for Airbus. The market demand observed in the joint venture will tell Airbus exactly what kind of aircraft are needed and what should be done to satisfy the requirements of the airlines and passengers.

Increased share in Japan

Furthermore, through a joint venture like this Airbus will be able to get an larger market share in Japan and can explore new markets. Few people trust goods presented in TV shopping programs because they would like to see, touch and feel the product before they buy it. The same can be said about airlines -- they want to experience the aircraft and its characteristics before they purchase it. Therefore, a joint venture and a leasing system like “ECO Share” will work both ways and create a win-win situation for the two major parties: airlines will get a better understanding of the aircraft and they might decide to purchase it after the lease term and Airbus can expand their activities in Japan. It is important to note that the conditions of a purchase should be stated in the initial contract.

Opportunities for Airbus and the airlines

Expansion in other areas

Moreover, we think that the same concept can be applied to areas other than Japan. In order to obtain a view as realistic as possible, we concentrated our efforts on the domestic Japanese market, because this is what we know best. However, we think that a similar scheme can work successfully in Europe and the U.S. as there are many crowded routes in these segments as well. To exploit this opportunity, however, further research is necessary.

THREATS

The last aspect of the SWOT analysis consists of the threats and how we can defend against them.

Threats on joint venture’s side

Lack of cooperation

Needless to say, the main threat is the lack of acceptance from the airlines. Being in a joint venture with your main competitor is something that might be hard to swallow. To conquer this threat, we will show concrete figures to the airlines. We will present the decrease in fuel burn, resulting carbon dioxide emission abatement (important when CO_2 taxes are introduced) and passenger waiting time. We will link these figures to financial resources. It is often said that a picture is worth a thousand words. In our case, a figure is worth a thousand words.

Threats on airline's side

Reduced demand

Changes in the market demand can reduce the flow of passengers and thus the demand for aircraft. However, we believe that the odds for this to happen in Japan are relatively small. For example, 9/11 resulted in a plunge of the number of air passengers in the U.S. and Europe, but the decrease in Asia, especially in Japan, although present, was not as significant as in other countries [34]. To give the airlines more certainty in the always changing market environment, we suggest a clause in the initial lease contract.

Other technological advances

The last threat worth mentioning is posed by other new technologies. In Japan, and possibly also in Europe, high-speed trains are a serious competitor to the airplanes because of the proximity of the stations to the cities. Most airports are far from downtown and passengers need a lot of time door-to-door even when the actual flight just takes an hour. Currently, the equilibrium between train and airplane for people traveling from Tokyo is at Okayama, a city about 600 km away (for reference, Osaka is about 500 km from Tokyo) [34]. Besides, a new train Maglev has been under development which will speed up the travel up by a factor two [35]. However, the development and operation costs have proven to be higher than originally expected and according to forecasts of the economists it will take at least 20 years after the launch of the Maglev train until profit is made. Therefore, even though the train technologies are impressive and do have their share in the domestic transportation market, it is safe to say that airplanes will still be in demand for the foreseeable future.

Table 7. SWOT Analysis

SWOT Analysis of “Eco-Share” Idea

Legend: AIRBUS’ perspective | Passenger’s perspective
Airline’s perspective | Joint venture’s perspective
Common (AIRBUS + Airlines + Joint venture)

	HELPFUL	HARMFUL
INTERNAL	**Strengths** • “WHAT you need, WHEN you need it!” • Minimal financial risk (no purchase required) • Existing market - low development costs • “Eco” - less fuel burn/less CO_2 emission per passenger • “Eco” awareness is very high at the moment • Promotion of new aircraft types in Japan • Reduction of cost per passenger → Possibility of cheaper tickets • “Eco” conscience (“Eco” passengers) • No increase in waiting times • Low costs to change the interior and exterior after the end of the lease term because of almost unified interior/exterior	**Weaknesses** • Possibility of temporary flight frequency reduction of aircraft (“resting” aircraft) • Unclear profit and responsibilities distribution among the airlines • Reduced competition • Crew training for new aircraft type • Leasing system implementation costs
EXTERNAL	**Opportunities** • Implementation of the same scheme in countries other than Japan • Experience with new aircraft types prior to its purchase • Emission trading (financial incentives) • Reduced R&D costs for new aircraft design due to close collaboration with the airlines • Increased market share in Japan	**Threats** • Lack of acceptance from the airlines • Changes in market demand • New technologies on the Tokyo – Osaka route (high speed Maglev (magnetic levitation) train)

APPENDIX C

C.1 Program Code (Data Acquisition)

GetBookingData program (folder)

C.2 Program Code (Optimization)

Optimization program (folder)

C.3 Data Used In the Optimization (excel sheet)

Load factor (version 2).xls

C.4 Fuel Burn Data (excel sheet)

FuelBurnData.xls

C.5 Airline's Current Fleet (excel sheet)

JAL Group and ANA fleet.xls

(MATLAB .m script files and Microsoft Excel files)

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APPENDIX D

D.1 Team “Forest Tokyo”

Airbus – Fly Your Ideas Challenge 2009 - Team “Forest Tokyo” Members

Team Members (in alphabetical order)

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