SIMULATION OF PASSENGER DEMAND FOR FUTURE AIR TRANSPORT CONCEPTS WITH CHANGED BLOCK TIMES

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Abstract

This paper describes the effect of increased block times on passenger demand and airline yields for the biggest three long-haul markets between Asia, North America and Europe. For this purpose, block times were increased between 0% to 20% and resulting loadfactors and yields for each region separately discussed. Furthermore, increased block times were assigned to developed future air transport concepts with reduced environmental impact to derive effects on passenger demand and yields.
The simulation results bases on a modelling approach of passenger´s individual booking behaviour based on utility maximisation theory. Flight alternatives with their different itineraries are modelled inside the simulation based on ticket, flight schedule and operating airline attributes. It could be shown that with small changes in operation (e.g. cruise speed or design range), negative effects could not be observed. But with a significant reduction in speed and range, loadfactors and yields are significantly decreasing depending on individual route.

1. Demand simulations for future air transport concept assessment

Global air traffic is crucial to mobility, communications and cultural understanding of the mankind, faces today, however great challenges with regard to ecology and economy.
For the future, these challenges will be intensified by ecology and society. The Advisory Council for aeronautics research in Europe (ACARE) developed 2001 in their Strategic Research Agenda (SRA-1) ecological and economic objectives for the year 2020. The objectives set in the challenges are quality and affordability, the environment, safety, air transport system efficiency and security. In the area of environment ACARE targets a reduction in carbon dioxide emissions of 50%, the external noise of 50% and the reduction in NOx emissions by 80% compared to world fleet in the year 2000. Despite these demands, reduced costs for transport and increased competition should be achieved as well. To achieve these ACARE goals studies propose among other things multi-stage operations for long range aircraft [2]. With a reduction of design range from 15,000 to 5,000km with unchanged payload, a 49% reduction in fuel consumption for multi-stage operations was calculated [2]. Egelhofer [3] calculated in a study a significant reduction in overall impact on the global climate, if future aircraft are designed with a reduced design range, lower cruise altitude combined with a lower cruise speed. A mission fuel reduction between 5% and almost 13% for a 3.000nm-mission- depending on the configuration- was calculated
While a reduction of cruise speed would affect all passengers and routes, the influence of a reduction in design range has to be considered differently. These new approaches trying to fulfil the ACARE goals strongly influence today´s operations inside the aviation system. For new aircraft concepts with these changed operational conditions, an economic viability for airlines and aircraft manufacturers has to be ensured. Economic viability has to be maintained from the beginning of an aircraft program, in order to be realized. In a simplified approach economic viability can be assessed for a new aircraft concept in terms of direct

operating costs and expected yields. While several multiple operating cost estimation models exist [4], there are no equivalent models to calculate the demand and the airline yields. Thus, future aircraft concepts with modified operational conditions result in a high uncertainty of the expected demand and yields.

Passenger demand and airline yields can be explained as aggregated results from passenger´s individual booking or choice behaviour out of flight alternatives with different attributes. The individual booking decision from each passenger between discrete different flight alternatives can be modelled with the help of discrete choice models.

Discrete choice models in the field of transport were applied since 1962 with trade-offs between travel time and travel costs to assess alternative transportation projects. A detailed description of the historical background can be found in [12] and [13]. Summarizing, it can be said that discrete choice models for transportation application are fully accepted by scientists [13], [14] and [15].

The discrete choice theory states that -if individuals are faced with a choice problem - individuals are choosing an alternative out of a choice set with the highest personal utility coming from alternative´s attributes. This is also called utility maximisation principle and follows rational choice theory. Transferring this theory into passenger itinerary choice problem, following definitions should be made. An individual is here an individual passenger with his individual characteristics. A passenger is evaluating different flight options with different itineraries; these itineraries can be called alternatives. All alternatives which are considered in his choice, is passenger´s individual choice set. A flight alternative or itinerary can be described by different attributes like departure time, number of stops or operating airline. The utility from an alternative, precisely from its attributes can be calculated based on utility or costs. The alternative with the lowest total costs out of the choice set is chosen, or -in this context- a flight alternative is booked. It should be mentioned that a detailed description of the entire theory and modelling techniques can be found in [12] and [13].

2. Passenger demand simulation *PARIS*

In the following chapters, the structure of the passenger demand simulation model *PARIS* will be described briefly. A detailed description of the simulation model can be found in [16,40]. The overall simulation can be divided into four following steps:

1. Definition of the decision maker, here the individual passenger
2. Definition of possible flight options or also called itineraries
3. Evaluation of all possible flight itineraries
4. Assignment of an individual passenger on a specific itinerary

2.1. The decision maker - Modelling passenger characteristics

To simulate passenger booking behaviour or precisely itinerary choice, passenger characteristics have been identified which influence the booking behaviour. These characteristics can be summarized in geographical, socio-demographic and behavioural criteria, which lead to a passenger segmentation by these criteria.

2.1.1. Geographical passenger segmentation

Inside the simulation, the investigated regions/markets have to be determined. The world aviation market –inside the simulation- is divided into 17 different regions according to the definition of OAG (Official Airline Guide).

2.1.2. Socio-demographic passenger segmentation

Socio-demographic segmentation criteria includes beside demographic factors like age, gender, family status or household size also socio-economic criteria like occupation/travel purpose or income. Inside *PARIS*, passengers are modelled by their travel purpose, income, occupation, age, gender, maximum willingness-to-pay (WTP)

2.1.3. Behavioural passenger segmentation

Behavioural passenger segmentation criteria are inside PARIS, length of stay, departure day, booking day, number of undertaken flights per year, the membership and status of frequent flyer programs, preferred cabin class and travel policy for business travellers.

2.2. The choice set - Modelling flight alternatives

After passenger characteristics have been setup and determined, this chapter describes a technique how to derive flight alternatives with their attributes as flight options/itineraries for the virtual passenger. One the one side, set of attributes of the flight alternatives are directly linked to the flight schedule (e.g. departure time, arrival time, properties of stops etc.). On the other side, the algorithm should determine possible air fares for a specific routing.

2.2.1. Path finding algorithm

The aim of the path finding algorithm is the definition of “possible” as well as realistic flight options or flight alternatives from a database. The used database was obtained from [17]. Unfortunately, OAG consists only of single direct flights; hence the algorithm should combine these single flights in a framework of heuristics to realistic itineraries. A detailed description of used heuristics inside the path finding algorithm can be found in [16,40]. The used heuristics showed that, the path finding algorithm selects possible routings in a very efficient and fast way. Validation showed that nearly 86% of all real routings were found by the algorithm.

2.2.2. Modelling of air fares

After the determination of all possible routes/itineraries between an origin and destination, air fares have to be determined for these routes. To derive mathematical functions for air fares, air fares have been queried from an internet-based travel agency and have been analysed later on. [20] could observe a dependency between air fares and OD-distance as well as OD-region. Hence, air fares are modelled inside the simulation based on distance and OD-region (North America-NA1, Western Europe-EU1 and North-west Asia-AS4). To reflect reality as much as possible, 8 different air fare functions were developed (4 functions representing four booking classes inside the Economy Class, 2 for Business and 2 for First Class air fares). The number of seats per fare class was obtained from [20] and set being constant for a simulation run.

2.3. The evaluation process – Modelling cost functions of flight alternatives

The evaluation of flight alternatives by the decision maker –here a passenger- can be made on an utility-based or cost-based approach. The latter one is used inside the simulation tool. All flight alternatives are assessed by cost functions from flight ticket, flight schedule and operating airline. With the definition of the main three groups of costs for flight alternative´s attributes, on which the passenger is choosing the one with lowest generalised cost, the following chapters deal with the derivation and definition of cost functions.

2.3.1. Cost functions of flight schedules

The first group of costs dealing with attributes of the flight schedule and includes costs for departure time, arrival time, properties of stops and total travel time.

Departure time

The influence of departure time onto passenger´s booking behaviour has been extensively investigated by various studies. Results can be found by [21],[22],[23],[24],[25],[26]. With the cost functions and ideal departure time distributions for private and business traveller types according to reference [26], costs of departure times are determined for the simulation.

Arrival time

The approach to model costs inside the simulation for arrival times is similar to departure times. Values and distributions are taken from [26] directly. It has to be mentioned that for arrival times, costs functions were only calculated by [26]. No other studies were found dealing with costs of arrival times.

Stops

There are quite a few studies [28],[21],[29],[30] and [27] using logit models to derive cost functions for stops, but these values are mainly constant, not correlating with different passenger characteristics or taking different stop characteristic, into account. More important studies with a detailed differentiation between passengers and stop properties can be found in [31], [32], [33], [30], [23] and [26]. With these studies, cost functions depending on passenger characteristics (e.g. private travellers, non-reimbursed business traveller or business travellers) properties of stops (e.g. single/double connect and interline connect) and OD-distance were derived.

Total travel time

Besides departure and arrival time, also total travel time is taken into account by passenger booking choice. In a simplified way, a reduction of travel time by a time unit leads to an increase of willingness to pay (WTP). This WTP is commonly used by expressions like value of time (VOT) or value of travel time savings (VTTS). Studies with VOT values can be found in [34], [35], [26], [30], [36], [28] and [29]. [32], [26], [37], [23] and [30] calculated values for travel time savings depending on travel purpose. In these studies, values between \$9.96/h and \$23.81/h for private travellers and \$25.76 and \$86.67 for business traveller can be obtained. Mean values from nine studies with a standard deviation of 0.3 [31] are used inside the PARIS simulation. VOT for private traveller were set to €15/h and 35€/h for business travellers.

2.3.2. Cost functions of airlines

In passenger´s view, airlines are assessed by their product (onboard and on ground) and their offered service [38]. To determine these manifold properties into cost functions for the simulation, a combination of two methods were used. [31] and [32] calculated costs for favourite and unfavoured airlines in their models. Based on results from [31], cost functions for a favourite airline depending on OD distance were implemented inside the simulation. In the next step, a favourite airline has to be determined for each passenger and OD. For the determination of a favourite airline, an approach from [39] was used and adapted accordingly. A detailed description can be found in [16,40].

2.3.2. Cost functions of air tickets

Costs for an air ticket are modelled inside the simulation resulting from the air fare (disutility) and possible costs (utility or negative costs) from frequent flyer programs.

2.4. The choice – Modelling passenger booking behaviour

With the definition of costs based on departure time, arrival time, properties of stops, total travel time, favoured airline ,ticket fare and FFP as well as depending on traveller type, income, travel frequency, age and gender, total costs or generalized costs of all possible flight alternatives inside the individual choice set can be calculated. Based on these generalized costs the alternative with lowest total cost is chosen or in this case flights are booked

2.5. Process of passenger demand simulation

For the initialization, simulated regions according to OAG have to be determined firstly. One or several regions up to the selection of all regions which covers worldwide air traffic can be done. However, the simulation of the whole air traffic requires big computing capacities. This founds itself from the big number in passengers who must be simulated for one week. In the case of the USA more than six million passengers must be initialized for one week. A simulation of a longer period would raise the number accordingly. By the definition of the region, number of simulated passengers results for every OD as well as the percentage of the business trips. With conditioned likelihood functions and generated random numbers for every single passenger, geographical, social and demographic as well as behavioural properties are assigned. If the required properties have been assigned to all passengers, the initialization of the passengers is concluded. For the start of the simulation the initialized passengers are sorted according to the advance booking period. The passengers with the earliest booking request are taken into consideration in the simulation as the first. Now based on the information of the origin, destination airport, departure day and length of stay as well as the availability of seats on single flights and cabin classes, the possible flight alternatives are calculated by the path finding algorithm. Afterwards the assessment of the flight options or alternatives is done on the basis of cost functions. The generalized costs of a flight option are calculated from the sum of the individual costs of the flight schedule, the airline and the flight ticket and contain therefore single cost elements like connections, departure time, favoured airline or also of the ticket price. The choice/booking of a flight alternative occurs on the basis of the lowest generalized costs. The booked passenger is assigned afterwards to the flights and availability of seats per class is updated. Then the same process with the next passenger occurs, until all passengers have been assigned. A more detailed description of the *PARIS* tool can be obtained from [16,40]

3. Passenger demand in dependency on changed block times

Egelhofer [3] developed five different conventional aircraft configurations with a reduced climate impact with a variation of design range, cruise speed and cruising altitude and compared the results with a baseline aircraft configuration similar to an Airbus A330-200. The developed configurations have reduced fuel consumptions up to 12.7% compared to the baseline configuration on a mission 3.000nm. The reduction of climatic impact was calculated between 4% and almost 34% on the basis of the SGTP$_{100}$ (Sustained global temperature change Potential for a time horizon of 100 years) [3]. A summary of design parameters of the five investigated configurations including the baseline configuration shows the following table.

Parameter	**Unit**	**Baseline**	**Green 1**	**Green 2**	**Green 3**	**Green 4**	**Ultra-green**
Design range	**[nm]**	**6.463**	**6.463**	**6.463**	**5.000**	**5.000**	**4.000**
Cruise speed	**[-]**	**0,82**	**0,81**	**0,78**	**0,78**	**0,80**	**0,76**
Cruising altitude	[-]	350	370	330	330	330	290
Span	[m]	58	62	62	62	66	66
Wing reference area	[m^2]	326	297	294	277	281	267
Aspect ratio	[-]	10,3	12,9	13,1	13,9	15,5	16,3
MTOW	[t]	219	209	211	181	182	168
Fuel consumption	[kg/nm]	10,8	9,8	10,3	9,5	9,5	9,7
Δ fuel consumption	**[%]**	-	**-10,0**	**-5,3**	**-12,5**	**-12,7**	**-11,0**
Δ SGTP$_{100}$	**[%]**	-	**-10,7**	**-4,0**	**-8,8**	**-8,9**	**-33,8**

Table 1: Design parameters of future aircraft configurations with a reduced environmental impact [3]

These new aircraft concepts are implemented into the *PARIS* simulation based on different block times. As a first step, simulations have been conducted with increased block times from 0% to +20% of real block times according to OAG. With these theoretical results of passenger demand and changed block times, the different aircraft configurations are assigned to these block times depending on the origin-destination distance.

3.1 Definition of block times for new air transport concepts

The additional block time caused by reduced cruise speed and design range can be assumed to be significantly only during the cruise phase. The change in block time during the climb out and descent phases was neglected and set to 20 minutes for each phase [41]. In addition, taxi-out phase was assumed with 15 minutes, whereas taxi-in phase was assumed with 5 minutes for all five aircraft configurations. The resulting time difference in real block time and the other flight phases was taken as a basis to determine the impact of reduced cruise speed. This approach includes also the effect of wind which is significantly especially on long-haul flights. With the linear correlation of the baseline´s cruise speed, new durations of the cruise flight phase was determined for the other five aircraft configurations. In case that the distance of an OD is greater than the design range, an additional stop for refuelling was considered for the block time determination. The additional time for a refuelling stop was calculated with 20 min for the descent phase, 5 min for taxi-in, a refuelling time, taxi-out time of 15 min and a climb phase of 20 min. The travelled distance for descent and climb was assumed to be 240nm for all configurations. Refuelling time was set as a function of required fuel and constant fuel flow rate of 1.200l/min during refuelling [4]

3.2 Impact of increased block times on routes between Europe and USA

3.2.1 Selection of routes

As the first application, effects of the changed block times for selected transatlantic ODs and airlines on demand and the expected yields will be analyzed. Therefore, ODs were selected with the highest number of transported passengers per week and available direct connections. Beside these two criteria, investigated routes should also differ in origin and destination airports as well as airlines.
Because of the extended area of North America (U.S. and Canada) additionally airports with different geographical location have been selected. One selected airport is situated at the east coast with a great circle distance of 3.771nm, two airports are located at the west coast with a distance of between 4.748nm and 5.108nm and two other airports with an OD-distance between 3.575nm and 4.382nm. In total five different routes have been chosen to assess the demand on transatlantic traffic.

Origin	Destination	Departure time [hh:mm]	Arrival time [hh:mm]	Block time [hh:mm]	OD distance [nm]
London (LHR)	Los Angeles (LAX)	16:25	19:30	11:05	4.748
Los Angeles (LAX)	London (LHR)	21:30	15:50	10:20	4.748
New York City (EWR)	Paris (CDG)	10:15	12:30	8:15	3.171
Paris (CDG)	New York City (EWR)	17:10	6:15	7:05	3.171
Chicago (ORD)	Amsterdam (AMS)	18:00	9:20	8:20	3.575
Amsterdam (AMS)	Chicago (ORD)	11:10	13:20	9:10	3.575
Rom (FCO)	Atlanta (ATL)	10:10	15:10	11:00	4.382
Atlanta (ATL)	Rom (FCO)	17:15	8:55	9:40	4.382
München (MUC)	San Francisco (SFO)	15:50	18:45	11:55	5.108
San Francisco (SFO)	München (MUC)	21:25	17:35	11:10	5.108

Table 2: Flight schedule of selected routes between Europe and North America

With a variation of block time the impact on airline networks was not taken into account. In the case of flights between LHR-LAX and LAX-LHR and an increase of block time by 20%, the local arrival times is later than local departure time. Hence, an operation with these times and only one aircraft cannot be maintained. For a final economical assessment of future air transport concepts with increased block times, the impact on airline´s network has also been taken into account.

3.2.2. Effect of increased block time on passenger demand

Because of the implemented stochastic in the simulation the results of load factors and yields bases on the mean value out of five simulation runs and are shown below.

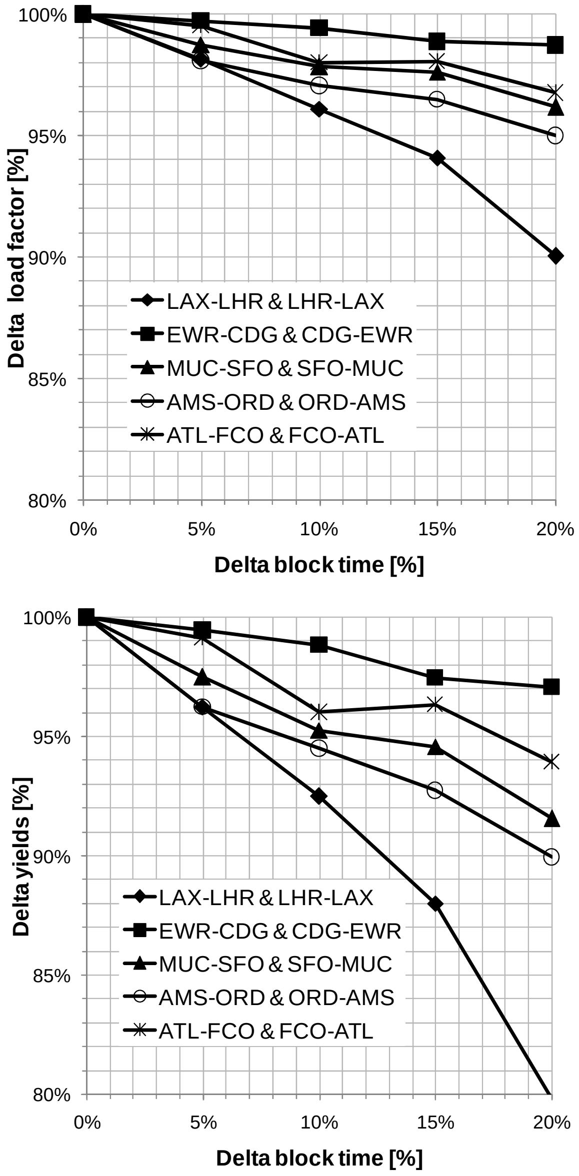


Figure 1: Simulated loadfactors and yields with a variation on block times on selected routes between Europe and North America

The left figure shows the influence of an increase of block time on demand respectively load factor. In general it can be seen that demand and yield curves are non-linear and strongly depending on the OD. With increasing block times, load factors on flights for example between New York City (EWR) and Paris (CDG) are less decreasing than on other routes. On the routes EWR-CDG and CDG-EWR an increase of block time by 20% results in a reduced demand by 1.1%. With a 10% increase of block time, load factors on routes between London (LHR) and Los Angeles (LAX) reach only 96% of the baseline level. With a 20% increase in block time, load factors reach levels of only 90% compared to the baseline block time. The impact of changed block times on the airline yields shows the rights figure for the five selected routes. Here greater differences between the different routes can be identified. While a 20% increase in block time between New York-Paris results in a reduction of load factor by 1.1%, yields will be reduced by 2.9%. The largest decrease in yields can be observed on routes between London-Los Angeles. Here, an increase of block time by 20% would result in a demand of only 79.8% compared to the baseline schedule. The stronger decline in yields than load factors refers to less booking of these flights at higher cabin classes like Business and First Class. For passengers booked on these classes, a shift towards other flights with no increased block time can be observed.

3.2.3. Passenger demand for future air transport operations on transatlantic routes

To be able to assign an according block time depending on selected routes and aircraft configuration, the following figure shows the operational range of three configurations (Green1, Green3 and Ultra-Green) using the great circle calculation with Los Angeles as origin. The operational range of each aircraft configuration as well as the selected routes, changes in block times can be determined according to presented method above (see chapter 3.1). As shown in the figure 3, block times increase for the Green1-configuration and selected routes only by 1.0% to 1.2%. This primarily results in the reduction of the cruise speed of Ma=0.82 to Ma=0.81. All routes between the US and Western Europe can directly be operated with this configuration.

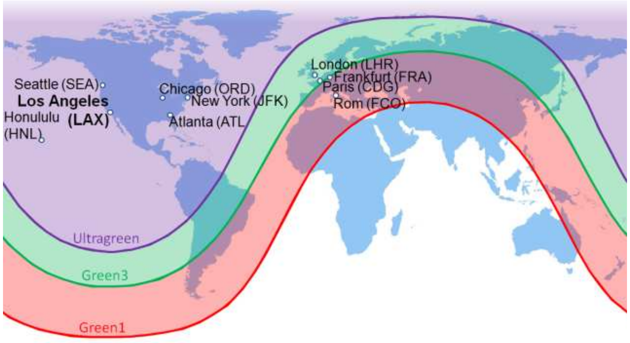


Figure 2: Operational range of Green1, Green3 and Ultragreen configuration with Los Angeles as origin

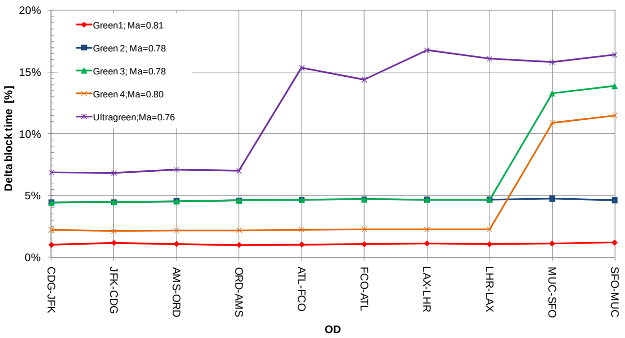


Figure 3: Calculated increase of bock times for five new aircraft configurations on selected routes between Europe and North America

For the Green3- and Green4-configurations, for four out of five selected routes an increase of block time between 4.4% and 4.7% can be observed due to cruise Mach number of 0.78. Direct operations between Munich and San Francisco cannot be maintained with the Green3 and Green4 configuration due to insufficient design range of both configurations. Therefore, the increase in block time of 13.6% bases on an additional stop. With the use of Ultragreen-configuration, direct flights can only be offered in aviation markets like New York-Paris and Amsterdam-Chicago. For all other markets an additional stop for refuelling would be required. Block times for the Ultragreen configuration increases on Atlanta-Rom routes by mean value of 14.9%, on routes between Los Angeles and the London by 16.4% and between Munich and San Francisco by 16%. The following figure shows the range of increased block times and the resulting load factors and yields for all selected routes for the Ultragreen configuration.

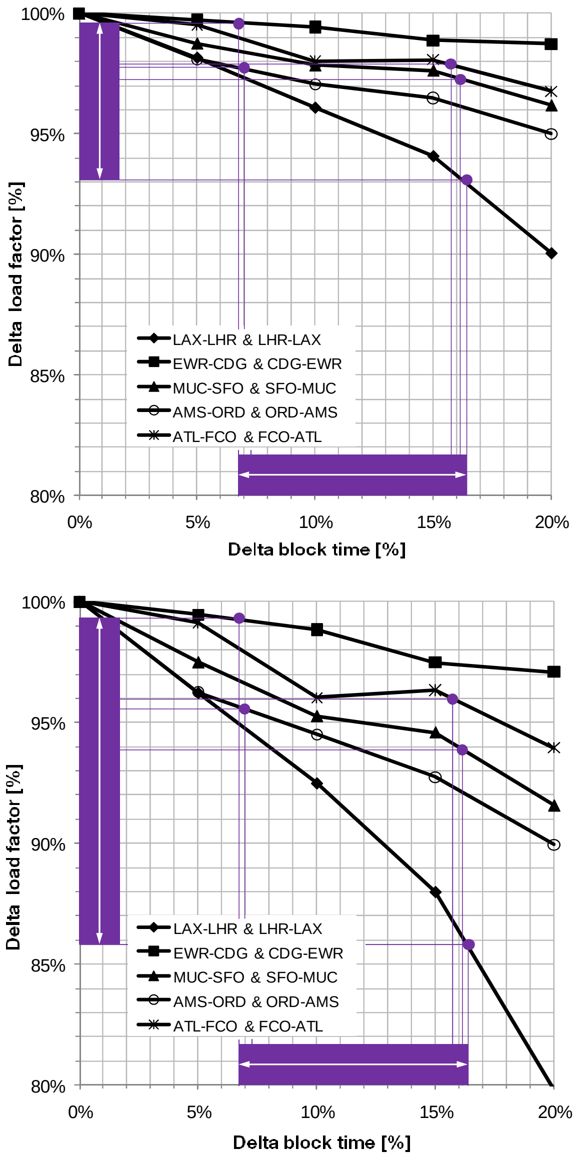


Figure 4: Loadfactors and yields with a variation on block times for the Ultragreen configuration on selected routes between Europe and North America

For the Ultragreen configurations block times are increased between 6.8% and 16.4%, resulting in a load factor decrease of 0.5% to 7%. Airline yields will decrease by 1% to 14% depending on the route. Reductions in load factor and yields are even smaller for Green1 and Green2 configuration. This mainly refers to similar cruise speeds and sufficient design range.

3.3 Impact of increased block times on routes between Europe and Asia

3.3.1 Selection of routes

As a second region the impact of changed block times was calculated for routes between Asia and Europe. In the case of air traffic between Asia and Europe the following routes were chosen.

Origin	Destination	Departure time [hh:mm]	Arrival time [hh:mm]	Block time [hh:mm]	OD distance [nm]
Singapore (SIN)	London (LHR)	9:00	15:30	13:30	5.879
London (LHR)	Singapore (SIN)	18:30	14:15	12:45	5.879
London (LHR)	Mumbai (BOM)	10:50	0:15	8:55	3.888
Mumbai (BOM)	London (LHR)	2:15	7:35	9:50	3.888
Frankfurt (FRA)	Seoul (ICN)	18:00	11:35	10:35	4.631
Seoul (ICN)	Frankfurt (FRA)	14:00	18:25**	11:25**	4.631
London (LHR)	Hong Kong (HKG)	22:30	17:30	11:50	5.209
Hong Kong (HKG)	London (LHR)	23:45	5:35	12:50	5.209
Tokyo (NRT)	Paris (CDG)	11:25	16:40	12:15	5.258
Paris (CDG)	Tokyo (NRT)	20:00	14:30	11:30	5.258

Table 3: Flight schedule of selected routes between Europe and Asia

Similar to the transatlantic routes, routes between Europe and Asia were primarily chosen on the weekly passenger traffic basis. More criteria, besides passenger traffic were also a variation of origin and destination airports as well as different airlines. Hence, departure and arrival times are distrusted throughout the day The selected routes have great circle distances between 3.888nm (LHR-BOM) and 5.879nm (LHR-SIN).

3.3.2. Effect of increased block time on passenger demand

As shown in the following figure, an increase of block time by 20% would result in a decrease of load factors of 2.5% to 9.5% compared to the baseline block time. The slightest decrease in load factor was calculated on the routes between London and Hongkong, whereas a maximum decrease can be observed on routes between London and Singapore. Primary reasons for the different decrease in load factors for the different routes are mainly passenger demand on these routes. An increased block time results in a less strong decrease in load factor if passenger demand is higher. Load factors of the baseline block times reaches more than 90%. In case of the market London-Hongkong, baseline load factors of around 96% were calculated.

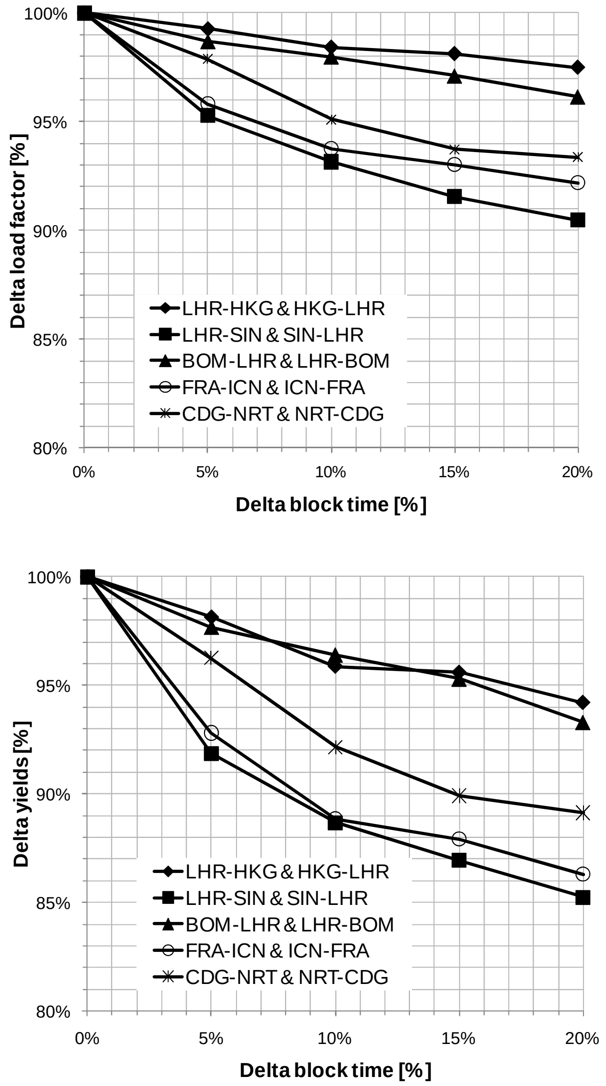


Figure 5: Simulated loadfactors and yields with a variation on block times on selected routes between Europe and Asia

3.3.3. Passenger demand for future air transport operations on transatlantic routes

To determine the expected increase in block times with an operation of the five new aircraft configurations according to Egelhofer (2009), figure 6 shows the operational area of Green1, Green3 and Ultragreen configuration with London as origin. A design range of 6.463nm for the Green1 configuration maintains an entire operation of direct flights between Asia and Western Europe. With a reduction of design range to 4.000nm, direct flights from and to Asia cannot be offered, hence an additional stop for refuelling is required.

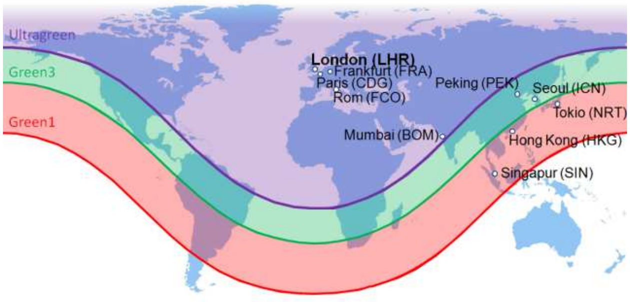


Figure 6: Operational range of Green1, Green3 and Ultragreen configuration with London as origin

This additional time for a refuelling stop can also be obtained from figure 7, where delta block times for the five aircraft configurations and five markets were calculated (see chapter 3.2).

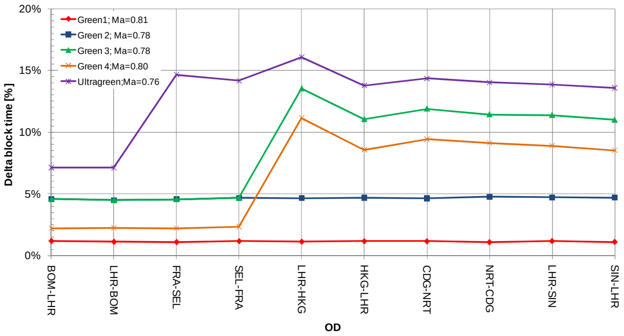


Figure 7: Calculated increase of bock times for five new aircraft configurations on selected routes between Europe and North America

While all selected routes can directly be operated with the Green1 and Green2 configuration, an increase in block time is primarily based on the reduced cruise speed.

With the Green3- and Green4 configurations only routes between Mumbai and London as well as between Frankfurt and Seoul can directly be operated. Hence, for these markets, block times are increased by around 2.2% and 4.5%. With the Ultragreen configuration only one market (LHR-BOM) can directly be served.

For other markets, an additional refuelling stop is required. For the Ultragreen configuration, an average increase in block times -due to the additional stop- of 13.7% (LHR-SIN) and 14.9% (HKG-LHR) was calculated. With an operation of the Ultragreen configuration block times increase between 6.8% and 14.9%, depending on the route. This leads to a decrease in loadfactors of 1.6% and 8.1%. Yields decrease between 2.9% and 12.6%. The stronger decrease of yields compared to loadfactors is caused by decreased demand of higher booking classes. For the Green3-configuration an increase of block time between 4.5% and 12.7% was calculated and results in a loadfactor decrease of 1.1% to 7.6% and a yield decrease of 2.1% to 12,3%.

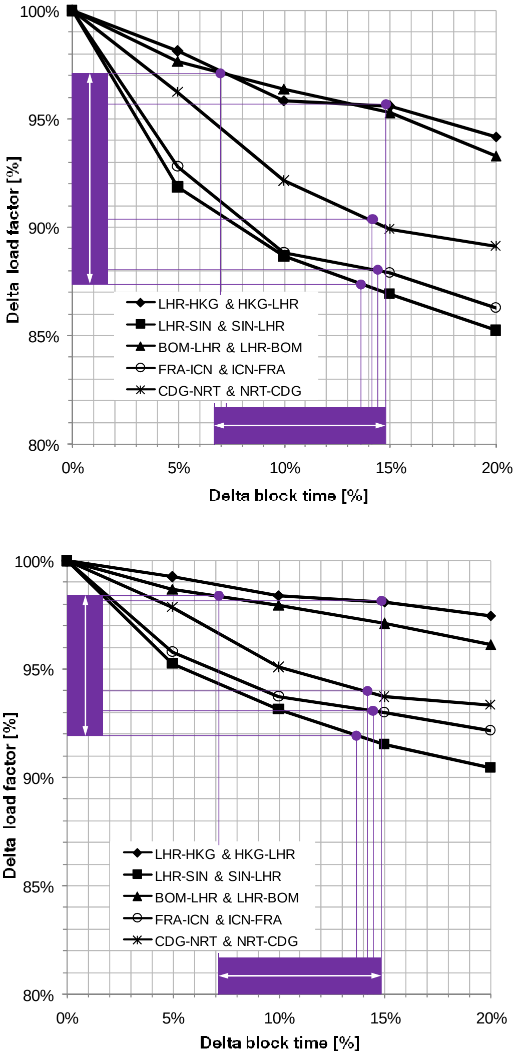


Figure 8: Loadfactors and yields with a variation on block times for the Ultragreen configuration on selected routes between Europe and Asia

3.4 Impact of increased block times on routes between Asia and the USA

3.4.1 Selection of routes

As the last region, five routes between the USA and Asia were selected. Equal to the other two regions, routes with the highest weekly passenger traffic, offered direct flights and a variation in origins, destinations as well as airlines were chosen. The chosen five routes can be obtained from the following table.

Origin	Destination	Departure time [hh:mm]	Arrival time [hh:mm]	Block time [hh:mm]	OD distance [nm]
Honolulu (HNL)	Tokyo (NRT)	11:00	14:00	8:00	3.318
Tokyo (NRT)	Honolulu (HNL)	20:35	8:40	7:05	3.318
Seoul (ICN)	Los Angeles (LAX)	15:00	10:00	11:00	5.209
Los Angeles (LAX)	Seoul (ICN)	12:30	17:20	12:50	5.209
Seattle (SEA)	Tokyo (NRT)	12:45	14:55	10:10	4.144
Tokyo (NRT)	Seattle (SEA)	17:25	10:00	8:35	4.144
Chicago (ORD)	Peking (PEK)	12:00	14:40	13:40	5.717
Peking (PEK)	Chicago (ORD)	16:35	16:25	12:50	5.717
Taipei (TPE)	San Francisco (SFO)	22:40	18:50	11:10	5.621
San Francisco (SFO)	Taipei (TPE)	1:05	5:30	13:25	5.621

Table 4: Flight schedule of selected routes between Asia and North America

The selected routes have a great circle distance between 3.318nm (HNL-NRT) and 5.717nm (PEK-ORD). Not shown in the table, four different airlines are examined, two airlines operating from their hubs in the United States and the other two from different hubs in Asia.

3.4.2. Effect of increased block time on passenger demand

In contrast to the studied routes of the regions Europe-North America and Asia-Europe, the selected routes show smaller changes in the loadfactors with an increase of block time. For an increase of block time by 20%, loadfactors decrease 2.1% and 6.5%. The strongest decrease in load factor is found on the flights between San Francisco and Taipei. On the other hand, the slightest decrease in loadfactors was found on routes between Los Angeles and Seoul calculated. In general, these slight decreases are a result of very high passenger demand on these routes with baseline loadfactors of around 96% for LAX-ICN market or 93% for the SFO-TPE market.

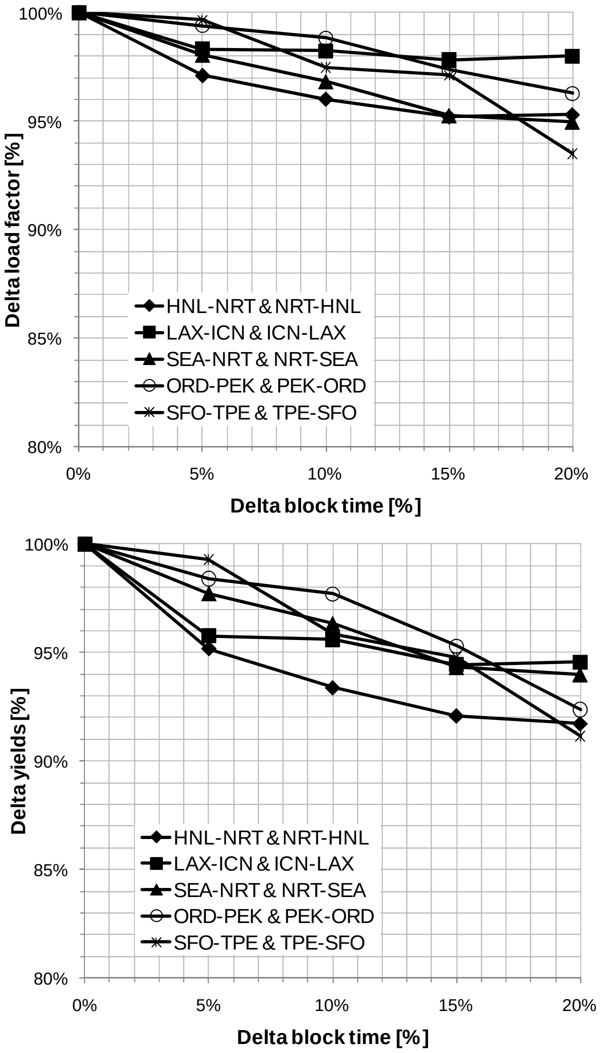


Figure 9: Simulated loadfactors and yields with a variation on block times on selected routes between Asia and North America

Regarding expected airline yields, an increase in block time by 20%, a decrease of 5.4% to 8.6% was calculated. Strongest decrease in yields was calculate on the routes between San Francisco and Taipei, whereas the smallest decrease was determined for the Los Angeles-Seoul market

3.4.3. Passenger demand for future air transport operations on transatlantic routes

Green1and Green2 configurations with a design range of 6.463nm ensure direct flights on all selected routes. For the Green3 configuration with a 5.000nm-design range the operational area is reduced, hence a direct operation from Los Angeles to Seoul or Chicago-Beijing cannot be offered. With this design range areas in Japan can still access directly but the big hub airports, such as Seoul, Hong Kong and Beijing could no longer directly operated. For the Ultragreen configuration with a design range of 4.000nm the operational area is much more constrained. From Los Angeles no international hub in Asia can be reached. In the opposite direction, flights from Tokyo could only fly to Honolulu directly. Because of reduced range no further direct operation to the east coast of the US can be maintained. Hence, two refuelling stops are required to offer flights with the Ultragreen configuration between main hubs in Asia and airports situated along the US east coast.

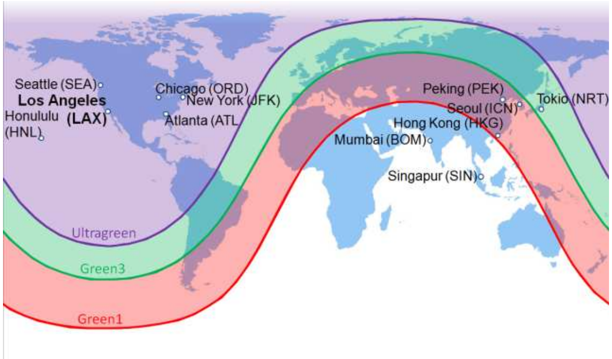


Figure 10: Operational range of Green1, Green3 and Ultragreen configuration with Los Angeles as origin

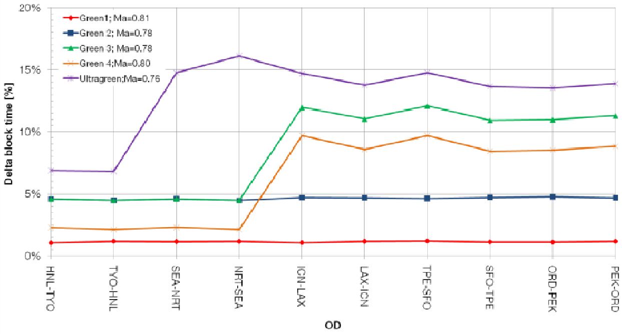


Figure 11: Calculated increase of bock times for five new aircraft configurations on selected routes between Asia and North America

For the Ultragreen configuration, block time increases between 5.8% and 15.4% depending on the route. The slightest change was calculated on routes between Honolulu and Tokyo, as these routes can be operated directly. All other routes require a stopover to refuel. For the Green3 configuration an increase of 10.9% to 12.1% was determined including additional times for refuelling. Without additional refuelling stops, for example on routes between HNL-TYO and NRT-SEA, block times increase only by 4.5% due to the decrease in cruise speed. For the Ultragreen-configuration the additional block time varies in a range of about 5.8% to 15.4%. This variation in block time leads to a decrease in load factor of 1.9% to 4.8%. For airline yields, a decrease of 3.4% to 5.6% was determined. Equal to the other region, a less decrease of loadfactors and yields for the other configurations was calculated. For the Green3 configuration a decrease in load factor of 1.4% to 2.5% and a decrease in yields of 2.1% to 4.8% were calculated.

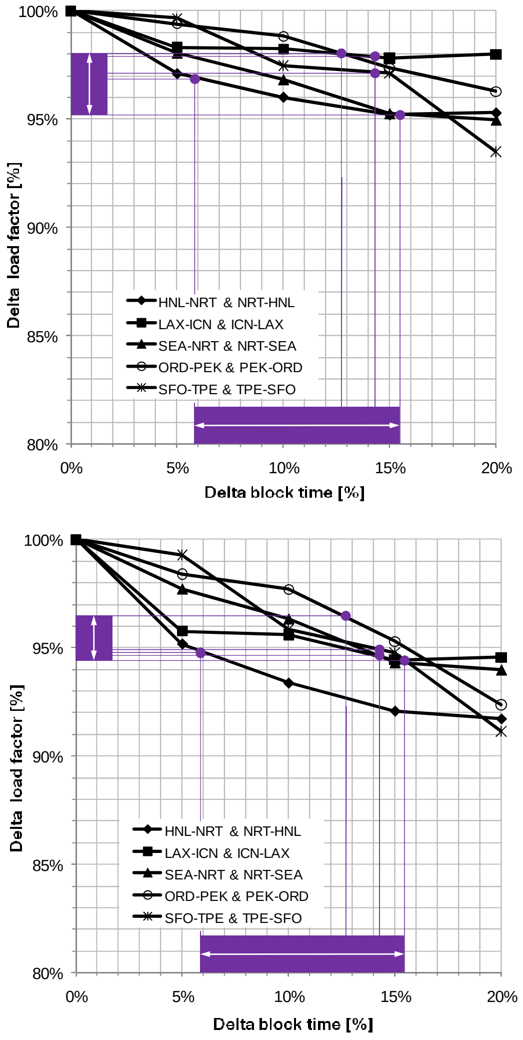


Figure 12: Loadfactors and yields with a variation on block times for the Ultragreen configuration on selected routes between Asia and North America

4. Summary and Conclusion

In the previous chapter, the influences of changed block times on passenger demand and yields for selected routes between Europe, Asia and North America was calculated. For each of these three regions, passenger demands for five different markets have been investigated.

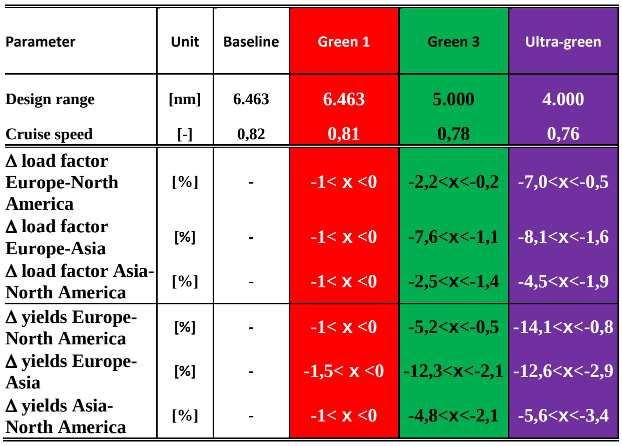
Europe-North America	**+20% block time**	
	Min.	**Max.**
Load factor	-1,1%	-10%
Yields	-2,9%	-21,2%
Europe-Asia	**+20% block time**	
	Min.	**Max.**
Load factor	-2,5%	-9,5%
Yields	-5,8%	-14,8%
Asia-North America	**+20% block time**	
	Min.	**Max.**
Load factor	-2,0%	-6,5%
Yields	-5,4%	-8,6%

Table 5: Summary of calculated loadfactors and yields with an increase of block times by 20%

During the assessment of simulation results, following effects are influencing demand and yields by changing block times:

- With high loadfactors for baseline flights, a slight decrease in loadfactors and yields for higher block times were identified
- An increase in block times result in strong decrease in loadfactors and yields, if other similar flight alternatives are available
- On routes with a high offer of direct flights and lower loadfactors (<90%) for the baseline flight, a very strong decrease in loadfactors and yields was observed
- Passenger demand is shifted from on airline to another, if both are member in the same airline alliance and baseline loadfactors are not a limiting effect.
- A higher decrease in yields compared to loadfactors bases on shifts in the booking behaviour of passengers tended to travel in Business or First Class due to higher time-sensitivity.

Because of the above-mentioned effects as well as other network effects it cannot be ensured that the here presented minimum and maximum changes as absolute values for a region. Further simulations of other routes and other airlines could reduce such uncertainty. However, the first here produced results indicate the likely impact of increasing block times on passenger demand and airline yields. With the linear approach on the relation of baseline cruise speed and cruise speed of the future aircraft configurations, the increase of block times for each route and configuration was determined and shown below.



Parameter	Unit	Baseline	Green 1	Green 3	Ultra-green
Design range	**[nm]**	**6.463**	**6.463**	**5.000**	**4.000**
Cruise speed	**[-]**	**0,82**	**0,81**	**0,78**	**0,76**
Δ load factor Europe-North America	**[%]**	-	**-1< x <0**	**-2,2<x<-0,2**	**-7,0<x<-0,5**
Δ load factor Europe-Asia	**[%]**	-	**-1< x <0**	**-7,6<x<-1,1**	**-8,1<x<-1,6**
Δ load factor Asia-North America	**[%]**	-	**-1< x <0**	**-2,5<x<-1,4**	**-4,5<x<-1,9**
Δ yields Europe-North America	**[%]**	-	**-1< x <0**	**-5,2<x<-0,5**	**-14,1<x<-0,8**
Δ yields Europe-Asia	**[%]**	-	**-1,5< x <0**	**-12,3<x<-2,1**	**-12,6<x<-2,9**
Δ yields Asia-North America	**[%]**	-	**-1< x <0**	**-4,8<x<-2,1**	**-5,6<x<-3,4**

Table 6: Summary of loadfactors, yields and design parameters of future aircraft configurations with a reduced environmental impact [3]

For a final assessment of these future aircraft concepts, the effect of changes in cruise speed onto airline networks -especially aircraft rotation- is essential. With the determination of new schedules for these aircraft configurations, detailed investigations of passenger demand and yields can be conducted. In this paper, it was assumed that additional block time in minutes is equal split and added to the baseline arrival time and subtracted to the baseline departure time. Furthermore, simulations should be carried out with different ticket prices for these new aircraft concepts. With this information, an economical as well as ecological assessment of future aircraft concepts as proposed by [3] can be done.

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