Development and Design of a Level of Service (LOS)–based Decision Support System (DSS) Tool for Disruption Management of Flight Operations Affected by the Airline Prioritisation Policy

Design of the Delaying VIPs Oriented Decision Support System - DEVOTED DSS Tool

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Abstract

In this research a design of a Decision Support System (DSS) tool for use in the Disruption Management of the Airline Operation Control Centre (AOCC) is presented. Based upon an examination made from the airline's operational point of view for a determined airline's prioritization strategy, the aim of the proposed tool is to assist the airline operation controllers in making decisions on whether to delay the departure of out-bound flights in order to wait for arriving-delayed high-valuable passengers from an in-bound flight.

Created is *Delaying VIPs Oriented Decision Support System (DEVOTED DSS) Tool* which comprises of evaluation of decision options and making recommendations, while evaluating accurately the impact of the decisions in operations disruptions on the high-valuable (or premium) passengers of an airline.

An identification of a causality of the high-valuable or premium passengers' importance to the airline and a conceivable influence of this importance on decisions on delays within its operation execution and disruptive situations has been explored. Particularly the influence of delayed connecting high-valuable passengers on making decisions on onward delays in the airlines' striving to deliver a better service quality (SQ) to these passengers, the passenger segmentation per flight and the associated consequences in terms of the Level of Service (LOS) performed by the carrier and the one perceived by the passengers, have been taken into account. The LOS delivered by the air carrier and the level of service quality expected and perceived by the passengers are determined quantitatively by using a created LOS-model which relies on the basic categorization rules of the Kano Model of quality.

An introduced confrontation of the in-bound and out-bound high-fare passengers within connecting flights was investigated as an influencing decision making factor in the airline disruption management. This is shown in a juxtaposition of the high-valuable passengers of the same cabin-class per each flight considered in the disrupted operational situation.

When it is about to make a choice between a monetary benefit and the retention of the reputation of a reliable service provider, an employment of the designed tool can aim at affording rather objective instead the still occurring intuitive decision making in the airline's disruption management.

The consequences of the decision solutions displayed in the designed form are practical in terms of user-friendly utilization of DEVOTED DSS being simple and easy to deal with.

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Content

1 Motivation and Research Purpose

1.1 Introduction

Flight delays cause not only inconvenience(s) and decrease travelers' utility negatively influencing passengers' satisfaction, but also may impact all aspects of the overall airlines' operations. If not managed timely, delays can severely affect the airline performance in terms of revenue, operational efficiency and customer satisfaction. Flight schedules on which optimal planning the considerable time, effort, and financial resources are already invested, during the execution on the day-of-operation often experience deviations and have to be revised and adjusted usually by delaying departures, cancelling flights, re-routing aircraft, re-assigning crews, and re-accommodating passengers (Jafari and Zegordi 2010, p. 203).

Although aircraft-recovery decisions affect passengers, recovering disrupted passengers has not been explicitly considered in most previous aircraft-recovery planning models, but far more as a sub-problem in integrated recovery models. This is due to the fact that unlike the free market of most other businesses and industries, the Air Transport System (ATS) imposes numerous limitations on airlines' strategic planning and daily operations execution, constraining them by the limited capacity of airports and/or Air Traffic Flow Management (ATFM) restrictions and requirements, as well as by the bilateral air transport service agreements between countries (Wu 2010, p. 9).

Since the ability of the airline industry to provide reliable or timely service has been considered as an important and also a critical quality component of the transportation system (Rhoades and Waguespack 2008), the impact of the above mentioned constraints and their outcomes on the airline operations becomes more evident when taking an overlook onto the some reported meaningful findings resulted from the airline performance analyses.

Reported was on approximately 10% of a typical airline's scheduled revenue flights that are affected by irregularities *resulting from operational problems* caused by (to large percentage) severe weather patterns and unexpected aircraft or airport failures (Clarke 1998, p. 67-8). Hence, *within the turnaround phase* they account for roughly 40-50% of total flight delays in Europe including those caused by weather, while following analysis the Eurocontrol data (2004a, 2005) reported in (Wu 2010, p. 64), the other delay-causes are contributed *by airline operations and scheduling*, in which reactionary delays may account for up to 20-30% of these 50-60% delay share.

At the same time remarkable and paradoxical is that, in spite of the fact that for the last fifty years the Airline Industry (AI) has been characterized by continued and rapid growth in demand for its services, it remained only marginally profitable, while most other industries and businesses faced with such high growth of demand for their products would expand in the substantial profits. Overcoming this contradiction between the airline industry rapid growth and its marginal profitability, or simply, matching supply (which management can largely control) and demand for its services (which management can influence, but not control) in an efficient and profitable way, has been seen as the principal issue of airline management and planning (Doganis 2002, p. 4).

In dealing with irregular operations, airline controllers, who have the authority and responsibility to resolve the problems developing from both regular and irregular operations, are required to make real-time-decisions by rescheduling the flights or/and rerouting aircraft and/or crews, having always the primary target: returning as soon as possible to the initial operations schedule (Clarke 1998, p. 69). These actions may again cause flight delays and cancellations which, in turn, affect passenger services and disrupt aircraft maintenance routing.

While so by far the most work on operational recovery problems has been reported on the aircraft resource, passengers are generally given a low priority in the disruption management literature. That is because the aircraft has mostly been seen as the easiest resource due to lowest complexity in rules, whereby crews can be repositioned fairly easy often having always available standby crews (Kohl, Larsen et al. 2004, p.10-11).

Since any change in scheduled flight operations can lead to delays and/or cancellations, it affects also the passengers' itineraries influencing as well their travel motivation (i.e. possibly, the travel purpose may not be any more actual or even necessary and reasonable).

Most of the previous research work on airline disruption management was primarily focused on resolving irregularities for the single resources at a time, which means on applying aircraft-recovery, crew-recovery and integrated recovery plans (Kohl, Larsen et al. 2007, p. 154). Only a few of the research work were focused on passenger recovery plan and passenger-recovery costs, even though considering the passengers only so far as an integrated problem consisting within aircraft-recovery or crew-recovery solutions in operations research.

This doctoral thesis focuses on the air travelling high-fare passengers as one of the most influencing decision-making drivers in the decision making process of the airline disruption management in the all-day operation execution.

1.2 Motivation

While flight delays incur costs to the airlines due to the extra resources which are required during schedule disruptions, impact of delays on the affected passengers in addition to the direct value of the loss of time, have also a profound social, business and personal impact, causing not only disruptions to passenger itineraries, but also business activities and social arrangements, too (Wu 2010, p. 39-40).

Taken as a whole, the AI was defined by Doganis (2002, p. 5) as the worst performing of any of the individual sectors in the air transport chain, emphasizing that these had even in the very bad years of 90's still outperformed the airlines by a big margin. This paradoxical financial performance characteristic of the airline industry, as well as numerous irregularities and disruptions caused by air transport system capacity reduction have been for years attracting attention in the literature from numerous researchers and business experts. Coming from many different fields which range from engineering, logistics and economy till the business administration, they have been trying to deliver various optimization models and solutions for dealing with different operational problems in terms of better scheduling, planning, efficient resources utilization, and recover planning.

Nowadays the AI becomes more and more customer- and market-segmentation oriented with an important change in trend of increased looking at the interests and needs of passengers. This change has been influenced by three major forces: the expansion of the services of low cost carriers (LCCs), the increasing use of the Internet, and the economic stress on all businesses (Taneja 2005, p. 2).

Although customer service coordinators are consulted, passenger disruptions rarely drive operational decision-making, while studies show that arriving on-time is the service characteristic most valued by passengers (Bratu and Barnhart 2006, p. 281). Therefore, providing it to travelers is important in striving for attracting high-value passengers who are sensitive to on-time reliability, as well increasing passenger loyalty and their retention rate.

On the other hand, the majority of the published work on the topic of airline irregularities and recovery plans has been done in conjunction with a sponsoring carrier (Clarke 1998, p. 75), consequently resulting in a strong correlation between existing decision supporting systems and published research articles. Hence, the data are sometimes used from various sources to be combined due to unavailability of some data. Tough they must not always match this might influence the final result.

This research work is focused exactly on the relationship between airlines operations decisions on delays due to delayed connecting-passengers who are high valuable to the airline, considering the accompanying consequences in terms of the quality level of these decisions. These are considered in terms of service quality (SQ) level both performed and perceived.

In the practice, the airline operations controllers have little or no help in estimating the quality of their decisions when they are about to implement one possible solution into the recovery flight plan, when solving irregularities and disruptions. This happens because the quality of a recovery option is difficult to determine and must involve a composition of several conflicting non-quantifiable targets such as minimizing the number of passenger delay minutes, returning to the original plan as quickly as possible, and at the same time minimizing cost of the particular recovery operation (Clausen, Larsen et al. 2005, p. 4).

The main objective of this research work is focused on monitoring of the possible problem solving options which are available at the moment of decision making, displaying not only the possible (i.e. expected) overhead-costs, but also the qualitative consequences of each particular decision. This aims at enabling the controllers to be aware of the level of quality of their decisions and the airline managers to follow/analyze consequences of the decisions made.

1.3 Problem Identification

Airlines schedules typically maximize revenue and optimize allocating the resources. At the same time these schedules are subject to the limited airport slots for departures and/or arrivals and the time constraint imposed by their own planned activities for conducting the aircraft-turnaround operations. And these are, on the other hand, subject to the stochastic forces which result from airlines' schedule planning and optimization (Wu 2010, p. 11).

However, it is not unusual that airlines sometimes have to operate contradictorily to their own benefits and with even losses of revenues, though, if it is for saving the corporate image, for propagated level of service, meaning business reputation, or for marketing and public policy reasons. Costs that arise due to decisions on such kind of airline operations have been identified as the *quality costs* in the work of (Castro and Oliveira 2007, p. 6), suggesting that these decisions could be determined and explained partly by the profile of passengers on the particular flight. Though, these data are not necessarily available for the research and public use remaining so for the researchers and experts in the niche of the airline business observations.

Nevertheless, concerning the disrupted passengers and passenger-recovery problem at all, limited research work can be found in the literature. According to Bratu and Barnhart (2004, p. 6), this is caused by the consideration strategy of the revenue-based management (developed decades before) which finds that as being not vital important nor for airline's further operations or its viability. Therefore, the impact of airline irregular operations on passenger disruptions in terms of missed flight connections, flight cancellations or flight delays have not been statistically recorded. On the other hand, these are needed for researcher and experts when they are about to develop supporting and/or optimization solving models for this disruption problem.

Focusing in this thesis on decisions that controllers make according to the developed carrier's extensive resolution procedure (i.e. airline-policy prioritization) which are generally implemented still manually (Clarke 1998, p. 71), some specific decisions are still based on controllers' experience or more on their somewhat "good or bad feeling" about some actions and events, also popularly called "rule of thumb". Well-known fact in the disruption management literature is that the passengers are generally given a low priority (Kohl, Larsen et al. 2004, p. 10), so it is in the recovering plans from disruptive events, too. For their image and business reputation, however, in some specific situations, the airlines are required to take decisions that are primarily to the benefits of passengers, especially when these relate to the travelers who are of the highest importance or/and monetary value to the airline.

Although there is a need in the praxis of airlines' businesses for having such an integrated tool for enabling generation of costs caused by late connecting high-fare passengers (which *already are in* the airline operations process as an active actor), a creation of a generally accepted optimizing model capable to be applied on any air carrier has various limitations.

Under the most implicating obstructions, access to the problem is barred due to the different airline prioritization policies in dealing with this kind of disruptions. On the other hand, these differences can be caused not only by the structure of a specific demand basis in the particular travel market, but also by the economic management of the disruptions, while remaining not necessarily available for researchers.

Therefore, the main idea in this research is to create a support tool not only for the evaluation of all available decision options but also for recommending the efficient solution, because the decision maker alone can have "a more direct and intuitive sense to make trade-off among different criteria" as proclaimed by Yu and Qi (2004, p.36). Herewith, operation controllers' awareness of all qualitative and quantitative consequences accomplished to each decision solution available for the particular flight (at that time period) can be increased.

It is proposed to design a knowledge-based support decision model which takes into account also the recovery-plan for the passengers who are highly important (monetary valuable) to the airline, as Business and First Class passengers, Frequent Flyer Program and Golden/Platinum-Card members, with the closer view on the relationship between costs, service quality delivered and passengers' satisfaction.

1.4 Research Issues and Objectives

This thesis is aimed at investigating the possible options among all (at that moment) available decision solutions which are related to the passenger recovery plan and particularly to the high-value passengers, while the airline seek to keep or save the reputation of a reliable carrier, offering these passengers the promised level of service quality.

The main objective of this research thesis is to develop and design a knowledge-based Decision Support System (DSS) tool, as computer-based interactive supporting system for operation controllers at the Airline Operations Control Center (AOCC). The focus is on the impact of decisions on delays on the high-valuable passengers involved in disruptive events and deviations in the daily flight operations. This aligns with the claim of Castro and Oliveira

(2007, p. 6) arguing that *it appears to be of the great importance* in some decision making situations *"who" the passengers* (i.e. their flight profile) *in transfer are*.

In this kind of disruptive events, the controllers need to make decisions on whether to wait for arriving delayed high-fare passengers by holding departure flights - if it is possible, or to depart the outbound flights without these passengers, leaving them to be overtaken and re-accommodated by the Passenger Service. To solve this, it can also be employed the airline's passenger-recovery plan and program, which may be internally developed and especially aligned for these passengers.

To consider the overhead costs that arise from decisions on waiting or not waiting for late transfer high-fare passengers is another issue to be addressed to. These costs will be taken only as a proportion of the Total Operational Costs per flight considered. Any further examination in terms of economic questions is not a subject to this research.

The primary objective of this doctoral thesis is to give answers to the following research questions:

1. *By taking into consideration airlines' seeking the prevention of losing passengers' goodwill, in the situation where the level of service quality (SQ) performed is not as high as the promoted one, how (at which extent) the disruptive/irregular events such as missed and delayed connections may affect the airlines' highest valuable passengers?*
2. *What kind of changes can occur in the airlines' prioritization strategies in reference to a possibly better improvement of the airline operations executions avoiding common consequences of irregular/disruptive events?*
3. *Which is the reference point up till an airline attempts to keep the retention, service quality delivered or its reliability?*
4. *Which role does the passenger-structure or passenger-profile play in the affected flight(s) in relation to the quality performed and costs?*
5. *Which role plays in such cases the compensation- and passenger-recovery strategy?*
6. *What choice-options do the decision makers have and how these may affect the high-fare passengers in terms of the LOS both performed and perceived?*

To investigate these issues, this research first develops a LOS-model for both the airline and passengers which is implemented into the proposed decision support tool - DEVOTED DSS, aiming at supporting the airline operation controllers in making this kind of decisions.

1.5 Scientific Hypotheses

For this research purposes, three main and three auxiliary hypotheses have been set.

The main hypotheses are:

H1*: Based on defined setup of objective decision driving criteria implemented in its design, the proposed tool can minimize still commonly occurring intuitive making decisions in the all-day operations of an airline when it is about to make choice between monetary benefit priority and the level of service to be performed (as promoted/promised) to the passengers.*

H2*: By monitoring both playing prioritization-targets, the proposed decision supporting tool aims at affording much more awareness of the decision maker in choosing rather optimal than "spontaneous/intuitive" decisions, increasing also the self-confidence especially of junior/greenhorn and recruits at the airlines' Operation Control Centres.*

H3***:*** *The use of the proposed tool in the making decisions on this kind of disruptions may aim airlines at improving a comprehensive higher level of satisfying requirements of the passengers who are of the highest (monetary) importance to the airlines.*

The auxiliary hypotheses are:

i. *The designed tool can aim at gaining increasing control over appropriate responding to the Service Quality requirements of the high-fare passengers and therewith their confidence and loyalty.*
ii. *Due to the tool-outputs (i.e. decision made/taken) and data being generated and saved, the airline management is enabled to analyze and optimize its planning and scheduling adjusting less optimal decisions i.e. flight connections to match the requirements and a higher satisfactory level of its highest-fare passengers.*
iii. *Aiming at achieving a better handling practice with the passenger-groups of the highest importance to the airline, the use of the proposed tool may contribute to the airlines' affording yielding more of this kind of passengers due to higher satisfaction level achieved.*

1.6 Research Outcomes

The main outcome of this research is a knowledge-based standing-alone decision support tool thus providing a nearer insight into an airline operations niche which was hardly available for research purposes and an overview of the in the praxis mostly applied solutions as well. Hereby in the focus are the associated consequences of this kind of operational decisions in terms of the level of service (LOS) quality delivered to the passengers, overhead costs which can arise within these decisions, as well as the level of the passengers' satisfaction achieved.

The proposed tool also aims at generating decision making data for further analysis of the influencing attributes i.e. costs, critical connections, number and profile of delayed connecting passengers, time and events that cause delays on the particular flights, for the purpose of well-targeted planning and purposefully scheduling. It helps moderating the effect of better decision making process with visualizer of quality and quantity of each operational decision. It is stressed out that the design of the decision support tool is human centered design (HCD)[1] based.

1.7 Contribution to Science and Practice

The main scientific contribution of this research is providing a nearer insight into one for the research grey zone of the airlines' decision on delays when caused by its highest-fare passengers. This is done by a juxtaposition of the passenger-segmentations of both inbound and outbound flight, letting them being evaluated in terms of the revenue-based importance as well as their ranking-importance to the airline in the decision making process. The confrontation of the segmented high-fare passengers per flight and per cabin-class (or ticket purchased) made in this research aims at measuring the decision solutions and satisfactory level of these passengers.

Moreover, their importance and impact on decisions on delays of outbound flights has been explored in order to find out how much this importance can influence the airline's decisions and its level of service quality performance.

Additionally, a LOS model of the service quality for both (high-fare) passengers and the airline, based on the application of an extended approach to the Kano Model of quality, was established for to be then implemented into the designed tool.

This research succeeded not only in stressing the main decision drivers when such disruptive events occur, but also in putting them into the multi- and contradicting-criteria juxtaposition in the solving-algorithm of the proposed tool.

The proposed knowledge-based tool has been created to support decision making process at the Operation Control Center of an airline. As all kinds of this type of supporting systems, also this one assists to controllers in the decision making process supporting them when they

[1] Maguire, M. (2001). "Methods to support human-centred design." Academic Press **55**: 587 - 634

are required to solve the problems with a high degree of uncertainty and those consequences within given (very short) time frame, but not replacing them.

Through the monitoring of the proposed scenario-based solutions, the operation controllers can gain more self-confidence within achieving more efficiency in solving passenger disruptions, even with a better performance.

When employed in trainings and simulation centers, the proposed tool may increase gaining of more controllers' self-confidence (especially novices and recruits at these positions) for gaining more routine in the decision making process.

The airline yield management, but also planning and scheduling department too, may profit on this model approach gaining an overview of the data that can be saved for to be statistically and analytically evaluated for further optimization of the decision making process as well as of the future operations planning and scheduling.

By employing the proposed tool which is created on the human-centred-design basis, while being not overloaded with nor digits and data or calculations, the operation controller will see only the final positions of both defined outputs positioned on one of the three coloured fields having so an easy and simple dealing with.

1.8 Delimitations

In this thesis work only the overhead costs that arise from the decisions on delay or not to delay a flight leg, in reference to the connecting high valuable passengers are considered. The direct and non-direct operational costs are not widely explicitly subject to this thesis.

The differentiation of the values of the passengers to the airline is taken as a subject to the choice between passengers of different classes and status per a particular flight, according to the purchased tickets, as well as the membership in a Frequent Flyer Programs. The terms *level of service delivered*, *passengers' satisfaction and passengers' loyalty* are considered only for the purpose of LOS-model designing related to the construction of the support decision tool, and as such only in the technical context. Their wider social or psychological meanings are not the subject to this research.

Therefore, only the knowledge so far in form of general terms onto the transport industry for the purpose of showing the relationship between air traffic passengers and air carrier services as well some important factors that influence this link is considered. These are, for example, the passengers' expectations and therewith the service quality requirements within the air traffic travelling, as well as the airline's service quality performance attributes.

The proposed tool optimizes neither decision process, nor decision options, but recommends one decision solution which aligns with the airline prioritisation strategy determined.

Herewith, supporting the decision maker (operation controller) but not replacing him/her, the tool also enables the decision maker to take the opposite decision.

1.9 Thesis Outline

This dissertation is organized as follows:

Chapter 1 outlines the research, giving an introduction of the thesis subject and the overview of research questions and purpose of the hypotheses, as well as the contributions to the science and the practice, and delimitations.

Chapter 2 gives a short description of the main terms and conditions in the Airline Industry focusing on the airlines businesses and the relationship between airlines and the passengers in the Air Traffic System.

In *Chapter 3* a state of the art research literature review divided into three subsections is presented. In the *subsection one*, a short overview of the passenger recovery plan as a strategy of an airline to deal with its passengers' disruptions is given. In *subsection two*, literature on the delay-costs, especially on passenger-delay-costs is overviewed. In *the third subsection*, literature overview on the level of service (LOS) quality is presented.

Chapter 4 consists of the introduction and the theoretical background of the level of service (LOS) model design of quality of both delivered/performed by the carrier and perceived by the high-fare passengers involved. This is made in order to be prepared for the implementation into the proposed solving-algorithm of the designed tool later on.

Chapter 5 introduces and presents the decision support tool - *DEVOTED DSS Tool* (Delaying VIPs Oriented Decision Support System), together with its multi-criteria solution algorithm and the appropriate mathematical background.

Chapter 6 consists of testing and presentation of the results showing the functions, aim and the use of the designed tool.

Chapter 7 summarizes the findings of this research and gives some directions for further work in this area.

2 The Airline Industry in the Air Traffic

2.1 Introduction

As a pre-stage to introduction and conceptualization of the suggested tool and its application in the airline operations, in this chapter an overview of the main terms and definitions fundamental for the airline businesses and airline all-day-operations is given.

Beginning with general terms about the airlines and their businesses in the air transport industry, the conditions in which they do operate, execute and control their regular and irregular operations, showing the most influencing factors on flight schedules and disruptive events that may occur, as well as how these irregularities can influence scheduled operations and affect passengers, and finally how do the airlines recover their operations are briefly displayed.

2.2 Airline in the Air Transport System (ATS)

Airline provides air transport services for travelling passengers and freight, supplying that services with their own or leased aircraft, varying from airlines with a single aircraft for carrying mail and cargo to the full service international airlines operating hundreds of aircraft, and they may form partnerships or alliances with other airlines for gaining a reciprocal business benefits.

Widely considered, other than in most other industries, the transportation, and also the air transportation product units, if unsold, cannot be stored and are geographically spread out, where some are in the motion (aircraft) other are located in different parts of the world (like air terminals) (Andersson 1989, p. 6).

However, the Air Transport System (ATS), unlike the free market of most other businesses and industries, imposes numerous constraints on airlines in their strategic planning and daily operations execution, which are especially characterized by the limited capacity of airports and bilateral air transport service agreements between countries. Finally the Airline Industry (AI), as the other industries, is a competitive market run by market forces like demand, supply and pricing (Wu 2010, p. 9).

Figure 2-1 depicts the operational pressures on an airline reliability that an airline faces in its all-day operations. Under the most implicating are: airline's revenue strategy which creates its own reliability challenges; the Air Traffic Control (ATC) within its Air Traffic Flow

Management (ATFM) due to weather and/or congestions constraints that causes flight delays and/or cancellations which are growing at critical airports. Finally, there is also the airline profitability, as the most important target for its business survival strategy which is given through its scheduling policy.

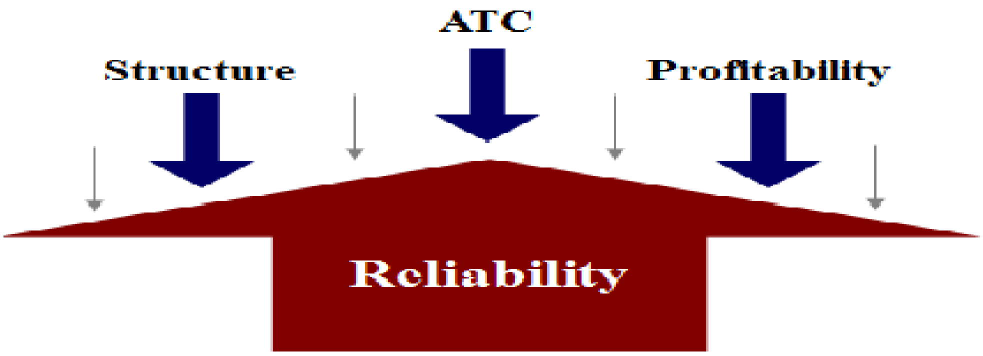


Figure 2-1: Operational pressures on airline reliability
Source: (Narasimhan 2001)

2.2.1 Airline Business and Airline Network

An airline can itself determine the supply of services it offers within any regulatory constraints, which means that it can be a low-cost operator or a high-cost operator. The way it organizes those services, as well as the management of required supplying inputs impacts directly on its costs (Doganis 2002, p. 7).

In general, in the airline industry more airline business models can be identified as follows:

- According to the service *quality* it operates, there are traditional scheduled or full service carrier (FSC), charter carrier, and low-cost carrier (LCC)
- According to the service *quantity* it operates, it can be organized as conventional scheduled airline or charter airline
- According to the *network-size* that an airline operates, the business model can be domestic, regional, international and intercontinental
- According to the *route-network* airlines do offer, the business model can be of
  - ➢ *network carriers* with an extensive international route network, complex hub-and-spoke system of short- and long-haul connections, offering loyalty schemes such as Frequent Flyer Programs (FFPs), often belonging to one of the airline alliances, or

- *point-to-point carriers* serviced by low-cost-carriers (LCC), focused on individual markets enabling direct flights between two airports, concentrated on maximum aircraft utilization and often operating with a single fleet type, keeping short turnaround times at secondary less congested and with lower charges airports.

However, the nowadays evaluation of the airline business model in its basic concept into the market-segmented and especially customer-oriented model has shown that it is not possible for one airline to efficiently serve all market segments with an undifferentiated service product, suggesting the successful airline marketing program and business strategies as optimally designed to serve one defined market-segment (Taneja 2005, p. 73-4). These had led to the evolution of the *dual* business models that integrate benefits of two or more already existing airline business models.

2.2.2 Airline's Image and Business Reputation

There is a variety of ways for creating and establishing of an airline image among its own customers and among the public at large, but very first what it needs is to identify its market position and marketing strategy. It will give the basic concept for developing a different image for low-cost and scheduled carriers (Doganis 2002).

As it is generally admitted in the most other service businesses what is significant for establishing an image and as the key element in image building, applied to the AI too, means the need to ensure that the promised quality level of the service before the flight actually materializes and meets passenger expectations when it takes place (Doganis 2002). This can be achieved through the kind of its advertising, promotions, its logo, the design of its aircraft interiors, as well as the level of service provided by its staff in the air and on the ground.

According to the common in use airlines measure *15 minute-on-time performance*, a flight-leg is considered to be *on-time* if it arrives within or less than 15 minutes after its scheduled arrival-time (Bratu and Barnhart 2004, p. 3), whereby for a flight-leg that arrives later than 15 minutes after its scheduled arrival-time we say that it is *delayed*.

An ***economic consequence*** of delays for the airline is the *delay cost.*

Social consequences of flight delays can be seen as affected reputation of a reliable carrier and the opportunity costs when the service quality delivered to the passengers is low. This is especially the case when an airline can not deliver the service quality which was promoted and proclaimed to the passenger by purchasing the ticket.

2.2.3 The Relationship between Airlines and Passengers

In the Air Transport System (ATS), airlines and passengers have the main interacting role, which can be described as following: *airlines* have to operate according to their published schedules, providing at least the promoted level of service to the air travelers, air traffic control authority and their business partners, while maximizing the profit with the efficient utilization of the available resources, and *passengers* want to depart at possible desired time, to arrive on-time, getting the promised level of service, and all mentioned to the possible favorable fare.

To be able to utilize their two most valuable resources for the scheduling process, that are aircraft and crew, the airlines take into consideration the passengers, as their third main resource segment represented through the seats available to be sold.

2.2.4 Level of Service of an Airline

On the air transport market nowadays, there has been offered a range of service quality possibilities, which can be recognized throughout the class and category of passenger tickets, scheduled, low cost and charter flights, as well as the whole arrangements in the widespread travel-packages which are known as the travel formulation “Flight and Hotel”.

On the other side, the relationship between operational quality and a customer’s choice of an airline may vary across different customer characteristics, and that is because, while different airlines use different operation strategies resulting in different service strengths, customers have different expectations toward differently operated airlines, which again significantly impacts customers’ choice of airline (Cho 2012, p. 24-5).This has been regularly seen in the cases where the customers who have relatively higher income and importance in time, such as business passengers, are more sensitive to quality variables such as nonstop flight frequencies, but less sensitive to fares (Cho 2012, p. 15). Nevertheless, this is also due to the fact that not all customers are exposed to all aspects of the airline’s operations (e.g. customers with bags checked are exposed to the operations related to baggage handling, while the passengers with only carry-on baggage will not experience this part of the airline’s operations).

There have been recognized and defined five key-product-features which affect passengers travel decisions and choice of airline such as *schedule-based, fare, comfort assessment, convenience,* and *image* (Doganis 2002, p. 240). Generally, the most important service product components are schedule-based and fare, because they can be seen and quantified *objectively*, they are explicit and precise, and therefore they can be compared. Assessment of comfort, convenience, and image are, by comparison, *subjective*. As a higher level of airline operational quality an *on-time performance improvement* can be viewed, whereas delays negatively impact customers. Poor on-time performance increases the chance that passengers arrive late at their final destination or miss a connecting flight at the intermediate airport, leading to a decreased probability that a customer will choose a particular airline again (Cho 2012, p. 24-5).

2.2.5 Airline Regular Operations

During regular operating conditions, airlines do operate their flight networks according to the schedule. The operations of an airline are best optimized within the planning and scheduling phase. If nothing would prevent an airline to operate according to these schedules, it would maximize its profits. However, many external events can disrupt the smooth execution of the scheduled operations, indicating why controlling and constantly monitoring of its two principal resources, aircraft and crew, must be one of the most important tasks for obtaining operational efficiency of airline’s service supply (Kohl, Larsen et al. 2007, p.149-150).

Airline operations have been seen as all other service businesses, as an example of just-in-time production (of the available seat mile), which is constrained through time and space across the airline network (Lettovsky 1997), because seats per flight are a perishable inventory item. That means, if not sold for that flight, the seat-revenue is lost forever and the management can not put it into inventory for some other time use (Kimmes 1989).

For this research purposes, besides possible disruptive events the focus will be on delays, which can occur on both arriving and departing flights, with a nearer insight into the delays on departure.

2.2.6 Airline Irregular or Disrupted Operations

In the airline planning phase, flight scheduling and crew assignment are usually made several months in advance. Though, changes may occur at any time to any of resources, making them in this way stochastic and unpredictable, and therefore difficult to prepare for.

Disruptions, such as late connecting passengers, late connecting crew, missing check-in passengers, late inbound cargo/baggage or equipment breakdown occur randomly and are normally seen in daily airline operations (Wu 2010, p. 64).

The airline operational stability and its ability to respond to unexpected events are dependent on variety of influencing factors such as of the management of its business model, as well as of the competences/abilities and experience its controllers. Depending on the disrupting level as well as the potential impact on the (predominantly downstream) network, there are different recovery tactics as a reaction of airline operations controllers on these disruptions, to either (under)taking an action to mitigate their further impacts on the network, or taking no actions and allowing the network to naturally absorb a potential delay propagation (Wu 2010, p. 187). The decision on whether or not to cancel a flight must be actually made by the airline planner who will take into account the overall system situation and the wider effects of the cancellation of that particular flight (leg).

When disruptions occur, airlines' scheduled flight operations have to be revised and adjusted. Airlines have more possibilities available for achieving it. Mostly they are delaying departures, cancelling flights or flight segments/legs, re-routing aircraft, re-assigning crews, and re-accommodating passengers (Jafari and Zegordi 2010, p. 203). However, it is not necessary and/or possible to act on all unexpected events. For example, some of them do not require changes of plans (such as in case of minor delays), because they may cause limited operations deviations and inconvenience to the passengers. Other disruptive events may be quite serious but with no capability or possibility to react on them, or to do anything about.

According to Wu (2010), there are generally two kinds of disruptions, if referring the definition of a threshold of delays set to be one hour. These are:

- Minor disruptions, as events which cause delays till up to 1 hour
- Major disruptions, as events which cause delays that are longer than 1 hour.

Hereby flight cancellations themselves cause two underlying kinds of disrupted flights:

(1) *residual-cancelled flights*, as flights which are cancelled due to aircraft equipment failures;

(2) *tactical-cancelled flights*, as flights which are cancelled in order to manage emerging delayed flight events (Sherry 2012, p. 9).

Therefore, in the striving to maintain integrity of its network, an airline can choose to rebook passengers and shuffle aircraft and/or crew, rather than take an excessive flight and crew delay.

2.2.7 Airline Disruption Management

Disruption Management of an airline is actually its Operations Control Centre (OCC). This is a sole operational group within the Airline Operation Control Centre (AOCC) with the authority and the responsibility to resolve problems that develop during the course of both regular and irregular operations. This is a specialized team of airline's experts for dealing with schedule disturbances and disruptions, actually an on-going-process of monitoring and scheduling the main airline's resources, in the all-day-operations (Kohl, Larsen et al. 2007, p. 152), (Clarke 1998, p. 69). The reason why this process can not be fully automated is principally because that in the key parts of the disruption management process humans must be involved, since they will be responsible for the consequences of the decisions, whereby human-communication and human-judgment play the key role, too.

Identifying the possible actions and evaluating them from the crew, aircraft and passenger perspective, the disruption management process involves the very broad array of potential options and the computational complexity of assessing the impact of each of these options (Kohl, Larsen et al. 2007, p.151-153). Currently at most of airlines the disruption management process can be described, according to Castro, Rocha et al. (2012, p. 1430), in the following five steps:

(1) *Operation monitoring* of all flight sequences to see if anything is not going according to the plan, including crewmembers, passengers (check-in/boarding), cargo and baggage loading

(2) *Taking action*, a quick assessment is performed to check if an action is required

(3) *Generating and evaluating solutions*, where the AOCC will find and evaluate the candidate solutions usually in a sequential manner, having all needed information related to the problem. First solving the aircraft problem, than using this solution they will solve the crew problem, and finally, the impact of these solutions on passengers will be considered.

In this sequence of the disruption management, operations controllers may consider also the main costs involved in resolving the problem, taking into account the following: (a) *crew costs* (with additional work hours, per diem days, hotel and other extra-travel crew costs); (b) *flight costs* (all airport and on-route charges, aircraft maintenance and service costs, fuel costs); (c) *passenger costs* (re-accommodation and compensation costs); and (d) less easily quantifiable *costs for delaying and cancelling a flight*, which most airlines estimate as a just assigned monetary cost value to each minute of delay or using some kind of rule-of-thumb or controllers feeling/experience when evaluating this impact on passengers.

Since the Westminster Report (Cook, Tanner et al. 2004) proposed as Passenger Opportunity Costs to be an average value of EUR 36/delay-minute though this value was calculated and estimated for and by only one carrier (i.e. here at the Austrian Airline), it could be concluded that actually each carrier will have its own value for the opportunity costs depending on its market share and its presence there (i.e. whether having or not any competitor(s))

(4) *Taking decision* where the solution is chosen between possible candidates, and finally,

(5) *Applying decision* where the final decision needs to be applied in the environment meaning that the operational plan shall be accordingly updated (adjusted).

2.2.8 Airline Operations Control Center (AOCC)

Depending upon the size of the airline, the Operation Control Center (OCC) may consist solely of: (a) decision-makers with responsibility for coordinating and controlling aircraft movements, or (b) can be organized either in *consolidation* (duty managers of all the key-supporting functions work at the same desk), or in *cooperation* (with established framework for cooperation between supporting functions), all providing a way of dealing with high complexity in communication, high degree of uncertainty and high volume of information (Kohl, Larsen et al. 2007, p.150-151).

Since this thesis is focused on an examination of particularly these operations and possible options available to the operations controllers. To enable an easier positioning of this thesis study objectives as well as tracking of the decisions made, in the following subsection the kind of supporting roles that could be find at the AOCC will be shortly discussed.

2.2.8.1 The most common Supporting Roles at the AOCC

Generally, the AOCC is large enough to include representatives from various supporting functions such as from pilot and cabin crewing, aircraft engineering, flight dispatch, meteorology, customer and commercial functions (Bruce 2011, p. 4).

Successful operating of an airline depends on coordinated actions of all supporting functions or expert teams in an AOCC. However, airlines like all large businesses, suffer from a “silo” mentality, where each department focuses on its best performance without regard for the overall good of the business (Taneja 2005, p. 72). This was possible to experience by most big European airlines, within the research work at the institute where this thesis has been completed, where the airline operations controllers still pay attention first to the consideration of their main resources availability (i.e. aircraft and crew) and/or limitations, and then or nearby would take care about costs and economical optimizations, with the slogan “if we have no aircraft and/or crew available, there is no flight, and consequently, there is no passengers”.

The most common supporting roles that have been generally involved at the AOCC are: *flight dispatch and following* (performing the flight preparation, following and progress); *aircraft control* (managing the aircraft resource); *crew tracking* (divided into cockpit- and cabin- crew tracking); *aircraft engineering* (responsible for unplanned aircraft service and maintenance); *customer service* (ensuring that the passengers’ inconvenience is taken into consideration in these decisions); and *coordination of ATC* operated by a public authority (Federal Aviation Administration in the US, Eurocontrol in Europe) (Kohl, Larsen et al. 2007, p.151-153).

2.2.8.2 Airline’s Recovering from Irregular and Disrupted Operations

When disruption occurs on the day of the operation, large airlines usually react by solving the problem in a sequential fashion: first, solving the aircraft infeasibilities, then crew infeasibilities, and, if necessary, ground operations. Finally, the impact on passengers must be evaluated for the most applicable recovery plan that intend to be implemented (Kohl, Larsen et al. 2007, p.151). Generally, operations recovery in the airline industry means aircraft-recovery, crew-recovery, or integrated recovery.

The disruptions are often highly complex so that the necessity to recover from them, being both individual and simultaneous ones, is under severe time constraints, calling for series of actions for recovering (Bruce 2011, p. 4).

In any case, according to Castro and Oliveira (2011), generally accepted as the best one is the solution to the disrupting problem, which does not delay the flight and has the minimum direct operational costs, or at least doesn't increase them.

2.2.8.3 The Passenger Service - One of the Supporting Groups at the AOCC

Depending on solutions, decisions taken on the AOCC will have also an impact on the passengers.

The Passenger Service, as one of the supporting sections at the AOCC, has the responsibility to consider and minimize the impact of decisions made with the disruption management on passengers. The main objective of this service is to act to the minimum of the passengers' inconvenience, seeking to no increasing their trip time. The passenger service role is mostly performed on the airports and with big airlines usually as a part of its Hub Control Center on their basis-airports or hubs (Machado, Castro et al. 2011, p. 2).

Does the passenger-rebooking have/or not the desired effect means whether the passengers that have already been rebooked are possibly still going to miss their connections, because the inbound-flight is going to arrive late, or/and the gate-change at the downline-flight station can make a connection impossible (Narasimhan 2001, p. 10).

An every-day example could be one well-known situation: from the passengers' perspective would be favorable to delay an outbound flight for ensuring ability of the passengers of a delayed inbound-flight to make their connections. In practice, this option has to be proved and evaluated primarily from the crew and aircraft perspective.

2.3 Passengers in the Air Transport System (ATS)

Airline customers can essentially be divided into business and leisure travelers. More precisely, beyond the business travel can be found business, first-class, elite-status, contracted corporates, or exclusive travel. Under the non-business travel purpose can be founded private, family, health, medical and spa, as well as pilgrim purpose.

Traditionally, airlines have simply segmented their markets on each route by trip purpose or travel motivation by dividing their passengers into business and non-business or leisure passengers. Even though some airlines made few further subgroups of non-business (or leisure) passengers by their trip purpose into Visiting Friends and Relatives (VFR), holiday, pilgrim, wealth and wellness, the air travel may also be multipurpose as, for example, business trip combined with a holiday (Doganis 2002, p. 188).

Officially, according to the trip purpose there are the three major passenger categories: business, leisure, and VFR (Visiting friends and relatives). Also, there are numerous sub-categories between each of them, whereby every airline will have a different method for defining the passengers' profile on a particular flight. Hereby, airlines face the fundamental issue that at each end of the same route nor the passenger mix or the proportion of the traffic originating is the same, which crucially influence airlines' marketing and pricing strategy (Doganis 2002, p. 184-5).

Nowadays this consideration is more complex so that the categorization not only by journey purpose but partly also by passenger needs could lead to a sub-dividing the business segment further into routine business and emergency business. The leisure segment could be split into an "inclusive" tour, a multi-destination touring, and a weekender segment (Doganis 2002, p. 188-9). However, neither all business passengers nor all leisure ones can be grouped together and just assumed to have similar demand characteristics and needs. For example, a senior manager or a director required to going to another country immediately because of unexpected events or crisis has different transport requirements and demands from a salesman who plans his regular overseas sales trips months in advance (Doganis 2002, p. 188).

The information about passenger demand in each market is an important requirement for airlines' managements in their planning, advertising, promotion and sales, as well as for determining their tariff policies, that is directly influenced by the customer base which becomes increasingly less homogenous with the changes in the economies, consumer demographics (i.e. income and trip purpose), and technology (Taneja 2005, p. 2).

In any case, the more an airline knows about its current and/or potential customers in order to meet the specific needs of each market segment according to its service quality policy, the easier is to plan and to target it.

2.3.1 Air Travel Motivation and Traveler Behavior

Well known is the fact that *air travel motivation* and aspects of the travel behavior, such as travel frequency, number of people traveling together, or travel booking-time, depend on the socio-economic characteristics of the individual traveler such as sex, age, occupation and income level, life style, size of family, impacting the frequency of travel as well as the duration of the trip.

While business travelers fly more frequently, they also take trips of shorter duration, where leisure passengers have the longest trips, especially those on (all-) inclusive tour holidays.

In his research on traveler behavior, Bonsall (2004) considered the term *uncertainty* as a norm in transport systems with complex and situation-dependent consequences that can not be ignored. Reminding that conditions and behavior change from one day to the next day, Bonsall suggests that decision makers' i.e. passengers' and operations controllers' attitudes to risk vary from person to person and from situation to situation. Therefore *"they must use heuristics when faced with data which are too complex or uncertain for them to process analytically".*

The psychological and social sides of the traveler behavior correspond amongst others with travelers' attributes in terms of their behavior- and choice-characteristics, use of accumulated experience and pre-existing knowledge of the system, as well as building and use of their beliefs and expectations.

The operational-technical and economic sides of the traveler behavior consider passengers as the important part of ATS, playing the roles of one of the resources in the airlines businesses and operations, and at the same time, of the customer to both airlines and airports. The focus here is to identify and understand the passengers' needs and requirements in order to meet them satisfactorily and optimally for both service-providers and the customers.

Doganis (2002, p. 186-8 + 237) has identified five key variable factors that influence customer behavior in making and taking travel decisions. What is more important, the travelers' choice between the airlines is different within each of the given travelling categories. These are defined as follows:

(1) Price factor

(2) Schedule-based factors, such as frequency, connections, punctuality

(3) Comfort-based factors, such as aircraft-type, airline lounges, ground/terminal service;

(4) Convenience factors, such as distribution, capacity, and seat-availability, and

(5) Image factor, such as FFPs, promotion, advertising, market position

How these various product features will be combined, in order to meet customer needs in their different market segments, each airline has to decide for itself.

IATA Corporate Air Travel Survey (2007) found out that the key determinants that influence business passengers' airline choice include:

- For short-haul flights: FF-Programs, convenient departure and arrival times, as well as punctuality of flights
- For long-haul flights: FF-Programs, non-stop flights, and seat-comfort.

For leisure travel segment it has been found that it is primarily influenced by the ticket price, travelers' disposable income (principally determined by economic wealth), and their available free time (Benner 2009).

2.3.2 Passengers' Satisfaction and their Switching Behaviour

Dissatisfaction with the service quality (SQ) delivered can cause not only the passengers' dissatisfaction generally, but also to affect their intention to switch to another airline, while SQ-requirements that lead to passengers' satisfaction influence building of their loyalty. This could confirm Juga, Juntunen et al. (2012, p. 2) in their examination, predicating how the overall satisfaction with the perceived carrier's SQ positively influences the buyer's loyalty.

However, it should be emphasized that from the passenger's viewpoint, even when the airlines wish to differentiate their products, they end up offering very similar products flying similar or identical aircraft, which Doganis (2002, p. 25) explains as: "to the passengers one airline seat is very much like another".

On one hand, the passengers who experienced flight delays are more likely to switch airlines for the subsequent flight than passengers who did not experience delays, whereby on-time performance affects the carrier's market share primarily through the passengers' experience and *not through the airlines' "performance advertisement"* Suzuki (2000). Though, the author suggests that the passenger's decision to stay at or to switch from a particular airline does not depend only on delay experience as the level of service (LOS) perceived below traveller's expectation, recommending this framework to be seen only as a "quick and dirty method" of passengers‘ switching behaviour.

On the other hand, a critical key aspect of the decision on whether to switch to the other airline or not as a choice possibility should be considered in terms of if there is one more competitor-airline with an appropriate schedule convenience, meaning, in which scheduling a desired flight city-pair with desired departure-time can be found. Being dependent on an alternate choice possibility in the case of its unavailability, decision on switching may drive passengers into the acceptance of less service quality than they did expect i.e. as if they would have had a choice. From that point of view, the critical service schedule-based features according to Doganis (2002, p. 238) are the number of destinations and flight frequencies operated, their departure/arrival times, and "whether flights are direct, or involve changes of aircraft in particular", while for Proussaloglou and Koppelman (1999) these are *schedule convenience of alternative flights*, *fare class amenities* and r*estrictions*.

2.3.3 Profile of the Passengers Considered

The passengers and passenger-groups taken into consideration in this research are the ones of the highest (economic) importance to the airlines.

The profile of passengers on each flight (i.e. the passenger segmentation per flight) is one of the core airline business data which may not be necessarily available for the public and/or research use. Hence, the passenger trip data as an important feature not only for a better planning but for targeting the airlines' services for meeting the specific market needs, is a proprietary airline data that can only be provided by airlines, as also emphasized by Wang and Sherry (2007, p. 3). Even the information about the exactly seats assignment per flight/aircraft and/or route is mostly kept confidential by the airline (i.e. not available for the public). By requesting a seat-assignment, passengers have no way of knowing how many there are already *really* assigned and in which area, since they don't show up on seat-maps (airliners.net). For example, if all seats are shown as reserved indicating that one section is already full, it is not possible to check whether there has already been the spill-over (but not showing on the seat-map!) whereby the passengers may be affected to start to spill into the higher section. This illustrates how the so called seat maps are no indication for the real state of inventory, since a portion of seats will be kept in reserve for getting seating at the airport check-in, as well as for the airline's internal use (e.g. employees, special guests and passenger groups). Finally, the seat-assignment remains (i) the business matter of the airline's yield management, and (ii) the property of the airlines while being not available for the public and/or research use.

However, near the basic fare categories, there are several sub-categories of each seat/fare categorisation depending on the airline pricing policy. Doganis (2005) reported on even 85 subcategories of fare-classes founded for a flight explored of a big European airline. These (sub-) categories are shown in the flight charts, where the airline controllers can follow which booking classes are on-board, if probably awarded or otherwise purchased. There can be found, for example, the "first-restricted"-class nearby the *first-class*, as well as a "business-restricted" nearby the *business-class* and so on can be introduced.

In the process of the identification of passengers, the very first step is the defining the target customer market. This is done by market segmentation and understanding customers' behaviour characteristics, their needs and expectations accomplished. However, for analysing, valuing and managing independently, it is important to have in mind the differentiation between customers (who purchase the product) and consumers (the end-user of that product). This distinction becomes particularly more important in the airline industry, where flights are often purchased and paid for by one individual/firm/entity for use by another (one) (Leick 2007).

Due to the heterogeneity of customers who have consequently also different characteristics, some of them might have relatively higher importance in time and convenience utility than in monetary value and therefore may be more influenced by service quality (Cho 2012, p. 21).

2.3.3.1 The High-valuable Passengers of an Airline

Exclusive travellers such as first class and elite-status passengers, contracted corporate members, and business passengers are considered as the high-fare or the high valuable passengers to the airline, being identified in the research of Leick (2007) as *the passengers who are financially worth to the airline*.

In such a highly competitive environment, as the Airline Industry is, the retention of valuable customers is an important objective and requires airline management to understand the underlying factors, such as what potential and existing customers expect from their relationship with an airline brand, that reinforce airline customers' loyalty toward a given airline brand, becoming so an increasingly effective means for securing a firm's profitability (Benner 2009, p. 10-11).

For this thesis research purposes and to avoid additional complexity, only the main high valuable groups of passengers according to their ticket-fare will be considered. These are VIPs, first-class and business passengers, as well as frequent flyers. This refers to the following cabin-classes: first-class, business-class, and Frequent Flyer Program (FFP) members (particularly the premier-frequent flyers i.e. elite-level frequent flyers of an airline). Hereby, the business passengers and the FFP-members will have the same fare-status in this research for the operations controllers when taking a decision on whether to wait on departure (or not) for these passengers when flying on an in-bound flight.

2.3.3.2 Business-passengers and Frequent Flyer Program members

On the basis of the literature findings on the high importance of the FFP-members and business passengers for the airline industry, in this research they have been considered as the high-valuable passengers that *are enough worth to be waited* for, even if it might cause some delays and sometimes adding costs on departure. Their importance in the airline all-day operations can be illustrated by using the findings of Suzuki (2000, p. 141) where argued is that from top 20% of all air travellers, frequent flyers account for 80% of the airline passenger revenue indicating that *the frequent flyers* generally *travel more than 10 times per year, or* approximately *every 4-5 weeks* on average.

Traditionally, *business travelers* have been thought to be primarily middle and senior in the meaning of in the upper age group such as managers, executives, established lawyers, architects, consultants, etc. However, the business market has been undergoing some fundamental changes, as internationalization of the world's trade, resulted in recent years in a growth of business travel by more junior staff and skilled workers. The most significant socio-economic variable affecting the demand for leisure travel is personal income because leisure trips are paid for by the travelers themselves (Doganis 2002, p. 187).

FFPs - The Airlines' Marketing Tool and Loyalty Scheme

"Frequent Flyers are our bread and butter", a United Airlines spokesman said, "We don't want to offend them", cited Toh and Hu (1998).

Due to their accumulated experience, frequent flyers are of the particular interest since they experience more delays and therefore are able to make better estimates of likely future delay(s), becoming more sensitive or more tolerant (or, just adjusted!) than typical passengers (Cook, Tanner et al. 2012, p. 14).

In their attempt to retain the high-mileage travelers over longer periods of time through club concept (loyalty programs) and with the objective of supporting and enhancing customer loyalty, airlines introduced Frequent Flyer Programs (FFPs) in the mid '80s. This is the way of improving airline's image, but also one of the methods of the retention strategy of the relationship marketing. Here the focus is on long-term financial benefits which can accrue once a customer has been won for the first time. This policy relies on airlines' appreciation of that marketing strategy. Recognizing how much the passengers give the importance to the free air travel miles as well as that more expensive is to recruit a new customer than retain an existing one, Gilbert (1996, p. 2) estimated this value confirming that is up to 5 to 10 times more (expensive).

As a measure of customers' value to the company, FFPs act also as a very powerful airline's marketing and segmentation tool by which passengers are classified according to their "value". They operate as clubs and long-term oriented programs enabling consumers to accumulate some form of program currency which can be redeemed later for free rewards, for bonding the passengers to the brand in exchange for their loyalty (Liu and Yang 2009, p. 94). Benefits can be introduced tactically with increases in points on selected routes and with communication to the club members (Gilbert 1996, p. 4), since the database developed for and from such clubs offers an abundance of information on travel patterns for which special promotional offers can (and will) be developed (Gilbert 1996, p. 4).

For the FFP-members, according to the findings of the research (OAG, 1992, in Gilbert 1996) cited in (Leick 2007, p. 12), following features are of great importance: waitlist priority (with an importance of 72%), mileage points (of 55%), lounge access (of 48%), upgrade availability and recognized status, while the others but not of essential importance are points from other schemes, luggage tracing, other awards, insurance schemes, and newsletters.

Almost every airline has a tired FFP where passengers are segmented in a hierarchical system according to the number of miles or points accrued, but they are also segmented beyond FFP membership on a different form of customer value.

FFP-segmentation based on bonus-miles does not provide an accurate measurement of customer value to the firm. Hence, it is shown that less than half of high-value customers are top-tier members of airline FFPs (Leick 2007, p. 27-8).

Some researchers have found that an accrual of mileage does not correlate with the customer value (as initially was), especially if known that this has been driven and further motivated by the fact that FFPs members' employers pay the expense of the flight. However, high-mileage passengers may be less profitable than others. The research of Leick (2007, p. 25) explains this FFP-aspect arguing that the frequent travelers who only travel on discounted fares reduce yield rather than generate a price premium as initially expected. This is so, because the airlines have been forced in this way to incur large costs to maintain FFPs only to sustain weak customer retention while requiring time and resources on both sides.

Studying loyalty program performance, Liu and Yang (2009, p. 2) recognized that loyalty programs do not operate as separate entities in an isolated environment emphasizing how their success depends not only on the programs themselves, but also on other facilitating or inhibiting factors present in the environment. Two problems are identified with airline loyalty schemes. The first one is that the members may be inactive while joining other schemes rather than having quit the existing one. The second results from some companies point of view that any rewards should belong to the firm which actually pays for (a buyer) and not to the individual traveler (user) (Gilbert 1996, p. 6).

Higher travel frequencies and accumulated delay experience of frequent flyers may cause switching behavior to have a greater effect on airlines, despite potentially reverting to the original airline sooner. Cook, Tanner et al. (2012, p. 14) suggest applying of these effects when multiplying these costs over longer periods of time or whole networks.

2.3.4 Disrupted Passengers

Disrupted passengers are passengers who have to be reassigned to itineraries other than planned, because their flight itineraries have experienced disruptive events such as one or more flights in their scheduled itinerary is cancelled, or the connecting time between two consecutive flights is less than the minimum connecting time (which is determined as the minimum required walking time between the arrival and departure gates of the consecutive flights) (Jafari and Zegordi 2010, p. 205). In the situations where the connecting passengers are not able to make their connections because the minimum connecting time is not available, it is necessary to make decision on which recovery plan to apply to these passengers. According to Bratu and Barnhart (2004, p. 25), connecting passengers are almost three times more likely to be disrupted than originating/departing ones. However, by missing their connecting flights they will be often re-accommodated on their *best possible*, but also rather on the best *available* itineraries.

This is particularly notable if among disrupted connecting passengers have been present the most valuable ones to the airline. Although from its decision processing is then required much more sensitivity and responsibility in searching for the optimal solution, an airline will always be attempting to minimize the adding overhead costs and to avoid the loss of passengers' goodwill turning them into the unsatisfied customers.

2.3.5 Airline's Recovery-Plan for Disrupted Passengers

The Passenger Recovery Plan is based on the need to reassign disrupted passengers to alternative itineraries, commencing at the location after their available times, and terminating at their destination or a location nearby (Jafari and Zegordi 2010, p. 204).

Since it is a fundamental part of each airline disruptions recovery strategy, it is required to have possibilities that enable an airline to recover from irregular operations, if not to quite satisfaction of its disrupted passengers, but at least to the minimal damages thus avoiding loss of passenger goodwill.

Although differing from one airline to another, generally the Passenger Recovery Plan depends on its network and business plan, as well as on its possible participation or membership in an airline alliance where more possibilities for the appropriate recovery would be available.

In the service industry well known is that the quality of service decreases with increase in demand for that service. Accordingly in the airline industry, the estimation of the airline's ability to recover disrupted passengers decreases exponentially when the average load factor increases, due to less resources available (Bratu and Barnhart 2004).

Generally, the recovery planning must satisfy some requirements. The most important one will be: each recovery itinerary must be operationally feasible requiring that all flight legs (in the recovery itinerary) are operated, and the *minimum connecting time* (MTC) is possible to achieve or is available (Bratu and Barnhart 2004, p. 9). This is already defined earlier as the time required to walk between arriving and departing gates of the consecutive flights is greater than MCT.

For the passenger re-accommodation, airlines may apply various policies such as:

(1) Unranked or first-disrupted-first-recovered policy, or

(2) Ranked, where the passengers are served (i.e. recovered) in order of decreasing fare-class-value (the most valuable first), or in order of decreasing FFPs-status (FFP-members first) (Bratu and Barnhart 2004, p. 8).

As one of the supporting sections at the Operation Control Center (OCC), the Passenger Service (PS) has the responsibility to ensure that passenger inconvenience is taken into consideration in the decision solutions if disruptive events occur. Decisions on delays and cancellations will also affect passengers who need to be informed and/or rebooked or provided with re-accommodation (Kohl, Larsen et al. 2007, p.151).

However, the best solution for the airline among the possible options for solving of a disruptive event must not be the best one from the passengers' point of view. Hence, it may be even badly acceptable one! For example, in the case of the aircraft failure, from the airline's resourcing perspective, flight cancellation would be an ideal solution, since this does not only require extra resources but may even result into unplanned providing of free resources for another flight with little changes in the planning. From the passengers' point of view, the cancellation is always the worst option, since some customers will not receive the service they paid for (Clausen, Larsen et al. 2005, p. 4).

When it is about to decide whether to wait on departure of the outbound flight for the arriving-delayed passengers from an inbound flight, for this research purposes assumed is that this is due to an issue of the airline's operation execution and therefore the required rebooking of the passengers will be in the responsibility of the airline. Otherwise, the recovering plan would be the responsibility of the airport in case, for example, of the gate changing whereby the minimum connecting time for the transfer passengers can not be achieved.

Focusing particularly on the above-described issue of the airline operation management, this research is concerned with the recovery possibilities of the most valuable passengers to the airline, as well as with those accompanying consequences.

3 Literature Review

3.1 Introduction

This chapter presents an overview of the relevant previous academic research work regarding the most influencing factors that drive decision making process at Operations and/or Hub Control Center of an airline, focusing the interests on delays due to (valuable) passengers in transfer. This chapter is organized into four sections divided according to the main themes that have been emerged in this kind of decision process. Thus, the basic research approach towards the theoretical framework for establishing and development of the proposed decision supporting tool is provided.

In the Section 3.2 the review of research work on the passenger-recovering (i.e. airlines recovery plan solutions within which passenger recovery solutions and recovery plan costs are considered) is represented. Subsection 3.2.1 displays a preview of the airline-accounting and the occurring costs giving (i) an insight into dependencies and relationships between the main playing factors, while (ii) enabling an easier positioning of the delay costs that are considered in this research. In the Section 3.3 the previous work on decision making process at the Airline Operation Control Center for gaining a valuable insight into the driving attributes of the highly complex relationship between humans and technology is reviewed. Finally, in the last Section 3.4, the related literature work considering the relationship between air carriers' level of service quality (SQ) delivered and passengers' satisfaction as well as SQ influence on the passengers' goodwill is reviewed.

The findings of the state-of-the art works provide a sound foundation on which this thesis research is built upon.

3.2 Literature Review related to the Passenger Recovery-Plan and Costs

This section briefly overviews literature that estimates passengers-recovery planning when irregularities and/or disruptive events occur, as well as the influence of these decisions on passengers and the costs to the airline. Although limited research work has been done on this subject, in the reviewed studies on operations recovery, passengers are considered primarily as an integrated problem which was included within aircraft-recovery and/or crew-recovery solutions.

The passenger delay costs, often dominating the overall cost of delays to the airlines (Cook, Tanner et al. 2010, p. 3), are estimated mostly in two ways or basing on two values, as (i) the "value of time" in the transport industry or as (ii) the booked ticket fare class.

In practice, most of airlines use some kind of "rule-of-thumb" by evaluating the impact of the recovery decisions on passengers, others just assign a monetary value to each minute of delay taking into consideration this value when evaluate the solutions (Castro and Oliveira 2011, p. 10). While most network airlines recognize that the passenger delay cost component is the main driver of their delay costs, especially the passenger *soft* cost component, relatively few have been able to invest in quantifying these costs (Cook, Tanner et al. 2012, p. 16).

The first passengers-recovery plan was reported in the PhD research by **(Lettovsky 1997)**. It dealt with an integrated recovery plan for the Airline Integrated Recovery (AIR) by developing a mathematical model for crew and aircraft, considering the passenger impact and providing three new separately solutions for crew, aircraft and passengers within 3 sub-problems: ARM (Aircraft Recovery Model), CRM (Crew Recovery Model), and PFM (Passenger Flow Model) using a decomposition scheme which is controlled by a Master Problem (i.e. given each solution to the master problem). Solving of the problem is suggested by providing a cancellation and retiming plan employing the solution algorithm which applies Benders' decomposition scheme. First as a crew and an aircraft are found for each assigned flight in the disrupted situation, a three-stage procedure, Passenger Flow Model (PFM) sub-problem finds then new itineraries for disrupted passengers. The main objective of PFM is to maximize the recovered passenger revenue by reassigning disrupted passengers to available seats following the next steps. In the first step, it performs aggregation of passenger itineraries, then generation of feasible paths through the now changed network, and finally, the allocation of passengers with respect to the seat capacity to given fleet type, while minimizing overall impact on passengers.

However, Lettovsky's integrated recovery model presents primarily an effort for solving the integrated problem of crew and aircraft, whereas the PFM considers disrupted but not delayed passengers, and evaluates passenger financial impact of the schedule changes, maximizing passengers' revenue.

The work of **Kohl, Larsen et al. (2004)** provided this thesis study with definitions and a general introduction into the airline disruption management. The authors reported on (1) the detailed description of the planning process and typical organization of an Airline Operations Control Center and (2) the project DESCARTES (DEcision Support for integrated Crew and AiRcraftT), the integrated recovery-plan. The project was supported by the European Union, which purpose was to develop a disruption management system based on a holistic approach. The DESCARTES should integrate the decisions of the four airline key resources: aircraft, cabin and flight crew, and passengers in one integrated feasible decision employing the individual prototypes for the dedicated solvers (i.e. dedicated *aircraft* recovery system, dedicated *crew* recovery system, and dedicated *passenger* recovery system) which development has been based on the Operations Controllers' experience and knowledge, tested and conducted by realistic scenarios.

For this thesis work of the main interest is in the DESCARTES project developed Dedicated Passenger Recovery solver (DPR) and its purpose to evaluate the possible recovery options from the passengers' perspective. It proposes an optimal re-booking plan that can be generated manually or automatically by other dedicated solvers in DESCARTES architecture. For each recommended recovery option, the DPR solver calculates the passenger inconvenience cost, plus any real costs associated with the suggested recovery option by finding an optimal re-booking plan based on following metrics of cost components:

(1) The cost of passenger delay (measured only at the passengers' final destination, taking into account the commercial value of the passenger which is based on the booked fare class and Frequent Flyer Program information)

(2) The cost of passenger off loads

(3) The cost of accommodation for disrupted passengers

(4) The cost of passenger upgrades and downgrades. Since these costs may be more difficult to estimate, besides the real costs for compensations, also costs for lost passenger's goodwill associated with downgrades had been taken into consideration.

The first study which has recognized two kinds of delay costs differentiating them into hard costs (monetary measurable) and soft costs (hardly monetary measurable) was the Westminster report on dealing with the costs of delays to the airlines reported by **Cook, Tanner et al. (2004)**. This extensive study conducted by the University of Westminster in cooperation of the Eurocontrol and two European full cost airlines was updated and corrected for economically reasons in **2009** (by taking into account inflation and the impact of EU-Regulation No. 261). This report is concerned with the delay costs calculated for four operational flight phases, for three cost scenarios, low, base and high, for each kind of 12 considered planes. It reports on airborne and ground costs caused by each cost element such as crew costs, handling, fuel and maintenance costs, airport charges, and passengers' compensations. In this study, the passenger costs of delay are based (also causing dependency) on data derived from two selected airlines (i.e. one is Austrian Airlines and the other carrier has to be kept confidential). The report is focused on delay costs to the airlines due to ATFM and it does not study the delay cost for passengers. What is not included in the ATFM-delays are delays that also can occur as a single or as a composition of other delay causes (i.e. reactionary delays, consequence of difference between the slot take-off and the actual take-off times caused by aircraft maintenance, ground handling operations, or airport operations and/or failures).

Although this report doesn't consider delays for passengers nor in arriving or in transfer (desirable inputs for this thesis research), it gives nonetheless an insight into the fractional classification of possible sources of passenger delay-costs, but explicitly the passenger costs of ATFM-delays. These costs are divided into “hard” and “soft” costs, both as a function of delay duration, estimated to be each for delays in the range of 5 till 300 minutes as following:

(1) Passenger *soft costs* (such as passenger satisfaction and loss of goodwill), hardly measurable but often dominant component in the economics of airline unpunctuality:

- For the low scenario: 0,01-0,27 EUR/passenger/delay-minute
- For the base scenario: 0,02-0,97 EUR/passenger/delay-minute
- For the high scenario: 0,03-1,08 EUR/passenger/delay-minute

(2) Passenger *hard costs*, monetary measurable (as re-accommodation, compensation):

- For the low scenario: 0,04-0,88 EUR/passenger/delay-minute
- For base scenario: 0,06-1,44 EUR/passenger/delay-minute
- For high scenario: 0,07-1,75 EUR/passenger/delay-minute

This thesis research is concerned with passenger delays particularly in transfer, regarding the passenger delay costs to the airline, whereas delays may be caused from/by different delay-sources and not only by ATFM. Hereby, the passengers’ satisfaction and their goodwill are closer considered.

Nevertheless, at this place it would be quite appropriate to apply the explanation given by **de Villemeur, Ivaldi et al. (2005)** emphasizing that the loss of passengers for two selected (private) airlines in the Westminster Study may represent a large cost displaying a decrease of their market size. The authors concluded here that, if considered the whole air traffic sector, it is expected that the passenger who quits an airline will move to another one and not just disappear from the air traffic market, and furthermore, after an amount of time, will be willing to come back purchasing ticket(s) by the same airline.

In their following study **(Cook and Tanner 2009)** the authors used the previous estimations of the passenger average soft costs, focusing on their distribution as a function of delay duration proposing how to combine these costs with other costs (i.e. crew, fuel and aircraft maintenance costs) for making cost-benefit trade-offs in the pre-departure and airborne phases of delay cost management. They argued that longer delays have higher associated costs per minute: hard costs are higher, as airlines pay more in recovery and care costs, and soft costs are also higher for longer delays, since passengers are more likely to be dissatisfied as the result of a longer delay than a shorter one. Arguing that the major component of the airline delay cost is associated with delayed passengers and many delay costs differ by phase of flight, they recognized the passenger costs as a notable exception, only as function of arrival delay. To express the propensity of a passenger switching from a given to some other airline, they used a Logit function for distributing the soft costs of delay, applying the Kano’s model (1984) for customer satisfaction examination. They suggested estimated costs to be taken into the decisions on delay recovery instead of the “rule-of-thumb” (widely used at many airlines at present), as well as the integration of disruption management techniques into flight planning phase. However, here are only different distributions of ATFM delays considered.

Exploring the implementation of an optimum schedule buffers (i.e. slack-times) into the flight schedule in their study work on airline delay costs, **Cook, Tanner et al. (2010)** focused on the trade-off between the strategic investment in buffers and the risk of incurring tactical costs (on the day of operations). They emphasized that these costs and strategic (at the planning stage) costs are not independent, while passenger "hard" cost strongly dominate the tactical savings. As they argued, passenger delay costs are an approximation and assumed not to vary as a function of anticipated delay. Thus, strategically are treated as zero and wholly assigned to the tactical phase of flights. Here, the authors declare the passenger "soft" delay costs to refer to a loss in revenue of an airline as a result of an experienced delay. This loss may be considered to be the gain of another airline through the gaining of a switching-passenger. Concluding that soft and hard passenger delay costs have complex interdependencies, the authors emphasize that lower soft costs may be a result of a generous airline compensation policy (resulted from tactical delays), but that will be at the expense of higher hard costs.

These conclusions will be of the most importance for finding their applications in this thesis work.

In their following work, **Cook, Tanner et al. (2012)** took into consideration only the delay costs having an impact on the airlines business, drawing on the primary survey data and additionally included the Kano's (1984) satisfaction model to enable modeling of passengers airline-switching propensity. They proposed a shift in the strategy from managing delay-*minutes* to delay-*costs*, as well as more investment into better data collection and tools, identifying that the use of statistics on passengers complaints data give only a proxy for passengers dissatisfaction. This can not be assumed to be a linear negative extrapolation of satisfaction with the service provided.

However, in all the research work abovementioned authors used the formerly estimated passenger "soft"-delay costs of 0,1 EUR, as a basis for all their further calculations.

The very recent work of **Cook, Tanner et al. (2013)** is a report on the project POEM (Passenger-Oriented Enhanced Metrics) designed as a full gate-to-gate model with modelling of passengers connectivities, applying flight and passenger prioritization scenarios. The key objectives were to explore the trade-offs between the flight-centric and passenger-centric metrics and to characterize the propagation of delay through the network. Re-assignment of passengers with missed connections due to delays to individual fights are based on the cost minimization. Within modelling of the passengers' re-accommodation, respected were flights load factors and the connectivity-capacity of a given airport, meaning that the disrupted passengers are reaccommodated regardless of their ticket and/or cabin class, but according only to total seat space available, excluding the possible up-/downgrading. Cost-estimations, especially for the passenger-delay expenses were based on the airline data available. Included was the passenger value of time (VOT) separately estimated for the passengers with the defined flexible and inflexible tickets, both quantified as a function of delay at the final destination?

For this study purposes, adopted is this VOT estimated for the passengers with the “flexible tickets” - referring to the passengers with the highest ticket fares which in turn corresponds with the high-valuable passengers considered in this thesis research.

Bratu and Barnhart (2004) developed the Passenger Delay Calculator (PDC) for computing passenger delays based on passenger-centric metrics, instead of already widely used the flight-based performance metrics (aimed at evaluating on-time-performance whereby passenger delays remained severely underestimated). Comparing the schedule performance measured by flight-based metrics and those on passenger-based metrics (using passenger booking data and flight operations data (US airline, August, 2000), the authors demonstrated that the airline schedule performance measure - experienced by passengers - and for the purpose of expressing schedule reliability, for the first time this is a function of passenger experience. They estimated the average *passenger*-delay of 25,6 minutes resulting as 1,7 times greater than the average *flight*-delay of 15,4 minutes.

This discrepancy resulted from estimations for passenger-trip-delays and flight-delays was further examined in the studies **(Wang and Sherry 2007; Sherry, Samant et al. 2010)**. The authors have calculated that out of total passenger delays, 19% were passenger itineraries disrupted by missed connections, 48% by delayed flights, thus confirming that passenger trip-delay is longer than the average flight-delay. They explained this discrepancy to be caused by ignoring of specific properties and behavioral patterns of airports and routes in the network of ATS that affect flight performance (measuring).

Bratu and Barnhart (2006) proposed a new approach to the airline schedule recovery plan, applying passenger-centric metrics based model, the PDC (developed and presented in their previous work from 2003). They designed flight operations recovery plan considering the passenger recovery, proposing two optimization models for integrated passenger recovery with the objective in Disrupted Passenger Model (DPM) to minimize the airline operating costs “jointly with some measure of passenger costs”, whereby in Passenger Delay Model (PDM) to minimize the airline operating costs and total passenger delay costs. The goal functions in both optimizing models focus on the operating costs and passenger recovery costs. Delay costs here are computed by modeling passenger disruptions. While in the DPM delay costs are only approximate, in the PDM delay costs are more accurately computed capturing hotel costs and ticket costs (in case passengers are recovered by other airlines), arguing that it is possible but hard to estimate delay costs to the passenger and costs of future lost ticket sales.

The delay costs that these authors used are set up to be as following:

(1) Delay costs for leisure passengers are set at $19,50 per passenger per hour

(2) Delay costs for business passengers are set at $34,50 per passenger per hour

(3) The average delay costs per passenger per hour is computed as $24,11 (in 2000)

However, for estimating passenger delay costs, Bratu and Barnhart employed the “value of time” that was recommended by the USA Federal Aviation Administration (FAA) in 1997.

Taking into consideration missed connections at 50 busiest US airports, analyzing available data on 2007 flight performance to provide an insight into the disruption performance of the US National Air Transport System, **Barnhart, Fearing et al. (2010)** found out that missed connections were responsible for 57,2% of all disruptions and 40,9% of all delays, and that highly peaked (or banked) flight schedules reduce connecting times increasing the risk of missed connections, thus delivering the most significant cause of travel disruptions for one-stop passengers. Analyzing the most important factors affecting cancellations and missed connections, they concluded that delays associated with passenger itinerary disruptions are impacted by both airport and airline, emphasizing how difficult is to separate the impact of airport-based congestion from those of carrier operations.

Since this thesis research takes into consideration scheduled airline operations and decisions on disruptive events that can be caused by both, airport and airline operations, the showings from the above-mentioned studies are significant improvements how strong impacted are connection-flights at airports resulting from operational side of both**,** airline and/or airport.

Claiming that actually the policy of airlines causes difficulties in defining and determining delays, in the report on the social costs of air traffic delays **(de Villemeur, Ivaldi et al. 2005)** and partially presented later by **de Villemeur, Quinet et al. (2011)** the authors examined buffer times that airlines introduce in their scheduled travel times in order to cope with delays and as a way to ensure that all connecting passengers are able to get their connecting flight legs. They considered the connections related to welfare losses that follow from delays, concluding that they are relatively small as compared to the potential benefits that would follow from a decrease in ticket price. The authors showed that previous estimated values for airlines and passenger costs are relatively heterogeneous giving a review of theoretical and empirical studies on the estimation of costs of air traffic delays, as well as on the estimation of the “value of time”. Emphasizing that many transportation research studies show a variety of “value of time”, they highlighted three research studies which deal with the costs of delays for the operator giving the different estimations, as following:

(1) Institut du Transport Ae´rien (ITA) study titled as “Costs of Air Transport Delay in Europe” (2000), estimated the delay costs for airlines and passengers in Europe, using data from International Air Transport Association (IATA) and Air Transport Association (ATA), completing with Eurocontrol data, and studying just the delays due to ATFM, offering a quite rough delay cost estimations:

a) For the Value of Time (VoT) of passengers ranging *34–44* €/minute, where the passengers are differentiated as business, personal convenience and tourism travelers (these values of time are over-taken from previous studies);
b) The delay cost for airlines was assumed to be *45* €/minute (the same values assumed for schedule and buffer delay costs)

(2) In the study on Evaluation of congestion costs at Madrid Airport in the period 1997-2000, Nombela, de Rus and Betancor (2002) considered both airlines and passengers delay costs based on an accounting approach but regardless of who has caused the congestion. Based on estimations also used from previous studies, the final cost estimation is assumed to be:

a) The Value of Time (VoT) for the passengers: 15,9 €/hour
b) Delay costs (for both arrival and departure) for airlines: 5000 €/hour

Here estimated value for passengers delay costs is the Value of Time proceeded from values which were estimated for Germany and Switzerland within the UNITE program (Quinet, Vickerman, 2004), applying the same value to all kind of passengers.

(3) In *The Report by the University of Westminster (2004)*, the authors suggest that total delay costs to the carrier are overestimated and set up to be an average cost of around 72 € per delay-minute, which is caused by the given definition of the “long” delay, for to be actually all delays longer than 15 minutes.

As **Morellet (1997)** estimated in the report on the Value of Travel-Time (VoT) for France in1990, for Air transport and the trip length of more than 80 km to be 47 EUR. He emphasized how values of time vary as a function of several parameters like income, group size, trip purpose, its length, but also as a function of the modal competition. It is emphasized that *the higher the competition on a particular route, the higher is the value of time*.

In contrary to previous studies, in **(Castro and Oliveira 2007); Castro and Oliveira (2011)** the authors examined not only the operational recovering in the airline disruption management, they included in a new proposed concept quantifying the “quality operational costs” by taking into consideration the passengers’ satisfaction into the final decision on recovery planning. They showed functionalities and competences existing in a typical Airline Operations Control Center (AOCC) represented by a multi-agent based system (MAS) that creates intelligent solutions as results of an autonomous reaction and adaption to changes in the environment, taking into consideration separated the direct costs and quality operational costs defined as:

(1) *Direct Operational Costs* (*DC*) (easily quantifiable) such as all crew related costs, all aircraft/flight costs including service and maintenance costs, and

(2) *Quality Operational Costs* (*QC*) (less easily quantifiable), which are estimated costs of delaying or cancelling a flight from the passenger point of view in terms of importance that such a delay or cancellation will have on the passenger, meaning that it is first to define the existing passenger profile(s) and then a delay cost for each passenger in each profile. They

also conducted an experimental survey to passengers on several flights for expressing the evaluating trend of each profile regarding *delay/time/importance* to the passengers, enabling the development of an accounting (case-valid) formula using three passenger profiles (business, pleasure, and illness), recognizing that in the practice, every airline will have a different method to define the passenger profile.

Finally, the *Total Operations Costs* (*TC)* of a specific solution are expressed as follows:

tc = dc + ß*qc, where ß is the coefficient which defines the weight or monetary value of quality costs.

When having to choose between two solutions with the same DC and delay time, they showed how decisions may depend on the profile of the passengers of each flight, meaning on the importance they themselves give to delays - constituting in this way the qualitative operational costs (i.e. the “quality costs”).

The impact on delay costs of the new European Union’s Regulation No 261/2004 (see also in the Annex C), which entered into force in February 2005, for affording passengers with additional rights in cases of cancellation, denied boarding and delay, was presented by **Jovanovic (2008)**, reporting on how this passenger compensation increases the costs to the airlines (translated into the price), in cases of delays in duration of more than 3 hours. Although these rights are applicable on all kind of flights from and/or with destination in the Europe Union, they are related only to departures and not applicable on arriving delays or missed connecting flight itineraries.

Finally, the thesis research of **Rabbani (2004)** addresses the passenger recovery the same as so far, as an integrated part in an airline disruption recovery module. The passenger function is called after the aircraft and crew module-segments to re-accommodate the disrupted passengers because of cancelled or filled flights. The overall objective of the module was to reduce the costs. The passengers to be re-accommodated are ranked according to the (decreasing) fare-class-value (the highest fare first). For the passengers misconnected, the re-accommodation is done after passengers arrive at the connecting-airport and these costs are computed. For stranded passengers (who could not be re-accommodated) the passenger cost is accounted for the lost revenue. No further (or indirect) effects of passenger disruptions were taken into consideration such as loss of passenger goodwill. The module does not consider all possible routings for stranded passengers, searching only for the best ones in term of passenger delay. If all flights were full, affected passengers remained not re-accommodated. Also emphasized was that during the simulations data were taken from various sources, whereby information from different sources have not had to match always, though might have had influence on the final result, which is actually an often problem in the research literature.

3.2.1 The Cost considered in the Airline-Accounting

In this research the costs due to delaying an aircraft waiting for the delayed connecting passengers will be rough estimated. The suggestion of Thengvall, Bard et al. (2003, p. 397) that it is virtually impossible for an airline to provide the accurate cost issues in a real time, is going to be taken into consideration, emphasizing that, the best that can be obtained regarding delay-costs on a currently observed flight are only the rough estimates.

However, contrary to above-cited author, in his recent study work Cook (2014, p. 27) has pointed out that the new applied passenger-centric metrics in a developed modelling for passengers and costs enable also a dynamic tracking of costs for each aircraft and passenger. Despite that, for avoiding processing complexity in the proposed model the authors used estimations for these costs which had been calculated from the airline data available for that time period.

It seems to be obvious that the data coming from the passenger-delay cost are well protected for the airlines business matters, and nor actually entirely generated or/and sufficiently statistically and analytically followed. This leaves space for supposing one of the reasons for this shortcoming to be founded in the complexity of the process chain.

For this study purposes only extra or so called *overhead* costs, which can occur in terms of costs for crew, ramp and/or ground handling staff, and/or possibly some airport extra charges are taken into account. Extra fuel burn costs can possibly occur in following cases (Cook and Tanner 2009, p. 2):

1) When the new-applied slot is bounded to a flight re-routing (i.e. if accepted a longer airborne way to the destination airport as previously planned on the strategic level within the airline's scheduling)
2) The flight management system can control the aircraft by using a change of cost-index (i.e. a parameter set in the cockpit which identifies the choice if to fly faster to recover delay or to fly slower to save fuel).

For this research purposes, it seems to be reasonable to take a short overview of the airline's accounting in general, in order to make an appropriate placement of the overhead-costs that may occur in such minor-disruptive situations as in the modelled one.

However, as previously mentioned, a deeper consideration of economic implications in terms of the associated consequences of the decision making process at an AOCC is not of interest of this study work. Only the cost that typically occurs as accompanied consequence of this kind of delays (i.e. incurred by waiting for the late high-valuable connecting passengers) is taken into account.

For providing a short overview of the airline accounting matters, the basic definitions and explanations have been adopted from Doganis (2002). Though, it is emphasized that the approach to cost-categorisation used by each airline is strongly influenced by (1) accounting practices in the home country of the particular carrier, and (2) the cost application adopted by the International Civil Aviation Organization (ICAO) that is providing this organization with a particular breakdown of airlines' costs each year.

According to Doganis, for a short presentation of this study purposes, accounts of an airline are generally divided into an *Operating* and a *Non-Operating* account, whereby the airline's Operating Account consists of its Operating Revenue and Operating Costs. However, it is emphasized that there is no *clear-cut* between these two items in practice. This is shown in Figure 3-1.

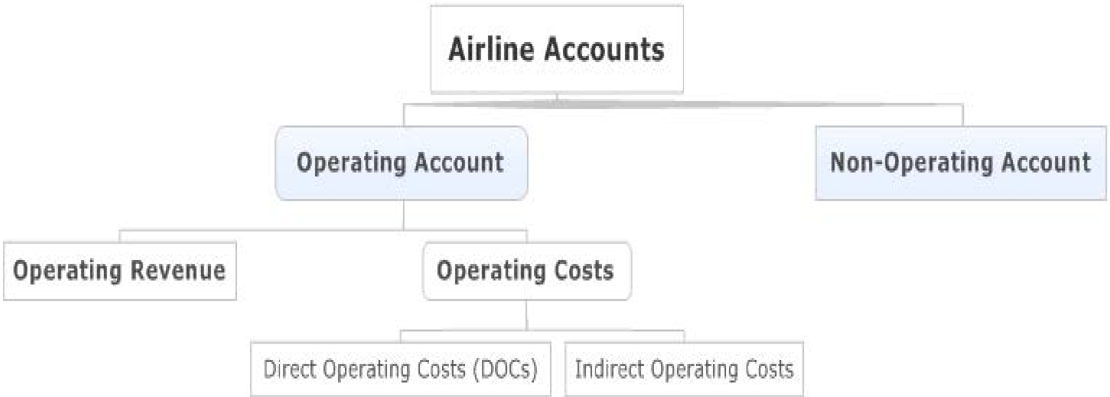


Figure 3-1: Airline's Accounts

Source: Created by the author, based on Doganis (2002)

The airline's *Operating Cost* consists of (see Figure 3-2):

- *Direct Operating Costs* (DOCs), which are dependent on the type of aircraft being operated and consist of: crew-costs, fuel-costs, aircraft-depreciation, airport-charges, and en-route charges. The DOCs are likely to be in the range of 30-45% of Total Operating Costs (TOCs) according to Coli, Nissi et al. (2011, p. 4), while depending on the airline's activity level (i.e. the number of flights);

- *Indirect Operating Costs,* which remain unaffected by change of aircraft-type operating and include station and ground expenses, the Passenger-Service costs (consisting of pay, allowances and other expenses directly related to aircraft cabin-crew and pay-service personnel; costs directly related to the passengers e.g. in-flight catering, accommodation for transfer-passengers, and premiums paid for passenger-insurances which is in form of annual-charge, as well as passenger-liability and passenger-accident insurance). Here belong expenses for ticketing, sales and the promotion, but also all general costs and administrative costs which normally make a relatively small element of the TOCs. And finally, all “other” operating costs, whereby if too much costs are to be found, this would mean that an *airline has bad control over its costs (*Doganis (2002).

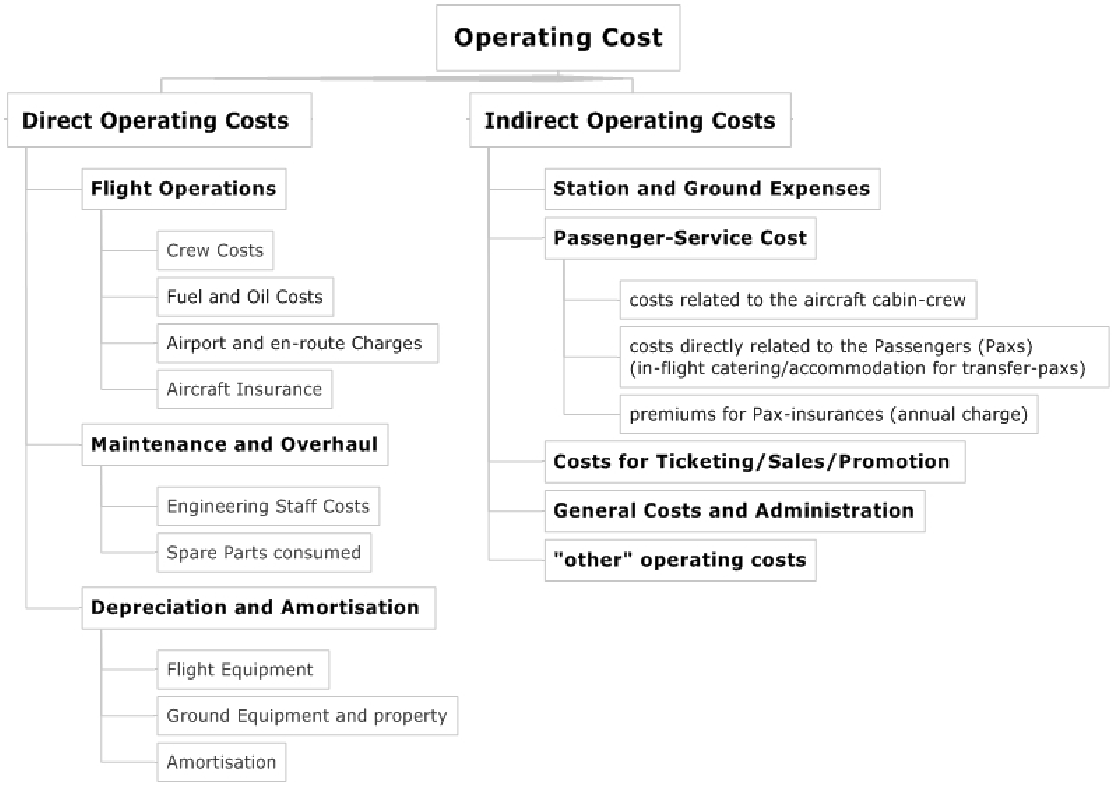


Figure 3-2: Airline’s Operating Costs

Source: Created by the author, based on Doganis (2002)

According to Doganis (2002), the Passenger-Service Costs make globally up to 13% of the airline’s Total Operating Costs (TOCs) with up to 11% of TOCs for expenses for the ticketing, sales and promotion (to compare, the fuel-costs are today high up to 15% of the TOCs of an airline (Doganis 2002)), whereby the TOCs involve both *direct and indirect* flight costs.

An airline’s *Non-Operating Account* (shown in Figure 3-3) consists of the gains and losses arising from retirement of property and equipment, interest paid on loans and any interest from bank, all profits and losses arising from an airline’s affiliated companies, all profits and losses from foreign exchange transactions, sales, and shares, as well as any direct or indirect government subsidies or taxes on profits (for example, this would be the received financial injection of state funds, or any other help in reducing an airline’s debts).

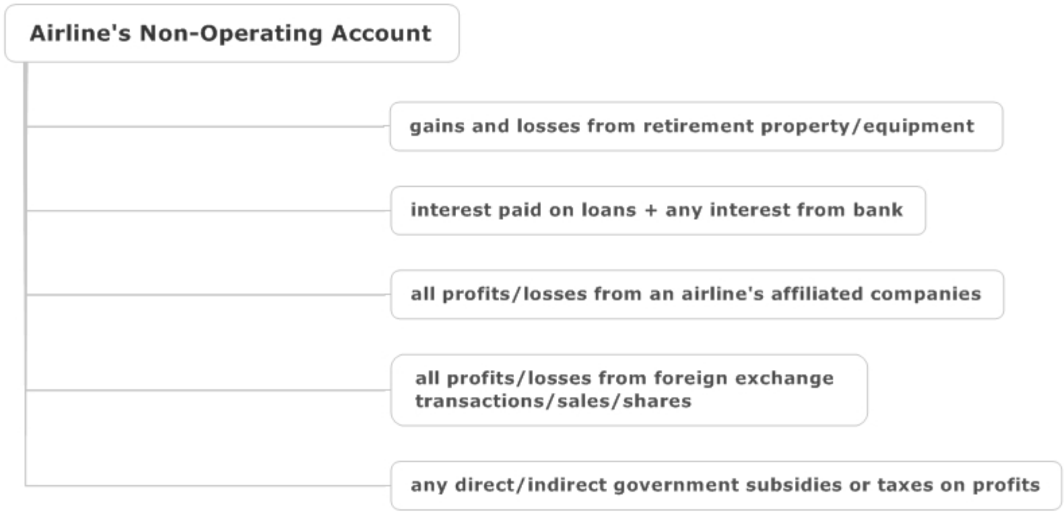


Figure 3-3: Schema of the Airline's Non-Operating Account

Source: Created by the candidate, based on Doganis (2002)

Presented airline's accounting enables a much easier allocation of the costs which occur due to delays and perceiving the importance of these costs to the airline.

Passenger-Service Costs include cost of in-flight catering, of accommodation provided for transfer passengers, for meals, and other comfort-ground accommodation. Premium paid for passenger-liability-insurance and passenger-accident-insurance, which are a fixed annual charge based on airline's total passenger-kilometres produced in the previous year are also included.

Refusing passengers in this research is not only an operational decision choice due to a shortage of the airline-seat capacity (including its alliance partners and any competitor airline at that particular market), but also caused by any other operational constraint. This happens in terms of refusing passengers without any recovery possibility, referring to the so called opportunity costs or spilled revenue costs (more about in Section 4.4).

3.3 Literature Review related to the Decision Making Process at the AOCC

In this section some deeper understanding of decision making processes at the operations control center, as well as the trend and the way of dealing with irregularities common in use at scheduled airlines today will be gained.

3.3.1 Tools to Supporting the Decision Making Process at the OCCs

Although there have been limited study works delivered on this subject, it is important not only to distinguish them depending on the problem dimension they are able to deal with, i.e. whether it is a solving recovery plan for a single problem or an integrated one that solves crew, aircraft, and/or passengers too (presented in Section 3.2), but also to identify the current tools in use at airline OCCs. This was the main issue of the observation in the recent work of **Castro and Oliveira (2011, p. 272)** who made the classification of these tools into three categories, according to the background processing service employed, which are:

(1) *Database Query Systems (DBQS)* as the most common situation at airlines that allows airline controllers to perform queries on the existing databases and to monitor the airline operation obtaining other data essential for decision making. Although these systems are very useful and relatively easy to implement and/or acquire, they have two main disadvantages: (a) the solution quality is dependent solely on knowledge and experience of the human operator; and (b) due to the usual difficulty of the human being in dealing with large volumes of data simultaneously, they do not use all the necessary and/or available information to take the best decision;

(2) *Decision Support Systems (DSS*), which have the same characteristics of the DBQS but include additional functionalities such as enabling large volume of data *and proposing solutions*. In this way DSS support airline controllers on considering much more information, enabling therefore taking better decisions;

(3) *Automatic or Semi-Automatic Systems (ASAS), which* automate the AOCC as much as possible replacing the functional part by computerized programs automating the repetitive tasks and searching for solutions. With the use of ASAS, the AOCCs do not need as much human operators as in the previous ones.

In any way, *the final decision depends on the human operators or supervisors*.

According to the given classification above, this thesis research proposes a scenario-based supporting tool that belongs to the Decision Support Systems (DSS) within the Airline Operations Control. It aims predominantly at monitoring of possible solutions and their quantitative and qualitative consequences as its main objectives, enabling more awareness of the operation controllers in the decision processes, though not intending to replace them. This may be particularly apparent when the disruptive events directly impact flight itineraries of the high-value passengers, where the final decisions have to be exclusively made by humans.

3.3.2 Human Decisions in the Decision Making Processes

Not solely because human reason is required for decisions in some special disruptive events, the inclusion of humans in the decision making process as a whole is determined by the selection of the alternative solutions with the highest utility among those available and/or possible at the moment of the decision, because humans will: (1) be responsible for the consequences of the particular decision and (2) make information validation and judgment, that will not exist in computer systems (Kohl, Larsen et al. 2007, p. 153).

For this thesis purpose of the prime importance is to gain the insight into ways in which operations controllers deal with perceived particular flight displays and how they gain situation awareness.

A much extensive understanding of the highly complex human decision making processes in aviation (necessary for establishing the suitable framework for tool development in this thesis) can be gained from the study observations demonstrated by **Bruce (2011).** Offering for the first time for public use a deeper insight in this specific area of the airline operations, the author, who has himself been for a long time period an operation controller working on disruptions, reports on the examination of the underlying human decision making processes at the OCC, led with an observed airline.

The main characteristics of the decision making processes, such as expertise, time, and information, the decision making process largely depends on the humans' ability to identify, access and carry out the actions required for solving disruptions, while mostly using a combination of their intuition and experience (Bruce 2011, p. 10).

Evaluations of the observations in Bruce's work which report on the ways and the art of decision considerations and decision-making-styles of the airline operations controllers have been adopted and applied for the concept of the supporting tool design in this thesis study.

3.3.2.1 "Decision Making" and "Problem Solving"

To be able to understand all the steps of decision making process, it is necessary to take a brief insight view into the main terms of this process.

The following definitions have been adopted from the research done by Bruce (2011, p. 10):

a) *Problem Solving* indicates an act mainly concerned with the search for possible options in order to achieve requested or designated target, choosing one among the possible options including the consequences of its possible outcome;
b) *Having a problem* means that there is a gap between an initial situation and a desired one;

c) *Decision-Making* indicates the way and steps of finding and defining a problem, and generating and evaluating solutions. However, decision-making may be seen as a problem-solving process with the decision as its solution.

3.3.2.2 The Two Styles of Human Decision Making

Capability of the operations controllers to develop their own levels of situation awareness regarding (i) the art how they consider the opportunities to overcome disrupted situations with numerous operational and commercial consequences or (ii) how they approach these situations, is crucial. Hereby their decision making style can be a rational or/and intuitive consideration of decision alternatives, whereby:

(i) *The rationale* decision making style is identified as a decision consideration in a very systematic way (step-by-step approach)

(ii) *The intuitive* decision making style is defined as a decision consideration of possible alternates relying on decision makers' good feeling, intuition, and experience which solution "might work" better than the other.

Although the intuitive and not the rationale style of decision making was propagated to be the most successful in conditions of very complex events with a high degree of uncertainty and time limitations, the final results showed that in high complex situations OCC experts rely on both styles, whereby surprisingly even more on a high-rational and some high-intuitive (a "sense of what might be working") decision making style (Bruce 2011).

3.3.2.3 The Three Levels of Humans' Expertise in Decision Making

To enable coping with a range of decision alternatives, the operations controllers may apply some strategies for consideration of the wide decision selection. These could be classified according to the degree of complexity of the considering situation. The term *complexity* is here used to point out the endless variety, uniqueness and combinations of operational problems (Bruce 2011, p. 10).

According to the findings from the observation made by Bruce (2011), it was possible to identify the three considerations levels on which human experts at operations control centers may consider the information in the process of resolving operations problems. Since the acquisition of situation awareness is a cumulative process, the ways of information considerations are actually its sub-categories. These are:

(1) *The Elementary Level* indicates the consideration of the fundamental aspects such as crewing, weather, and flight planning and maintenance, important for gaining initial situation

awareness. Identifying the likely consequences of potential disruptions, the controllers are mainly focused on key relevant information from the flight display;

(2) *The Core Level* is the consideration not only of ways to resolve the problem, but also identifying of constraints and working within them, as well as looking for alternatives;

(3) At *the Advanced Level* operations controllers seek the ways to *avoid* rather than to *reduce* the consequences of disrupted events, through assessing the situation quickly, identifying a number of the particular situation consequences. Beginning to devise contingency plans by taking into consideration the alternative actions, the OCC experts are able to comprehend the complexity of the situation.

3.4 Literature Review related to Influence of the Airline Service Quality on the Passenger Satisfaction and Loyalty

This section reviews relevant studies regarding the level of satisfaction of air travel passengers with the level of service quality provided by an air (full service) carrier, supporting airlines' reliability in the air transportation as well the passengers' loyalty to the airline.

It is divided into two subsections according to the direction of effect and valuing of the level of service quality as delivered quality (by carriers) and as perceived quality (by passengers).

For the purpose of this research the implications of a trip delay experience as a possibility which may affect passengers' switching to the other airline will be considered, causing in this way the loss of future ticket revenues. However, it should be kept in mind the fact that the economics of delivering punctuality vary not only from airline to airline, but also from flight to flight, and from minute to minute (Cook, Tanner et al. 2012, p. 16).

3.4.1 Service Quality Delivered - Airline On-time Performance (Reliability)

Although different customers may require different level of service quality (SQ), for this thesis purpose it is needed to identify the major determinants of the carriers' operational qualities that directly impact the travelers' choice and satisfaction.

While well-known is that an on-time performance and cancellations do affect the airlines image, there is a range of attributes representing carrier's level of service that can be found in the literature. However, o*n-time performance* seems to be "a must" SQ-attribute. Within various aspects of service quality, also the importance of belonging to the frequent flyer programs as a significant figure in the relationship between passengers' satisfaction and their loyalty to an airline will be taken into consideration.

Shipley and Coy (2009) have identified 5 operational parameters based on length of haul, having an impact on an ideal airline performance. These are taxi-in time, taxi-out time, on-time arrival, turnaround time, and cascade delay. They found out, only the *on-time arrival* has a direct impact on the *perceived quality of flight service,* especially on flights that are feeders to multi-segment flow(s), whereby some flights may be important more for marketing reasons. It was emphasized that the business passenger demands greater quality than the leisure one, suggesting that it is “worse to lose a business passenger”.

Considering the airline profitability, Bratu and Barnhart (2004, p.1) emphasized how *on-time performance* and *service reliability* are important for achieving long-term profitability, identifying the *flight schedules* and *ticket prices* as its proven main drivers.

In the book of airline economics of O'Connor (2001) the term “*quality of service”* refers to *flight scheduling* and *load factor*, whereas “quality” is employed to include the time between “when a person would like to depart” and the time “the flight is scheduled” and the chance that that person will get space on that flight. The meaning of the “value of service” to each passenger determined by a complex c*ost* of service–*value* of service interaction was examined. It was concluded that the “value of service” is often greater to a business-traveler than to a tourist/leisure traveler. The business-passenger is far less sensitive to fare changes then is a vacation traveler. The *value* of service on a long trip is greater than on a short one.

Proussaloglou and Koppelman (1999) identified the main operational quality as *on-time performance*, direct flights, and baggage handling as influencing factors on the individual travelers’ choice, concluding that business and leisure-passengers are willing to pay (more) to avoid schedule delays, and suggesting that the particular offered level of service is conditioned by airline economic principals.

In his observation of an impact of airline *on-time performance* (i.e. reliability) on customer re-purchase-intent by the same airline, Narasimhan (2001, p. 11) concluded that the delays have an average impact level on customers’ repurchase-intent by an airline, whereby travelers’ tolerance decreases significantly when delays exceed 30 minutes.

Suzuki (2000) used 4 variables to capture the service quality of an air carrier such as *on-time performance*, *over-sales, mishandled baggage*, and *in-flight food quality*, measured to the industry average figure.

Though the level of service quality of a carrier is widely used to be seen in terms of disharmonised characteristic-combinations that are classified into several different groups of SQ-attributes, common and the most important aspect of the service quality measure of an airline is its *reliability or on-time performance*.

The particular set-up choices of SQ-attributes examined in the literature differ in their concepts and purposes which make the establishing a single definition for probably covering all types a little bit difficult. But, regardless the examination concept and/or purpose they all include, an *on-time performance* feature can be found in each chosen set of service qualities examined.

An overview of the selected study works on this subject is shown in Table 3-1.

Table 3-1 : Selection of the SQ-attributes of air carriers examined in the literature

Sources	*Research objectives*	*Examined SQ-attributes*
Proussaloglou and Koppelman (1999)	Quantifying importance of the chosen SQ attributes on the carrier's demand	1. Carrier's overall presence in an origin market 2. Overall quality of service 3. Reputation 4. Its FFProgram
Sultan and Simpson (2000)	Explored if consumer expectations and perceptions of the airlines' SQ vary by nationality (EU and USA)	5 Dimensions of overall SQ: 1. Tangibles 2. Reliability 3. Assurance 4. Responsiveness 5. Empathy
Suzuki (2000)	Modelling the relationship between Paxs' on-time arrival experience and market share in the airline industry	On-time arrivals
Suzuki, Tyworth et al. (2001)	Developed a model representing the relationship between Service Quality and market share in the airline industry	1. On-time performance 2. Over-sales (overbooking) 3. Mishandled baggage 4. In-flight food quality
Tiernan, Rhoades et al. (2008)	Analysis of the service quality of the members of the main airline alliances of EU and USA	1. On-time arrivals 2. Baggage-reports 3. Flight cancellations

Source: Created by the candidate

Modelling the relationship between the carrier's on-time performance and its market share (i.e. airline demand), Suzuki reported on that, when experiencing flight delays once, passengers are more likely to switch airlines arguing how an on-time performance affects a carrier's market share not through the "advertisement" of its performance, but primarily through the passengers' experience and perception (Suzuki 2000, p. 139, 152). For the approximation of the passengers' switching behaviours, this author suggests this method to be taken only as a "quick and dirty", because the carrier's on-time performance may not be the only one reason for the passengers' decision on switching to another airline.

SQ attributes such as carrier's *on-time performance, over-sales*, *mishandled baggage*, and *in-flight service quality* were chosen for the examination of the effects of the carrier's service quality on its market share in a study of Suzuki, Tyworth et al. (2001). They took the measure for the service variable to be in relation to the median market reference point represented through the service quality and price levels at time *t*. Interestingly, they found out that if an airline's service quality falls below the market reference point, its market share will decrease significantly. But if the service quality increases from the reference point, this will not implicitly increase an airline market share. This is based on *the loss aversion theory* (i.e. human choice behaviour tendency theory) which suggests that consumers evaluate product/service-attributes relative to a certain reference point or their expectation, reacting more strongly to losses than to the equivalent-sized gains. Also Teichert et al. (2008), cited in Cook, Tanner et al. (2012), have shown that punctuality is a dominating factor among the interviewed frequent-flyer programme (FFP) members on European short-haul routes.

Sultan and Simpson (2000) have explored whether the passenger Service Quality (SQ) expectations and perceptions vary by nationality (comparing European and US passengers). Their results supported the rank order importance of the 5 SQ-dimensions, such as: Tangibility, Reliability, Responsiveness, Assurance, and Empathy, indicating the Reliability to be the most important SQ feature while the Tangibles as the least important. The authors concluded that passengers' both, expectations and perceptions, of the carrier's service quality *do vary* by nationality (2000, pp. 200 - 201).

The latter findings might give an explanation why some high-level SQ-attributes offered by few scheduled airlines on their long-range flights between Central Europe and Middle East are greeted in superlative by majority of the first-class passengers originating from the Middle and Far East. (E.g. cabin-crew comes each 1-2 hours into the separated single-cabin, being not permitted to be locked, to check if anything needed and/or everything OK, awaking the (usually) slept passenger). Whereby, following findings of an inquiry made for these flight destinations at an European airport within completion of this research (known to the institute where the thesis has been done), the same SQ-attributes have been critically seen by the first-class passengers mostly originating from Northern and Central European countries causing rather irritations (because, these want, for example, only to be left alone to sleep, for to become fit and prepared for important meetings taking place soon after the arriving at the destination airport). This is especially noticeable in case when the business passengers become extremely annoyed with the application of some even needless or redundant service features when flying in the first class area to the international/intercontinental destinations for the business matters. An obvious discrepancy in the perception of these high quality service features by different travellers experiencing the same SQ might be explained by the differences in the culture (i.e. Eastern/Western) and life expectations of the travellers. Also, some reasons referring to the business position, duties and responsibilities of the business passengers certainly play a significant role in service expectations and experience when travelling on a long-range flight.

However, some confirmation references can be found in the literature. Considering the pricing strategy of an airline and explaining the three basic fare-types according to the separate cabin classes (first-, business- and economy- one), Doganis pointed out that “On most European routes and a few long-haul routes, there are may be a first-class fare, agreed through IATA, but no first-class service” (Doganis (2002, p. 278).

Proussaloglou and Koppelman (1999, p. 3) chose following SQ attributes of an airline: its *overall presence in an origin market*, its *overall quality of service and reputation* (here emphasized as “reflecting a *carrier’s on-time performance*, its safety record, and the terminal and on board amenities”), as well as *its Frequent Flyer Program* which reflects the loyalty-inducting influence on travellers’ carrier choice. They have used the results to quantify the importance of the SQ attributes on the carrier travel demand.

In the study of Tiernan, Rhoades et al. (2008) the service characteristics such as o*n-time arrivals*, *baggage-reports* and *flight cancellations* are recognized as the key areas of estimating the airlines’ service quality. The authors took the officially reported service quality indicators from statistics international airline alliances, observing and determining *a remarkable overall similarity* in the service quality delivered.

3.4.2 Passenger’s Satisfaction with the Level of Service Delivered

The literature supports the findings that the time that customers most want to avoid is the *transfer time* which has therefore the highest value to the travelers followed by *travel duration time*. Especially the passengers with a high value of time (as business passengers) consider *connecting flights* to be an inconvenient and unreliable service (i.e. through the number of connections and flight duration) Cho (2012, p. 69, 76). The author cited the findings of US Customer Report (2010) of the 12 top grievances among flyers in the U.S. and among their top complaints (regarding air travel), *the luggage charges*, *added fees* and *rude or unhelpful staff* are on the top of the list (Cho 2012, p. 218).

Juga, Juntunen et al. (2012) examined the influence of perceived operational *service quality* on *buyers’ satisfaction* and the *buyers’ loyalty*. The authors confirmed that the buyers’ overall satisfaction with the perceived carrier’s SQ positively influences the buyer’s loyalty. The investigation showed that the customer loyalty depends on customer satisfaction, i.e.: (1) perceived quality influences overall satisfaction which affects loyalty, whereby *an image has an indirect effect on loyalty - via satisfaction*, and (2) outsourcing relationships (perceived service quality – customers’ overall satisfaction) affect loyalty directly without an impact on satisfaction that is so-called “halo effect” (Juga, Juntunen et al. 2012, p. 8). Giving an overview of evolution of loyalty conceptualization, from its initially behavioral dimension (simply measured proportion of re-purchase), till the attitudinal and cognitive dimension (related with the consumer’s decision-making process by the evaluating the product), they emphasized that loyal customers are less costly to than acquiring new ones, since they increase firm's revenues through repeat sales and referrals (involving also advantages for themselves through functional benefits such as time savings and convenience) (Juga, Juntunen et al. 2012, p. 3).

Yang, Hsieh et al. (2012) used simple structural modeling to investigate relationships between service quality, airline image, customer value and behavioral intentions for passengers to fly with Low Cost Carriers (LCC), focusing on flyer's expectations of the types of services that they can enjoy.

Their analysis indicates that the service quality has a significant positive effect on the customer value especially in terms of reliability, tangibles, responsiveness and assurance, suggesting that they care not only about low prices, but also about other service quality issues. Arguing that airline's image does not itself significantly influence behavioral intentions, they concluded how customers' repurchase intentions are essentially determined by the perceived value, emphasizing the importance of their own sources of information and prior experiences.

3.5 Conclusions

The presented works provide a sound basis for this thesis research acting as a basic framework for the design of a supporting tool for airline operations controllers.

As shown above, it has not been easy to come up to at least homogenous estimation of the passenger delay costs. The approaches vary from classifying them into "hard" costs, which are monetary measurable and "soft" (or social) costs, which are hardly monetary measurable. These terms refer to the "value of time", what is again, particularly in the transport industry, a specific issue. This can ranges till just using a certain monetary value and applying it to the passenger delay costs.

A homogenous estimation, in a reliable and proper way for both passengers and carriers, could be possible if the use of these considerations would be relevant for all passengers and each carrier, based on a unique and universal approach.

Indeed, as Levinson, Gillen et al. (1998) emphasize questioning whether the value of time saved in transport shall or can be greater or less than the wage rate as the valuation of work, and, whether to consider this as a positive or a negative consequence of it. Within many approaches for valuing the travel time, some experts take the value of time for the business traveler to be the wage-rate, as travel substitutes for work, ignoring any differences in the quality of both the trip and the work (i.e. the work which can be done while traveling), as well as at what time occurs much business travel, which creates also problems in valuing the time *of non-business travel (ibid, p.25), explaining it as follows:*

The wage rate cannot be assumed to be the only factor used in estimating the value of time. Since travel itself is an intermediate activity, and thus provides no utility, the time saved in travel (for instance, due to an improvement) can be spent either consuming leisure activities or earning income. Therefore the value of the time in travel must be compared with its time at work and at home.

The main focus of this thesis is on delayed connecting flights with high-valuable or important passengers to the airline, such as business travelers and Frequent Flyers, since this plays an important attribute of the passenger choice options in their decisions on satisfaction with a delivered service quality when experienced delay with an airline.

According to the very limited literature, presented in the Section 3.4 as well as from the reports on experience at operations control centers with European airlines, the operation controllers have very little or no possibilities to check the quality of their decisions. Although equipped with the various supporting computer-based tools and utilities available, operation controllers are not able to possibly compare the quality of other decision options available, sometimes even not until aftermath of the recovered events. This thesis research offers one possible solving solution on this issue. The basic knowledge of the main terms and definitions gained from the reviewed literature, as well as a better understanding of highly complex decision making processes in aviation gained from the study work done by Bruce (2011), will be applied for the conceptual framework of this thesis research.

4 Level of Service Modelling

4.1 Introduction

In this chapter the methodology of the research is presented in the following order: a particular every-day operational situation which is modelled is presented for to be introduced into the designed modelling of the service quality attributes of both, delivered by the carrier and perceived by the passengers. The service quality attributes are chosen according to the available literature findings, for to be ranked and categorized by applying a proposed model, in order to enable its use as one of the main impacting decision factors implemented into the designed decision support tool.

4.2 Background and Outline

Examination of the Service Quality (SQ) attributes in the decision making process at the Airline Operations Control Centre (AOCC) which have a higher impact on the passengers' goodwill in this research refers to the travellers' satisfaction with the service quality provided by the chosen airline, whereby the reliability of the particular airline has been considered from its operational viewpoint.

From its operational dimension, the service quality (SQ) has been seen as the corporate image and reputation referring to the customers' perception of the SQ performed. Coming out from the long-term experience (i.e. firm's credibility) service experience and satisfaction in turn have a significant positive impact on customers' loyalty (Juga, Juntunen et al. 2012, p. 3).

On the other hand, in order to maintain brand quality for customers, major airlines have undertaken airline alliances agreements, code share and franchise agreements which have led to airlines requiring certain service levels and safety standards to be achieved (Francis, Humphreys et al. 2005, p. 2).

Previous studies confirmed that connecting flights increase the travel time, incur inconvenience of changing planes, adding connecting time and causing passengers to experience the undesirable effects of the flight delays and lost baggage. According to Adler and Colder, cited in Cho (2012, p. 69), the number of flight connections negatively impact the customers' choice of flight itinerary making them to avoid connecting flights due to unreliability of experienced connecting operations. Since trips with fewer connections result in a shorter in-flight travel time, eliminate waiting time for connecting flights, and constitute a lower chance for facing connection disruptions and in particular missed connecting flights, they lead to a greater reliability and greater convenience (*ibid*, p. 54).

However, for the operational, strategic, but mostly for economic reasons, scheduled airlines' networks usually rely on the hub-and-spoke configuration, offering not only the direct or nonstop flights, but also supporting some considerable advantages in terms of better meeting passengers' demand and better exploitation of a particular market. Wave-structured network, typical for hub-and-spoke, allows the airlines to offer (i) a wider range of destinations known as generating economies of scale, and (ii) higher flight frequencies known as gaining economies of densities, where the latter is the primary factor of an inherent cost advantage over smaller or regional airlines, attaching a major importance to the length of individual flights (Caves, Christensen et al. 1984, p. 3).

When considering delays in the air traffic, the following has to be differentiated: *where* they occur (on the ground i.e. at-gate, on taxi-way, or in the air i.e. en-route), *how* they occur i.e. if trigged by current flight-leg, propagated from earlier flight-leg(s), or, as a result of "knock-on" effects on the day of operations execution caused by the different aircraft and/or different flight, as well as *why* they occur (due to airport's and/or airline's operations, weather constraints, or air traffic flow management en-route). Hereby, one of the most important aspects of flight delays is their economic side - the delay cost to the airline (i.e. per passenger, per minute), which is dependent on the ticket prices and the length of the delay. This is especially noticeable when the airline is required to compensate the delayed, as well as particular "denied boarding"- and stranded- passengers.

For ensuring operational and economic aspects of the service quality, airlines make an effort to retain the reliability or on-time performance whenever possible for both above-mentioned reasons. Hence, in attempt to meet the customer requirements, the airlines have also to deal with an inconsistency between the customer satisfaction and the SQ improvement.

Considering the passengers' side, some passengers are satisfied with the service delivered, while others are not even by the same level of service quality, which sources for this discrepancy Cho (2012) recognized as:

- An improvement in the *wrong areas* (the airlines improve rather the quality in some other areas than those needed or expected by passengers)
- An improvement for *wrong customers*/passengers (due to some different individual characteristics some customers might be easily satisfied with the improvements, while others might be not).

Since the business travellers put emphasis on travel time, *transfer time is the time that travellers most want to avoid* (Cho 2012, p. 76). As customers with a high value of time, the business passengers consider connecting flights as to be an inconvenient and unreliable service (ibid, p. 77), for being sensitive to the number of connections in their flight itinerary due to the unavoidable travel time adding which they perceive as the loss in its value (i.e.

value of flight-itinerary) and an increased chance of missing the scheduled arrival time (Adler, Falzarano et al. 2005, p. 25).

Referring to the focus of this research on decisions on departure delays caused by waiting for the arriving-delayed high-valuable passengers of inbound flights, hereby into consideration taken is not only the airline SQ performed but also the satisfaction of these passengers with the carrier's service level delivered.

4.3 Theoretical Background

Within execution of disruption management decisions at the Airline Operation Control Centre (AOCC), it is difficult to determine a *common* quality level of any recovery option when it is about to take a decision on disruptive events. The airline operations controllers usually have little or no help in estimating the quality of their solutions when they are about to implement one possible solution into the recovery flight plan (Clausen, Larsen et al. 2005, p. 4). The authors explained this through a composition of several so called non-quantifiable conflicting targets, which they supposed to have been involved in each of possible solutions, such as delivering the promoted or promised level of service to the as much as possible desirable passengers' satisfaction. On the other hand, according to the airline's business policy, an effort is always returning to the original plan as quickly as possible, while minimizing both the number of passenger delay minutes and the cost of the particular recovery operation at the same time.

The role and tasks of the Operations Control Centre (OCC) of an airline are already represented in more details in Ch. 2 of this study. At this place, they will be emphasized since its main responsibilities are to monitor the flight operations and solve the problems. Their overall objective remains always the same: to minimize both the impact of the decisions on passengers and the additional costs to the airline.

Defining the Disruption Management of an airline, Kohl, Larsen et al. (2004, p. 2) stated it *as actually and practically its Operations Control with the role of its Disruption Management* at the same time. However, in the current practice at most large airlines the resource-recovery hierarchy order is strongly defined and followed when disruptive events occur: firstly the aircraft-recovery is to solve, then crew-recovering plan, ground operations problems, and lastly the implication of these recovery decisions on passengers inconvenience will be considered (Clausen, Larsen et al. 2005, p. 3). Hereby, the role of the Passenger Service is to prove the passenger-recovery possibilities while minimizing their inconvenience as well the additional costs to the airline.

A starting hypothesis in this research is based on the implementation of monitoring of each decision solution and its accomplished level of service quality respectively.

In the next three sub-sections the decision making process in steps, in terms of *what* and *how* the controllers do act in their striving for the capability to manage disruptive events in the all-day operations execution, in detail is presented.

4.3.1.1 What the Operations Controllers Do when Disruptions Occur?

One recovery option in common practice always can be “doing nothing”, letting the network naturally absorb the disruption. Generally seen, different recovery tactics i.e. reactions on disruption depend on the scale of disruptions where, according to Wu (2010), the *minor* disruptions cause delays less than 1h while the *major* ones cause delays more than 1h.

Disruption management currently in use at most of airlines can be described as a process consisting of the five main steps (Castro, Rocha et al. 2012, p. 1430):

(1) Operation monitoring

(2) Taking action (after a quick cross-checking if an action is required)

(3) Generating and evaluating candidate solutions (usually in a sequential manner), considering also the costs

(4) Taking decision (choosing one solution between possible candidates)

(5) Applying decision where the operational plan or a new one will be accordingly updated or adjusted. This means, it will be continuously monitored whereby the main actions that can be taken by dispatchers according Babić, Kalić et al. (2010, p. 258) are:

- *Delay flight*, which directly affects the passengers on that flight, and indirectly the passengers on following flights in the rotation of the particular aircraft;
- *Swap aircraft*, which deploys a different aircraft to service the flight and not in its original rotation, if the capacity matches the number of passengers on the given flight;
- *Cancel flight*, an extreme option both for passengers and the airline, which may cause serious disturbances;
- *Ferry flight*, an option which lets an aircraft fly without passengers;
- *Introduce spare aircraft*, possible if an airline has a spare aircraft resource only.

4.3.1.2 Situation Awareness when Disruptions Occur

For the development of a decision supporting tool, the most important is firstly to generate the solution possibilities and their driving attributes when solving a problem. In such complex situations, it is very important as a key factor in the decision making process for the operation controllers to develop their own levels of situation awareness in order to manage airline operations disruptions (Bruce 2011, p. 155/157).

Since the acquisition of situation awareness is a cumulative process, the accumulation of information, which is often achieved through re-checking the information provided in dealing with the disruptive events, is fundamental (*ibid*, p. 106).

4.3.1.3 The Way the Controllers React on Disruptions

In the process of managing disruptive situations and the search for the best (if possible, optimal) solution before taking a decision on irregular operations, the operations controllers have to come along to a certain degree with some common i.e. standard actions and reactions required for gaining situation awareness while considering a wide selection of decision alternatives. Following findings done by Bruce (2011, p. 110-120), these actions can be summarized in the following steps:

(a) The controllers are required to access the situations in individual scenarios through the monitoring explanation and execution;

(b) They identify sources of potential disruptions particularly regarded maintenance aspects;

(c) Assessing the cross-checking through (for the day of operation), they look for potential threats that may disrupt the operations as well as the weakness that could be exploited to help in resolving;

(d) Generating decision alternatives, the controllers consider the fundamental aspects of the scenarios identifying ways to overcome the limitations of a situation.

The above-presented conditions and influencing factors of the decision making processes environment at the AOCC are taken into consideration for the design and architecture of the proposed support tool.

4.4 Terms and Definitions

This section presents the main assumptions and definitions that are needed for creation of the algorithm and for designing the supporting decision tool. This is also useful for a closer understanding the conditions and relationships that take place in the process of decision making on particular disruptive events within the airline's all-day operations execution.

(1) The term *high-valuable or high-fare passenger*, introduced in Subsection 2.3.3.1, in this research refers to the economic value of a passenger to the airline, which can be acquired by the highest ticket price purchased, or by any higher flyer-status that a passenger may

acquire at the particular airline The reasons for which these passengers are of the most importance for scheduled airlines are based on research literature findings on importance of FFP-members and business passengers for the airline industry, being considered as the ones who are enough worth to be waited for, even if it might cause some delays and possibly adding costs.

(2) *Level of Service (LOS)* of an airline is defined as on-time performance or its reliability. *Service Quality (SQ)* has been seen as a measure of how well the LOS quality delivered matches customer expectations (Yang, Hsieh et al. 2012, p. 1).

The term *service quality (SQ)* of an airline is the key to customer retention according to Payne and Holt cited in Leick (2007, p. 21). Hereby, the term *quality* refers to customers' expectations and perceptions, and the term *delivering quality service* refers to the responsibility of everybody in the airline and particularly of the whole its staff i.e. on the ground and in the air.

(3) *An Airline-policy Prioritisation* will have each frill or scheduled airline according to which it will deal with the different passenger groups in terms of "who" or which passenger group is *more important,* as well as whether the declared priority shall be in force for the whole network or should apply only onto particular flights on critical and/or specific route or city-pair. However, this priority policy may refer to the specific passenger-groups or to the "special passengers", independently on which flight they are travelling on.

In practice, for some airlines this can be due to its determined priority in terms of reliability or on-time performance, no matter the delay cause and/or who the passengers are. For another airline this can be, for example, an "attempt to keep the high-valuable passengers to their satisfactory with the promoted and service quality which is paid for", taking into account that relying on this policy can sometimes lead to some adding costs and with the time generally to downgrading in its performance. For others, the priority policy might be "to keep always its revenue higher than cost" whereas the airline will always be attempting to avoid all possible extra costs not giving a priority to the high LOS performance.

(4) *Airline Prioritisation Strategies* considered in this research are the followings:

I. Of a particular importance in dealing with delays on departure can also be "*who*" on those flights the passengers are, in terms of Personality/Name/Position (i.e. VIPs), which satisfaction/dissatisfaction with the service quality delivered by the carrier might critically influence the airline's business reputation. Therefore, under particular circumstances the operation controllers may be required to pay more attention on the successful availability of the connectivity (particularly of those passengers) than on profitability of the airline for that particular flight. This decision item is modelled as *the* priority *LOS to the passengers*, referring to the corresponding airline priority-strategy

II. When the operation controllers are required to decide which is the one passenger-group they should give the priority, or which one is "more valuable or important" to the airline, a *passenger weighting value* is applied (comparing the prices of the tickets purchased)

III. If there is “the same-value” of the passengers to the airline considering departing and arriving ones (and this, according to the ticket-prices), then the number of passengers of each Pax-group will be considered

IV. When the airline-policy prioritisation is based on the revenue objectives in terms of maximizing revenue or, at least, minimizing losses, *the priority of operating profitably* (i.e. to keep revenue higher than the cost per flight) is modelled.

(5) *The Overhead Costs* due to delaying the departure of an out-bound flight can occur as extra costs for any airport and/or ground handling operation extra charges (e.g. extra costs for a ramp agent, baggage transfer/handling, or any adding standing charges), extra passenger-costs, and an additional fuel burn in order to compromise or, at least, to smooth the ground delay on departure (by flying with a higher speed than the calculated flight-optimums). Accordingly, any *extra crew costs* for additional minutes beyond their planned duty time (i.e. marginal crew costs incurred by airlines during delays per flight), including any extra *aircraft maintenance* (relating to mechanical attrition of aircraft waiting at gates or some other position on the apron) should be added, as argued Cook and Tanner (2009, p. 4).

(6) The O*pportunity Cost* per passenger includes not only the lost revenue for that flight leg, but serves as a measure of the expected revenue *that would be lost* on connecting flights that the refused passengers *would have flown* as emphasized in the study by Klincewicz and Rosenwein (1995, p. 6), meaning in the future and with that particular carrier.

In this research, the opportunity cost is taken into consideration as an *economic consequence* of delays in terms of lost-revenue from the purchased passenger ticket while adding the cost of value of time (VOT). In terms of its *social consequences*, the opportunity cost is treated as a *low level of the service quality* both, delivered by the carrier and perceived by the passengers.

(7) *The Maximal Allowed Delay* is the pre-defined maximum period of time that an aircraft can wait beyond the planned departure time. This is specified by the particular airline according to its business policy and for each aircraft type, as well as for each flight (city-pair). However, each airline can decide to act else than according to its defined policy-priority, especially by emerging disruptive technical or operational constraints and/or shortages and changes. This amount of time refers to the fundamental conflict in operational trade-offs between implementing slacks, which are built-in non-productive times into the planned schedule as means for absorbing disruption, and therefore missed opportunities to utilize costly perishable resources (Ahmad Beygi, Cohn et al. 2010).

From the airline’s operations point of view this can, for example, appear as following: for the domestic or continental flights the airline set up the maximum waiting times on half an hour, while for its international or intercontinental flights it can be set up on maximum one hour. This means that after these time-limits the airline cannot wait any longer without loses and will depart, which translated into terms of this research conditions would mean, without its arrival-delayed connecting passengers. However, this general rule can be disregarded only for/due to waiting for its in-bound high-fare passengers delayed in arriving. At this place, also a need of assistance in supporting of making this kind of decisions can be recognised.

(8) *Slot-regulated or Priority Flight* in this research refers to the operational definition, widespread understood as a slot-regulated or slot-constrained flight, differing from the established well-known definition for *priority flights* coming from the air traffic safety and ATFM issues. In this research applied flights are regulated by the air traffic authorities (i.e. Air Traffic Network or Air Traffic Flow Management) or, these are the flights with assigned time frames for their departure/arrival times. According to the slot definition given, *the slot is actually a period of time within which the take-off takes place. In Europe this is defined as the time frame between −5 and + 10 minutes from calculated take-off time (CTOT)* (http://www.eurocontrol.int/articles/about-atfm-slots). Hereby, slots are determined by the air traffic control authorities considering the airlines planed scheduling, current weather conditions and air traffic flow management en-route, as well as the operational constraints and/or restrictions of the origin and destination airports (city-pairs).

(9) The Issue of *the New Slot(s)* considered in the proposed tool refers to the Eurocontrol instruction about this issue: “If a slot is missed or if it is already certain in advance that it will be missed, the Network Operations Centre assigns a new one. A different aircraft which has a slot because of the same regulation may be issued an improvement on its slot to make use of the newly available capacity” (*ibid*). Coming from the Air Traffic Control side and impacting the decision on to wait/not to wait beyond the planned departure time, important is to take into consideration whether the new slot *is available* and for the airline *convenient* i.e. achievable. This means, primarily operationally available/achievable and, if possible, not bound to the re-routing while being airborne (since flying on a longer route can cause a burning up of an adding amount of fuel).

(10) *The Passenger Recovery Plan* is the airline’s appropriate plan for the passengers’ reassignment to their best flight itineraries for bringing them timely to their final destination(s). In other words, airline’s passenger-recovery plan must be built so that ensures enabling all disrupted passengers to get their destination-airports by certain times. This is often considered in the research literature as the passenger re-accommodation. It is defined as the time required for transporting the customer on an alternative flight itinerary to that passenger’s destination (Marks and Jenkins 2010).

4.5 Model Design of the Level of Service

According to the definition given by Wu (2010), as emphasized the threshold of delays is set to be one hour, generally two kinds of disruptions are used: *minor* (causing delays till up to 1 hour) and *major* ones (causing delays longer than 1 hour).

In this section a scenario of the particular minor disruption event i.e. the delay due to late high-valuable passengers in the all-day operation executions at the airline operations or its hub control centre is described.

4.5.1 Introduction to the Modelled Operation Situation

Among the main possible reasons for the *flight departure delays*, there can be found irregular events caused by: aircraft delays (e.g. from previous flights), crew delays, cargo/baggage loading delays, as well as delays of the passengers.

At most airlines, operation controllers are required to consider predominantly three main operations aspects: aircraft-maintenance, crewing, and passenger boarding and tranships (Bruce 2011, p. 88).

In any case, the controllers will always be attempting:

- To solve the disruptive event both timely and locally, and
- Not to allow that an irregular event expands through the network and/or through the rest of the day or in some cases even longer, up over few next days (i.e. “ripple” effects throughout the day and/or network).

The focus of this research is on modelling the situation where the airline controllers have to make a decision on delaying the departure of an out-bound flight in order to enable the connecting high-valuable passengers from the late in arriving in-bound flight to reach their following flight-leg for to bringing them to the final destination. Hereby, also considered are especially the origin high-valuable passengers on the out-coming flight who might miss their further flight connections due to the delay on departure of their origin-destination flight.

4.5.2 Possible Decisions

In an all-day operations-execution situation, the controllers are required to decide on to wait or not to wait for some times just (a) few of high-valuable passengers who are late on arriving of an in-bound-flight for their following connecting flight to their destination-airport(s). This scenario can be described as follows:

“The in-coming flight F1 departed from the airport A is late on arriving at the airport B, where the aircraft of the out-coming flight F2 is waiting (sometimes as already “ready”) for the departure to the destination-airport C. Hereby, some of the passengers on the flight F2 have to be enabled to reach their following (onward) flights, which have to depart from the airport C.”

Figure 4-1 shows a simplified network example, representing the above described situation, as two successive flights where the flight F2 shall wait for the flight F1 to arrive, which carries the connecting passengers as well as high-valuable amongst.

Figure 4-1: A simple network-example representing two successive flights: F1 (A to B), F2 (B to C)

Such a quite common all-(every)-day situation in the airlines’ operations execution can be presented in more details as follows:

(i) The aircraft of the flight F2 is at the gate of the connecting airport B

(ii) The Ground Handling Operations are completed

(iii) The Origin-Passengers are already put through the airport operation utilities (check-in procedure and baggage handling, as well as custom and security check are completed); it is expected that the origin passengers for this particular flight are ready for boarding or the boarding is already on-going

(iv) The aircraft of an in-coming flight F1 is late on arrival, carrying connecting passengers to be taken onto the out-bound flight F2 for flying to the destination airport C.

From the departure-*time* point of view, this situation is shown in the figure below:

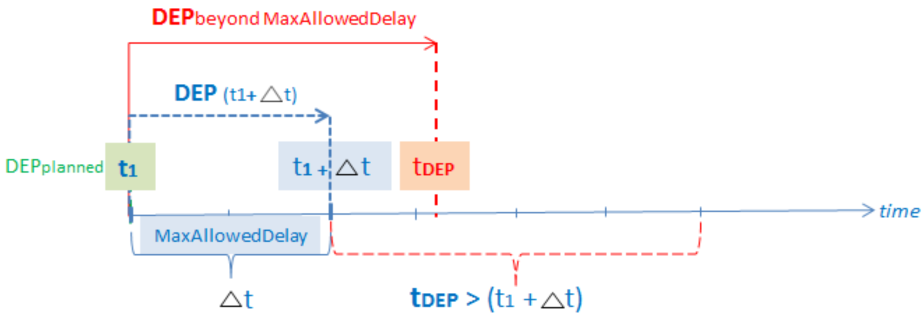


Figure 4-1a: Departure-time after the defined "maximum allowed delay" time

The operational situation shown in Figure 4-1 being seen on a departure-time axis is illustrated in *Figure 4-1a* which can be described as follows: the departure of the flight F2 scheduled for the departure-time t_1 (in green) may depart within the „maximum allowed delay" time, which is defined by the airline business policy, being signed as Δt (in blue). Indeed, it is quite possible to depart also beyond this time. If the flight F2 is waiting for the delayed in arriving in-bound flight F1, it will depart at the time moment which lies somewhere beyond $t_1 + \Delta t$ (signed in red). This research focuses particularly on this kind of delay-decisions.

What can the operation controllers do to solve this disruptive situation?

Generally, if a flight is delayed, from the possible general actions available in dealing with the problem and irregularities according to Castro and Oliveira (2011, p. 16) the operation controllers may choose:

(a) To assign the passenger to a later flight

(b) To re-assign/reroute the late passenger to another (as initially booked) flight-leg(s) to the destination airport, or

(c) To delay the actual flight waiting for the late connecting passengers, and finally,

(d) Although as the worst solution from the passengers' point of view, due to operation constraints the controllers can decide "to refuse" the late passenger(s), letting the Passenger Service at the connecting airport to search for another available transport solutions and for organizing the re-accommodation and/or compensation of the passenger(s).

These choice possibilities are taken into consideration for the creation of the multi-criteria algorithm of the proposed tool, displaying each solution in conjunction with its accomplished consequences in terms of airline delay costs and the level of both quality of service performed and the passengers' satisfaction with the quality of service delivered.

The most relevant exploring questions at this place would be:

(1) How to determine and model the reference point till which an airline can try to keep the retention of its service quality perform? And, what is the "price" of a reliable carrier?

(2) How far would the monitoring of qualitative and quantitative attributes (as outputs) of each available decision solutions: (i) help in dealing with such disruptive events and (ii) support taking better decisions?

Hence, could it aim at developing of a better operation control strategy of operation controllers through trainings and/or simulations in this way?

For the purpose of the proposed human-centred design tool and for its multi-solutions algorithm, as well as for a more precise insight into the modelled situation, it is useful to divide the modelled disrupted situation into two separated situations. Separated entities are presented in more details in the text below. In practice, however, they have always been considered as being merged into one entity in the decision process, when it is about to take a decision on above described situation.

The *first* situation refers to an all-day operation situation where to make a decision on the delay of an out-bound (out-coming) flight in order to wait for an in-bound flight is required.

In-coming flight F1 is late on arriving carrying the high valuable connecting-passengers who have to be taken onto the out-bound flight F2. Figure 4-2 illustrates this first scene.

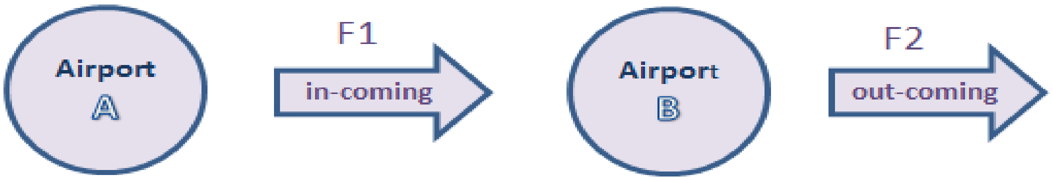


Figure 4-2: The first situation: In-bound flight F1 arriving at the airport B and departing out-bound flight F2

The connecting-passengers from the flight F1 will have their own needs and expectations regarding the level of service to be delivered by the carrier. Service quality requirements to be taken are: on-time performance (for to be able to get the connecting-flight) and not to become the “refused-passenger” – which could give an equivalent effect to a cancelled flight without a recovery passenger plan.

The *second* situation is shown in Figure 4-3. Among the origin passengers with high-valuable ones amongst departing from the airport B are possibly to be found passengers who do not end their travel at the airport C, having to continue their travel with one of the following flights (here: F3 or F4), which depart from the airport C.

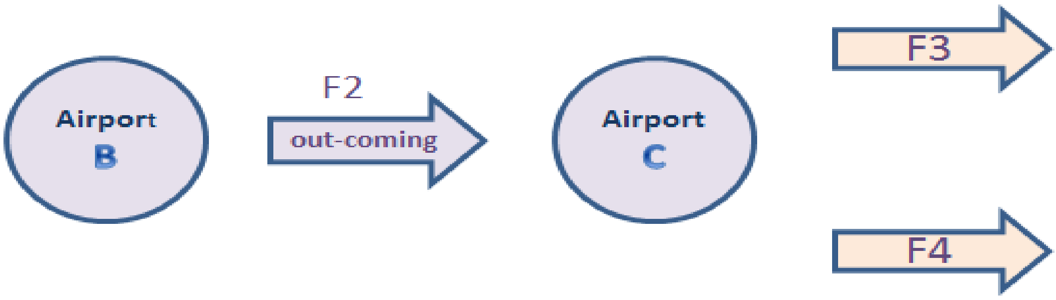


Figure 4-3: The second situation: Out-bound flight F2 flying to the airport C and the follow-flights F3, F4

Thus, some of the departing or origin passengers from the flight F2 become the connecting-passengers themselves, too. These passengers will have their own requirements and expectations on the level of service (LOS) to be delivered by the carrier. These are: (1) to have an on-time service (i.e. flight), (2) to be enabled to get the connecting flight as it is promoted in the airline scheduling, and (3) if they are late in arriving and therefore might miss their connectivity, that they would not become the "refused-passengers" (while expecting that they would get some recovery possibility offered in order to continue their travel and get their final destination timely).

Taking into account all presented quality-attributes (introduced in Section 3.5), as well the defined or declared business policy of the particular airline in dealing with disruptions in its every-day operations, it can be concluded that the operations controllers are required contemporary and concurrently to deal with following several items:

(1) The general instructions and ongoing changes given by the airline's management
(2) Seeking not to cause extra costs
(3) Respecting updated requirements given by the air traffic control
(4) Satisfying passengers' SQ-requirements by providing the SQ-level the passengers paid for.

4.5.3 Measuring the Decision Solutions Quality

One more influencing issue in the decision making process at the airline operation control centres can be described as "using of some kind of *quality costs* when taking the decisions" Castro and Oliveira (2007, p. 6). The authors suppose using of "some kind of rule of thumb or hidden knowledge" making the operation controllers to choose or not a candidate (best) solution when they are about to deal with disruptive events. So far this has been a unique work found in the research literature in this manner referring to the quality of the decisions on disruptive events in the airline all-day operations.

A kind of decisions quality has been applied in this research in decision cases where the high valuable passengers (i.e. very important persons (VIPs), first class, and business passengers) are influenced by decisions made within the operation execution.

Since the valuation of such decision solutions can not be uniquely quantified, it has been assumed that these decisions have to be based on controllers' personal experience, representing an important part in the decision making process.

For this research purpose, the Kano's quality basic categorizations definitions (Kano, 1984) are adopted for the cases of high-valuable passengers' requirements which purpose is to describe the impact of the SQ-requiremets fulfilment on the passengers' satisfaction level quantitatively in the overall analysis.

4.5.3.1 The Basics of the Kano Model

The customer satisfaction so far has been seen mostly as one-dimensional performance i.e. it has widely been considered as follows: the higher the perceived product quality, the higher customer's satisfaction level. However, fulfilling individual customer expectations to a great extent does not necessarily imply a high level of customer satisfaction.

The basic rules for establishing the importance of product categorization/service quality attributes, especially the ones of quality to the customers' satisfaction are introduced by the Kano Model of quality (1984). The model is based on how well these attributes can satisfy customer requirements and/or needs at the moment of the consideration.

In the original five-level questionnaire categorization, Kano Model distinguishes five types of product/service requirements that differently influence customer satisfaction, as described by Sireli, Kauffmann et al. (2007, p. 382):

(1) *Must-Be Requirements*: these are basic criteria of a product and if they are not fulfilled, the customer will be extremely dissatisfied, whereby even with the high quality requirements performance, the customer satisfaction will not rise above neutral;

(2) *One-Dimensional Requirements*: the higher the level of fulfilment, the higher the customer's satisfaction. Satisfaction of these quality requirements provides customer loyalty;

(3) *Attractive Requirements*: product/service criteria with the highest influence on customer satisfaction that differentiate the product from competitors and may be not expected ones;

(4) *Indifferent Requirements*: the customers are not very interested in whether this product/service attribute is present or not;

(5) *Reverse-Requirements*: not only that the customers do not want this product attribute, but they also expect the reverse of it.

Figure 4-4 depicts the Kano's categories of perceived quality attributes, showing in which way product/service-requirements influence customer satisfaction with that product/service.

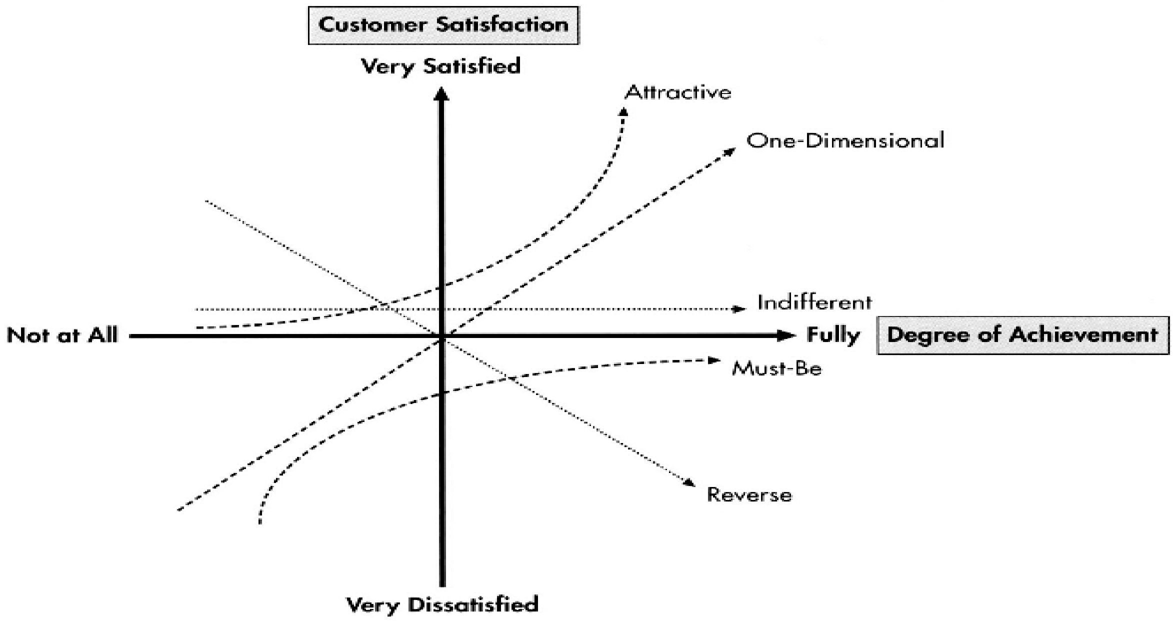


Figure 4-4: The Kano Model: categories of customer satisfaction with the service quality delivered

Source: Wittel and Dominguez (2005) cited in: Hsu, Chang et al. (2007, p. 2)

It should be emphasized that not only certain service attributes (or quality elements) primarily have an impact on creating satisfaction while others primarily create dissatisfaction, but also that the same product/service attributes have a varying impact on overall customer satisfaction depending on the current level of performance (Mikulic 2007). Mikulic indicated that some quality attributes are of their product/service life the *attractive* ones (not expected) at the beginning, while after a period of time the same quality attributes become "*basic*" or "*must be*" ones. In this way, they are expected as "standard"-offered quality attributes, while the *time* factor is working against the already established quality-level categorization.

Once being established and finally matched by competition, the "attractive" service quality attributes will likely go through an adoption process of becoming *expected* by customers. This walking way into the *implicitly expected* service quality attributes makes the reversing from such attributes very difficult, according to Khalifa (2004) cited in Leick (2007, p. 73).

The original Kano Model gives information on the degree of achievement of product/service quality-requirements based on the questionnaire on customer satisfaction level perceived. Referring to this research subject, this means that an airline should exactly know which service quality attributes and to which perception degree of achievement are required and desired by its high-valuable passengers on each of its flight-legs (i.e. city-pairs). These sensitive data can be enabled through the data maintenance of its loyalty programs (e.g.

diverse memberships and frequent flyer programs), which is, as a matter of course, only for an intern and not for a public or research use.

However, within the airline operation execution, particularly at the moment of a decision making in disruption situations, such information may rather be nor implemented or considered in the decision process.

For the creation of the modelling of the SQ-attributes in this research, which has to be then implemented in the proposed decision support tool, required is a kind of *converting* of the same SQ-requirements for the three passenger-groups of the two flights considered. This is needed because the SQ-attributes required by the high-valuable passengers are expectedly dependent on their current position within their travel according to the passenger segmentation and/or configuration (i.e. being on an arriving or on a departing flight, being a one-flight-leg passenger or a connecting one).

Modelling-creation has been done by classifying and ranging of chosen SQ-attributes adopted from the reviewed research literature in a matrix form, which is then after graphically presented in tables for the airline and the passengers separately.

4.5.3.2 Extended Approach to the Kano Model

The perception of the SQ-attributes for two main passenger groups who take part in the air travel situation is modelled. These are connecting and origin ones, whereby the origin passenger group is further divided into two sub-groups according to their final travel-destinations, i.e. the one which ends its travel at the destination-airport C, and the other one which has to continue its air travel with following flights which depart from the destination-airport C.

To categorize the SQ-attributes required by the high-valuable passengers, the basic categorizations from the simplified version of the Kano Model (2001) are adopted and then adjusted for both expected and perceived SQ-requirements.

Taking into consideration typical characteristics of the high-valuable passengers and their travel behaviour referring to the air travel SQ required and/or expected as well as the relationship between an airline and its Frequent Flyer Program members (cf. Subsection 2.2.4 and Section 2.3), a customized modelling of SQ of both the airline and all 3 passenger-groups involved, is developed by employing:

- The categorization of SQ-attributes differently *required* and/or expected by 3 different passenger-groups (i.e. arriving one and two originate ones) flying with the same carrier on the route consisting of two or more flight-legs (i.e. consuming the air transport service according to the purchased tickets);

- The SQ-attributes *performed* by the carrier according to the defined airline SQ-requirements, fitted to 3 passenger groups individually.

Four main criteria levels of the requiring SQ-attributes of each passenger group are described in four quality sets, to be than customized appropriately to the each passenger group individually:

1) “Must be” quality requirements, as basic customer service quality needs

2) “One-dimensional” requirements are usually explicitly demanded by the customer

3) “Attractive” qualities (which are not expected, or, “latent customer needs”) can provide competitive advantage with the greatest influence on customers’ satisfaction

4) “Reverse” quality requirements which lead to the high customers’ dissatisfaction when the performance of these quality elements is high and to the customers’ satisfaction when the performance of the quality attributes is low.

4.5.3.3 Integration of the Kano’s Quality Categorizations into the Modelled Situation

For an implementation of the Kano’s model into the customer quality requirements in the operation situation modelled, it is useful first to define and classify the service quality attributes for each of all three passenger groups.

To enable presenting the level of satisfaction/dissatisfaction with a particular service quality attribute for both the passengers and the airline, a scale of 5 satisfaction levels is applied. It ranges from *very dissatisfied,* over dissatisfied, neutral, and satisfied, till the *very satisfied* (i.e. delighted) with a particular SQ-attribute. The satisfaction level *neutral* here is considered in terms of *indifferent* or *being not affected with.*

4.5.4 Modelling the Satisfaction Level of the Passengers

While being served, customers are differently exposed to operational quality attributes of the chosen service provider. This can affect the relationship between a service provider’s operational quality and a customer’s choice of service providers. This especially takes effect in the case of customers who are of the highest (economic) importance to the airlines.

The focus of this study is on high-valuable passengers who are travelling from the airport A to the airport B, where the connecting passengers have to change the aircraft to continue their travel to the airport C. In the modelled situation of the decision making process at the airline control centre, the connecting and origin passengers are divided into three travelling groups according to their final destination.

Categorization of the modelled SQ requirements is first introduced generally for all passengers. Then after, it has been customized for the SQ-requirements of each passenger-group individually. This generates the following relationships:

(1) *Must-be requirement* defined as a non-cancelled flight, represents the basic service-attribute offered by the carrier. This means, if a flight is cancelled, the passengers are dissatisfied, whereby the not-cancelled flight will not lead to higher satisfaction because the flight is expected (as a promoted service by the airline);

(2) *One-dimensional requirement* is defined as the carrier's on-time performance. This is the SQ-attribute the airline competes with. It is a linear quality attribute, since, as much as the flight is nearer to the on-time performance, equivalent is the passengers' satisfaction with this SQ-attribute. Being as far from the target (i.e. on-time) performance, the dissatisfaction of passengers increases;

(3) *Attractive requirement* is defined as an airline's decision on waiting for delayed connecting passengers on arrival. This SQ-attribute leads to the highest satisfaction level since this was not prior awaited by passengers;

(4) *Reverse requirement* is defined as "become a refused passenger", meaning if a passenger becomes "refused" or left behind (passenger is prohibited to travel further) at the connecting airport, this SQ-attribute will lead to the highest dissatisfaction.

4.5.4.1 LOS Modelling for the Passenger-Group I

Passenger-Group **I** consists of the connecting high-valuable passengers on the flight leg (in-coming flight) F1, travelling from the airport A to the connecting airport B for changing the flight to the out-bound F2 to their final destination, i.e. the airport C.

Integration of the basic service quality categorizations from the Kano's model results in the following relationships between the SQ-requirements and the satisfaction levels of this passenger group:

I. *Must-be requirement is* declared as an "on-time performance", meaning if the airline provides an on-time performance, passengers are neutral-satisfied (i.e. not impacted), because they do expect it, while a delayed flight leads to their dissatisfaction

II. *One-dimensional requirement* is taken to be "getting the connection-flight" for travelling further on to the destination-airport C. As much as achieved, it will be accompanied by the equivalent degree of the passengers' satisfaction

III. *Attractive service requirement* is taken to be "waiting on departure for the late passengers", which if provided as a not-expected or a surprise-attribute will cause a high degree of passengers' satisfaction. If this is not fulfilled, it will not cause high dissatisfaction

IV. *Reverse service requirement* is defined to be the service performance in case when a passenger "becomes a refused" one. This results in a high degree of dissatisfaction when achieved. A low degree of its achievement will result in passengers' satisfaction.

Table 4-1 shows the relationships between the SQ-requirements of the passengers from the flight F1 and the satisfactory degree achieved in the above-described situation, giving the key features for the modelling of the SQ level for the arriving Passenger-Group I.

Table 4-1: Modelled SQ-requirements of the Pax-Group I

SQ-requirements of Pax-Group I	**Must-be**		**One-dimensional**		**Attractive**		**Reverse**	
SQ-attributes	On-time perform	Delayed	To get the connecting flight	Not to get the connecting flight	Being waited	Being not-waited	To become "refused-pax"	Not to become "refused-pax"
Satisfaction of Pax-Group I	Neutral	Dissatisfied	Satisfied	Dissatisfied	Very Satisfied	Dissatisfied	Very Dissatisfied	Neutral

Source: created by the author

4.5.4.2 LOS Modelling for the Passenger-Group II

Passenger-Group II consists of the departing (origin) passengers on the out-bound flight F2. Among the origin passengers, some high-fare passengers could be found. For building-up of the input classification for the proposed tool, the origin passengers are divided into two further groups, according to their definite travel destination, i.e. whether they end the travel at the airport C or they have to continue the trip from the airport C: (1) the origin Passenger-Group II-1 does end its travel at the airport C; (2) the origin Passenger-Group II-2 does not end its travel at the airport C flying further from the airport C to its final destination. Translated into the model design, the SQ-requirements of these two passenger groups are similar; their perception of satisfaction/dissatisfaction differentiates only.

Integrated categorization of the SQ-requirements of the **Passenger-Group II-1** is presented as follows:

I. *Must-be requirement* is taken to be a not-cancelled flight i.e. the flight is promoted or promised, leading to dissatisfaction if the flight is cancelled. A non-cancelled flight will not lead to a higher satisfaction because it is taken for granted if fulfilled;
II. *One-Dimensional requirement* is taken to be an on-time performance, which results in satisfaction when fulfilled, and in dissatisfaction when not fulfilled;

III. *Reverse requirement* is taken to be waiting for the connecting Pax-Group **I** with a delay on departure. This may lead to the *neutral to dissatisfaction* of the Pax-Group II-1 since they are on-time. Not waiting for the connecting-passengers from the flight F1 will not lead to a higher satisfaction as nor awaited or requested by the Pax-Group II-1.

Table 4-2 illustrates the relationships between service quality requirements of these passengers and the level of their satisfaction with the SQ delivered by the carrier.

Table 4-2: Modelled SQ-requirements of the Pax-Group II-1

SQ-requirements of Pax-Group II-1	**Must-be**		**One-dimensional**		**Reverse**	
SQ-attributes	Not-cancelled flight	Cancelled flight	On-time perform	Delayed	Wait for Pax-Group I	Not-wait for Pax-Group I
Satisfaction of Pax-Group II-1	Neutral	Dissatisfied	Satisfied	Dissatisfied	Neutral/Dissatisfied	Neutral

Source: created by the author

Categorization of the SQ requirements of the **Passenger-Group II-2**, which does not end the travel at the airport C but continues the air travel further on, is presented as follows:

I. *Must-be requirement* is declared to be an “on-time performance” (this SQ-attribute is promoted), leading to a dissatisfaction if not fulfilled, while if fulfilled will not result in a higher passengers’ satisfaction (i.e. fulfilling is taken for granted).

II. *One-Dimensional requirement* is taken to be “enabled to get the connecting flight”. When fulfilled, as much as achieved, it linearly results in passengers’ satisfaction.

III. *Reverse requirement* is defined to be “waiting for the connecting Pax-Group I” *with a delay* causing by the Pax-Group II-2 dissatisfaction, supposing these passengers might be late and possibly miss their own connecting flight at the destination airport C. Hereby, not-waiting on departure will not result in a higher satisfaction meaning that they may feel “neutral” or not affected in this case.

Table 4-3 illustrates the relationship between the SQ-requirements of the Pax-Group II-2 and the satisfaction level with the SQ attributes delivered by the carrier.

Table 4-3: Modelled SQ-requirements of the Pax-Group II-2

SQ-requirements of Pax-Group II-2	**Must-be**		**One-dimensional**		**Reverse**	
SQ-attributes	On-time perform	Delayed	To get the connection	To miss the connection	Wait for Pax-Group I	Not-wait for Pax-Group I
Satisfaction of Pax-Group II-2	Neutral	Dissatisfied	Satisfied	Dissatisfied	Dissatisfied	Neutral

Source: created by the author

4.5.5 Modelling the Level of Service Quality of the Airline

Generally, from the airline's point of view, the main SQ requirements can be seen in terms of reliability and a positive profit (the unit revenue is higher than the unit cost). On the other hand, this indicates also a positive impact of the travellers' perception of the carrier's service quality (Proussaloglou and Koppelman 1999).

Although not the unique service attribute that the airlines attempt to rely on, reliability or an on-time performance is taken as a major service quality measure of an airline in this research. In addition to the *operational*-defined quality target, each airline has its own business-policy and/or business-strategy according to which its priorities are set-up. This may be also explained as following: if the airline has to choose *when* and *what* more important is, this can be in terms of time, money, and/or passenger(s), or whether the airline's priority will be either an on-time performance, or savings of overall extra-costs, or its valuable and very important passengers (hereby adding-costs equal).

Therefore, an on-time performance is taken as a general measure of the SQ of an airline respecting the fact that, for its business, strategic or operational reasons, it can always otherwise decide (if to operate in the defined manner or it will give any other priority within a current execution of its operations).

4.5.5.1 Modelling the Airline's Service Quality Attributes

In the first step, SQ requirements of the airline will be translated into the integrating categorization of the service quality attributes. This is needed for the design of the tool, referring to the level of the service requirements performed from the airline's point of view.

The basic categorization of the airline's overall SQ-requirements is given as follows:

I. *Must-be requirement is* defined as the airline's on-time performance, meaning that when fulfilled, it leads to its satisfaction and when not fulfilled to its dissatisfaction;

II. *One-dimensional requirement is* defined to be the airline's revenue being higher than its cost per flight. It means, when higher the degree of fulfilling this SQ-attribute the level of airline's satisfaction will be equivalent;

III. *Reverse requirement* is defined as the cases where: (i) the passenger-recovery has to be done by another airline whereby the home-airline lose the ticket revenue, and/or (ii) the passengers must "be refused" due to operational constraints and lack of suitable alternative solution whereby the home-airline has losses of both the ticket-revenue and the reputation of a reliable and serious carrier. Since these operation decisions affect both the airline businesses and particularly connecting passengers, accordingly the reverse requirements with a low degree of achievement will result in a higher satisfaction. Far better, when not appearing these attributes will lead to the airline's satisfaction;

IV. *Attractive requirement* of the airline is defined as the case where the airline (i) gets all its passengers on board (the connecting and origin) and (ii) can deliver an on-time performance having at the same time its revenue higher than its costs.

Defined SQ requirements that are categorized in terms of the Kano's quality-requirements, can be described as following: an airline delivers a performance in a satisfactory manner if it manages to get a higher revenue than its costs, to perform on-time, and to get all its passengers on board, and not recovered by another airline (by its alliance partner or even by a vendor airline). Furthermore, it will always attempt not to cause extra costs during the operation execution.

The relationship between the airline's SQ-requirements and its satisfaction level with their achievement is shown in Table 4-4.

Table 4-4: Modelling of the airline's overall SQ-requirements

Airline's SQ-Requirements	**Must-be**		**One-dimensional**		**Reverse**		**Attractive**	
Airline's SQ-Attributes	On-time Perform	Delayed	Revenue > Cost	Revenue < Cost	Pax-recovery by other airline	To refuse Pax(s)	All Paxs are on-board	On-time Perform and revenue>cost
Airline's Satisfaction Level	Satisfied	Dis-satisfied	Satisfied	Dissatisfied	Dissatisfied	Very Dissatisfied	Satisfied	Very Satisfied

Source: created by the author

Following this, if the passenger-recovery must be made by another airline, the home airline suffers a loss of the ticket profit, while at least its business reputation as a reliable carrier can be saved. But, if the airline is required to refuse some of its passengers, it suffers not only a loss of the ticket profit, but also its business reputation of a reliable trustworthy carrier. This will not lead to the airline's satisfaction with its performance provided. However, in its promoted service i.e. published flight plan the airline actually "promises" that it will transport all its passengers to the desired destinations, enabling all the required planned connections i.e. existing in its flight schedule, to the declared fares.

In this way, the classification of service quality requirements from the airline's point of view is complete. The individual satisfaction levels of the each passenger-group in the modelled situation have been shown earlier in this work (Subsection 4.5.4).

To enable adjusting the airline's overall SQ-attributes in the next step, it is required first to establish a categorization of the airline's satisfaction level with its own performance. After applying the categorization of the SQ level delivered for and to each passenger-group considered, its service quality to each passenger group will be shown.

In this way it is modelled how an airline may measure the influence of the particular service attributes of its performance for (and to) each passenger group involved. In the decision options of the proposed supporting tool this will be used as the output of the SQ level delivered-considering.

4.5.5.2 Modelling the Airline's SQ Level for each Passenger-Group

Adjusting the airlines overall SQ-attributes for the three passenger groups by integrating the quality requirements categorizations, the relationships between the SQ-attributes and the satisfaction level of the airline for the case of each passenger group are pointed out. This is needed for the design of the designed tool outputs.

When the airline is about to take the decision whether to wait for its connecting high-valuable passengers on departure or to depart on-time disposing them to the Passenger Service and the corresponding recovery-plan, there are three possible decision solutions considered in terms of the distinctive operation situations. These are:

(1) *The airline decides to wait for the connecting passengers from the flight F1*

- The airline's *on-time performance* in the situation when it is about to wait for the delayed Pax-Group I, applied on each passenger-group results in the airline's satisfaction in case of the Pax-Group **I** (they will not be left, and the airline delivers what has been promoted in its schedule); to the Pax-Group **II-1** and Pax-Group **II-2** this is not the satisfactory performance, because they are on-time and do not get the SQ-attribute that is promoted/sold; additionally, it might happen that the passengers who are going to continue their travel from the airport C (of the Pax-Group II-2) possibly miss their connection-flight.

- When it is about to value its own decision performance whether the *revenue is higher than its cost,* the following issues should be considered: by waiting for the Pax-Group I, the airline saves the overhead-costs that eventually might rise from the rebooking costs of these passengers. There is a risk of some adding costs if the Pax-Group II-2 misses the connecting flight at the airport C. This is due to the recovery-plan for these passengers and to the requirement if this action requires some extra staff
- If the passenger-recovery of the delayed passengers of the Pax-Group II-2 in terms of rebooking and possibly re-accommodation must be done by a vendor-airline (there is no possibility neither to recover the passengers nor at the home airline or by its alliance partners. The passengers must be offered a recovery solution by another airline which may result home airline's dissatisfaction due to the loss of the ticket gain

(2) The airline decides to depart on-time without the inbound connecting passengers

- The airline's *on-time performance* in the case where it takes decision on on-time-departure without the connecting passengers from the flight F1 will result in satisfaction only with its performance to both departing/origin passenger-groups i.e. the Pax-Groups II-1 and II-2. In the case of the Pax-Group I, such a performance leads to dissatisfaction of the airline, because these passengers are late on arriving (not fulfilled on-time performance on the 1. flight-leg already), additionally to this, they have to be left to the Passenger Service for recovery planning
- Within the evaluation *whether the revenue is higher than the cost,* the following shall be considered: since for the origin passengers (Pax-Groups II-1 and II-2) any further or overhead costs must not be expected, the airline can account to have its gains higher than the costs, resulting in its satisfaction for both passenger-groups
- In case of the Pax-Group I, which is late on arriving and has to be recovered, it could happen that the recovery plan is not possible to execute by the home airline or its alliance partners, thus causing possibly some costs for the adding resources
- Departing on-time and not-waiting on its delayed high-fare connecting-passengers from the flight F1, the airline can experience two typical effects, offering the left connecting passengers either the suited recovery-plan or refusing them without solution for that day/date/route. The delayed passengers have *to be recovered* and possibly re-accommodated. This can be done a) in the best case by the home airline, b) by its alliance partners, and c) in the worst case by a vendor airline (hereby additionally to the losing gains from these tickets, possibly to refund the ticket price differences). Besides the overhead costs for the passenger-recovery and for some additional resources, there is always a possibility of the loss of passengers' goodwill for future travel with that particular airline. Therefore, this decision may not lead to the airline's satisfaction with its own performance accompanied by such consequences.

(3) The airline has to refuse (i.e. to leave behind) delayed connecting passengers

- In the modelled situation this is the worst decision case for both the passengers and the airline. Due to the airline's schedule shortages and/or air-traffic constraints for the particular route or city-pair and/or for the required day/flight, the airline may be required/forced to depart on-time not taking the connecting passengers with. The airline faces the situation of *being required to refuse* the passengers for that particular flight-leg or leaving them back at the connecting airport, if there is no reasonable or acceptable recovery solution in terms of: there is no more travel-motivation of the travellers for continuing the travel on that day, or the passenger-recovery plan is not available on the same day/date by the home airline or its alliance partners or by any other airline. In such case, additionally occur some accompanying so called spilled revenue costs.
- In such a decision situation, a much more important consequence for the airline is that the dissatisfaction of the passengers may easily result in loss of their goodwill for future travelling with this airline. Finally, the case of "refusing the passengers" can not lead to the airline's satisfaction with its SQ-performance due to the loss of not only the ticket revenue but also the near-threatened reputation of a reliable and serious carrier.

In Table 4-5 the described decision solutions referring to the fulfilling of the SQ-requirements of the airline, as well as the level of the airline's satisfaction achieved with its performance to each passenger group individually are shown.

Table 4-5: Modelling of the airline's SQ-requirements adjusted for each passenger-group

	If to wait at departure				**If not to wait at departure**			
Airline SQ-requirements	**Must-be**	**One-dimensi-onal**	**Reverse**		**Must-be**	**One-dimensi-onal**	**Reverse**	
Airline's SQ-Attribute / Delivered to	*Revenue > costs*	*On-time perform*	*Pax-recovery by other airline*	*"Refused-Pax"*	*Revenue > costs*	*On-time perform*	*Pax-recovery by other airline*	*"Refused-Pax"*
Pax-Group I	Satisfied	Neutral	Neutral	Neutral	Neutral-to-dissatisfied	Dissatisf.	Dissatisf.	Very Dissatisfied
Pax-Group II-1	Satisfied	Neutral	Neutral	Neutral	Satisfied	Satisfied	Neutral	Neutral
Pax-Group II-2	Satisfied-to-neutral	Dissatisf.	Dissatisf.	Very Dissatisf.	Satisfied	Satisfied	Neutral	Neutral

Source: created by the author

The modelled airline's SQ-requirements are needed for creation one of the outputs of the designed support tool, particularly for the quality measurement of the modelled airline's satisfaction level. It is integrated in the airline prioritisation-policy (APP), in this research defined as the sum of the levels of both the service quality delivered to the passengers and the operating profitably.

When they are about to decide whether to wait or not on departure of an out-bound flight in order to enable the arriving-delayed high-valuable passengers to get their connecting flight, the operation controllers are required to deal with several constraining aspects at the same time. On the one hand, it is the airline's on-time performance as the service quality attribute witch a carrier competes with. On the other hand, airline's promoted SQ attributes affect passengers' loyalty through gaining their satisfaction. Thereby the controllers have to consider the requirements of the airline's business policy respecting its defined policy prioritisation strategies taking into consideration all changes and/or constraints currently coming from the air traffic control while implementing them into the operations.

An overview of possible consequences of each available decision solution that can be taken in the whole modelled disruption situation as seen from the airline's point of view is given in Table 4-6.

Table 4-6: Modelling of the Airline's Satisfaction-level with its LOS performed to each Passenger-Group

	Airline's Decision on departure-delay	**If to wait**	**If not to wait**	**If to refuse a Pax**
Airline's Satisfaction-Level	*Pax-Group I*	Satisfied	Dissatisfied-to-neutral	Very dissatisfied
	Pax-Group II-1	Neutral-to-dissatisfied	Neutral	Neutral
	Pax-Group II-2	Dissatisfied	Satisfied	Very Dissatisfied

Source: created by the author

Being required to decide whether to wait or not for the late arriving passengers and displaying the SQ-requirements customized to each passenger group, the relationships between the LOS of the airline based on the aforementioned possible decisions and the satisfaction-level of the airline (achieved with its set up performance relating to each passenger-group) are presented. According to the modelled LOS of passengers (shown in Tables 4-1 to 4-3) or how each passenger-group individually may react experiencing the airline's decisions either to wait or not on departure for high-fare connecting passengers or a decision on refusing the passengers, shown here (Tbl. 4-6) is how the airline may evaluate its SQ-level performed.

For example, in the case of the origin Passenger-Group **II-1**, the decision of the airline to wait on the late passengers from the in-bound flight F1 leads not to its satisfaction with the performance. It causes rather its satisfactory level of “neutral” or “not impacted”. This is because these passengers end their travel at the airport C having no risk to possibly miss the follow-up flights, but being on-time on boarding, they do expect to have the service performance they paid for. Therefore is the airline’s satisfaction level here declared as “neutral to dissatisfy”.

In the case of the origin Pax-Group **II-2**, which does not end the travel at the airport C flying further to the destination-airports, the decision of the airline to wait for the late passengers from the flight F1 leads to dissatisfaction Pax-Group II-2 (see Table 4-6), because the Pax-Group II-2 itself is on-time. This can be seen as a sign of missed on-time performance delivered to the Pax-Group II-2.

However, these passengers may feel “neutral to dissatisfied” level of satisfaction, as same as the airline itself, in the case of decision “to refuse the passengers”. This is because, in spite of the fact that these passengers are not in danger to experience this decision on themselves at the airport C for their further travelling, they are also aware of this possibility. But, this fact is clear only to the airline in this modelled situation, since the controllers will not allow that this disruption on the flight F2 (from airport B to the airport C) expand through the down-line network, affecting the subsequent flights (F3 and F4) which depart from the airport C.

The given modelling of the level of SQ-attributes of both, performed by the airline and perceived by the passengers, will be used as one of the most influencing criteria implemented in the proposed support tool aiming at making decisions on whether to delay the departure of an outbound flight in order to wait for the connecting high-valuable passengers of a delayed inbound flight.

5 Design of the Delaying VIPs Oriented Decision Support System DEVOTED DSS Tool

5.1 Introduction

In this chapter the architecture and the design of the proposed knowledge-based support tool - Delaying VIPs Oriented Decision Support System (DEVOTED DSS), as well as implemented airline-policy prioritisation strategies as the main influencing decision making factor are presented.

Serving the purpose of both evaluation of possible option scenarios available at the moment of the decision making and recommendation of a specific solving-solution, design of the proposed multi-criteria algorithm and its mathematical formulations are shown and explained. Likewise, the tool output in terms of its graphical presentation and mathematical formulation is presented.

5.2 Background

The importance of carrier's performance measurement has been long recognized, which is not only to monitor operational, safety and financial aspects of performance, but also for enabling the evaluation of customer responses to the services delivered (Francis, Humphreys et al. 2005, p. 1). Shown was that additionally to the expected performance indicators such as *load factor* and *punctuality*, also the *cost per seat kilometre* has been widely used as operational performance measure, whereby the latter has been seen as most useful to the airline managers.

However, the literature findings confirmed that on-time performance is especially important to elite business travellers who are also ready to pay more for its improvement, for being on-time for these passengers can also be a matter of importance in terms of business opportunity for generating revenue. This attribute can be an important selection criterion for high-valuable passengers. Nonetheless, it should be noticed that business passengers tend also to appreciate convenience more than leisure travellers, because they may want not only to work but also to rest while travelling (Cho 2012, p. 67).

Related academic works have been done far more as part of an integrated recovery models mostly using operation research (OR) methods (reviewed in Chapter 3). Published works especially focused on operation disruptions and recovering from disruptions, within an explicit consideration of disruptions and recovering due to, and for, high-fare passengers have not been found yet to the best knowledge of the author of this thesis.

The service quality items such as the carrier's on-time performance and its reliability play an important role in the airline operation processes, influencing not only its business reputation on the market but also its operation decisions per se. Within designing of the DEVOTED DSS tool, these important operation aspects have been taken into consideration from side views of both, the passengers and the airline. Focusing on decisions on delays caused by waiting for the arriving-delayed connecting high-valuable and business passengers, into consideration particularly taken is the satisfaction level perceived by these travellers.

Mathematical background of the evaluating algorithm and influencing variables are presented as a framework for design of the proposed stand-alone tool. According to Castro and Oliveira (2011) given categorization of the tools currently in use to support decision making processes at the Airline Operation Control Centers (AOCCs), the scenario-based DEVOTED DSS Tool has been classified into the Decision Support Systems (DSS). Literature review in Chapter 3 (Subsection 3.2.1) gives more details of this.

Respecting the main key elements of Human-Centred Design (HCD)[2], the design of the tool incorporates:

(i) the user's perspective considering the disruption events conditions by giving an output disburdened from data and numbers but being shown up in an user-friendly form of generated outcomes, mapped on a designed 3-colour bar, and

(ii) organizational requirements such as the airline-policy prioritisation strategies and accompanying consequences of the possible decision options.

The architecture of the DEVOTED DSS Tool is illustrated in Figure 5-1 showing the main influencing factors on the decision making process which have been taken into consideration.

[2] Maguire, M. (2001). "Methods to support human-centred design." Academic Press **55**: 587 - 634

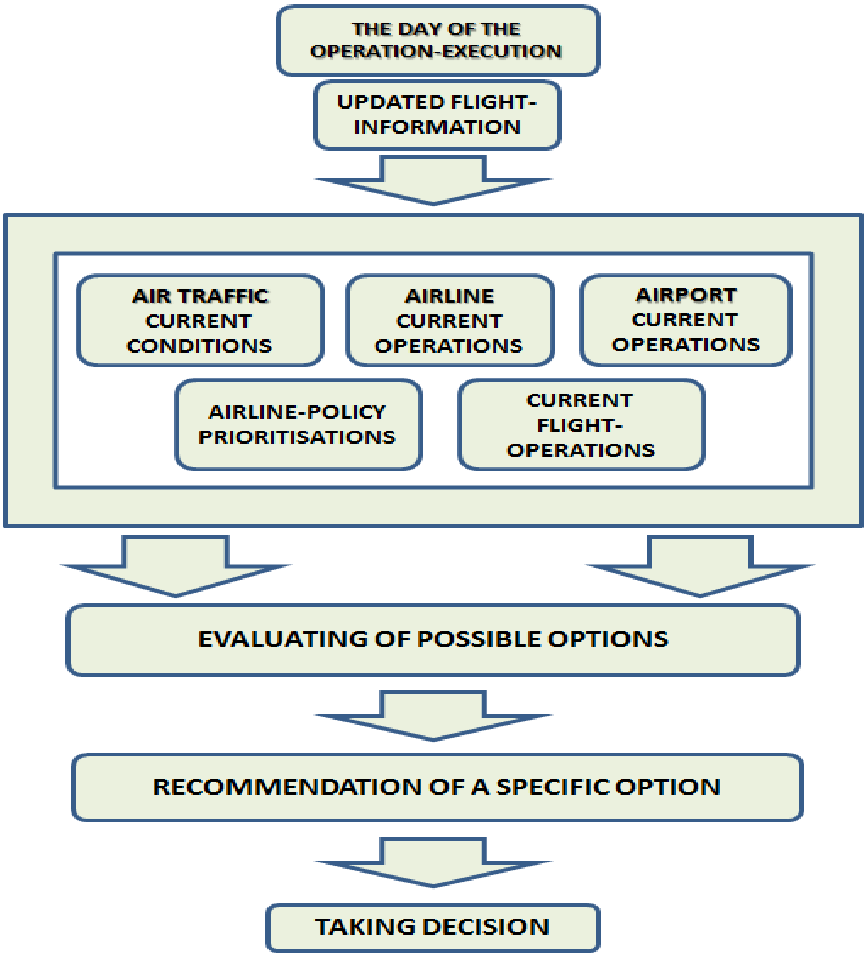


Figure 5-1: Architecture of the DEVOTED DSS Tool

Source: created by the author

Since the Operation Control Centre (OCC) of an airline plays also the role of its Disruption Management in situations when disruptions occur (Kohl, Larsen et al. 2004), so their process of making decisions have to be in accordance with the airline's business policy and its predefined priority strategy.

Having a prevailing influence on each of its operational decisions, the airline policy prioritisation has been implemented into the design of the proposed tool.

5.3 Airline-Policy Prioritisation (APP) - Settings

When it is about to decide whether to delay an outbound flight in order to wait for the connecting passengers who are late on arrival with an inbound flight, the airline operation controllers are required to consider some given priority rules that are predetermined by the airline policy and which also within the decision making process have to be respected.

The prioritisation strategy of an airline depends on determined operational, tactical, strategic and economic goals and constraints of its businesses. This can vary even for the same route (city-pair) in the all-day operations, as well as based on requirements of the airline's managerial departments (i.e. due to operational and/or tactical updates and decisions).

Prioritisation order applied in this research in the modelled operational situation refers to the high-valuable passengers as the arrival-delayed passengers on an inbound flight, while on the departing out-bound flight they may travel not only as one-flight-leg passengers, but also as the connecting ones too (on their onward flights).

The airline-policy prioritisation (APP) strategies implemented in the designed DEVOTED DSS Tool are displayed in. Figure 5-2.

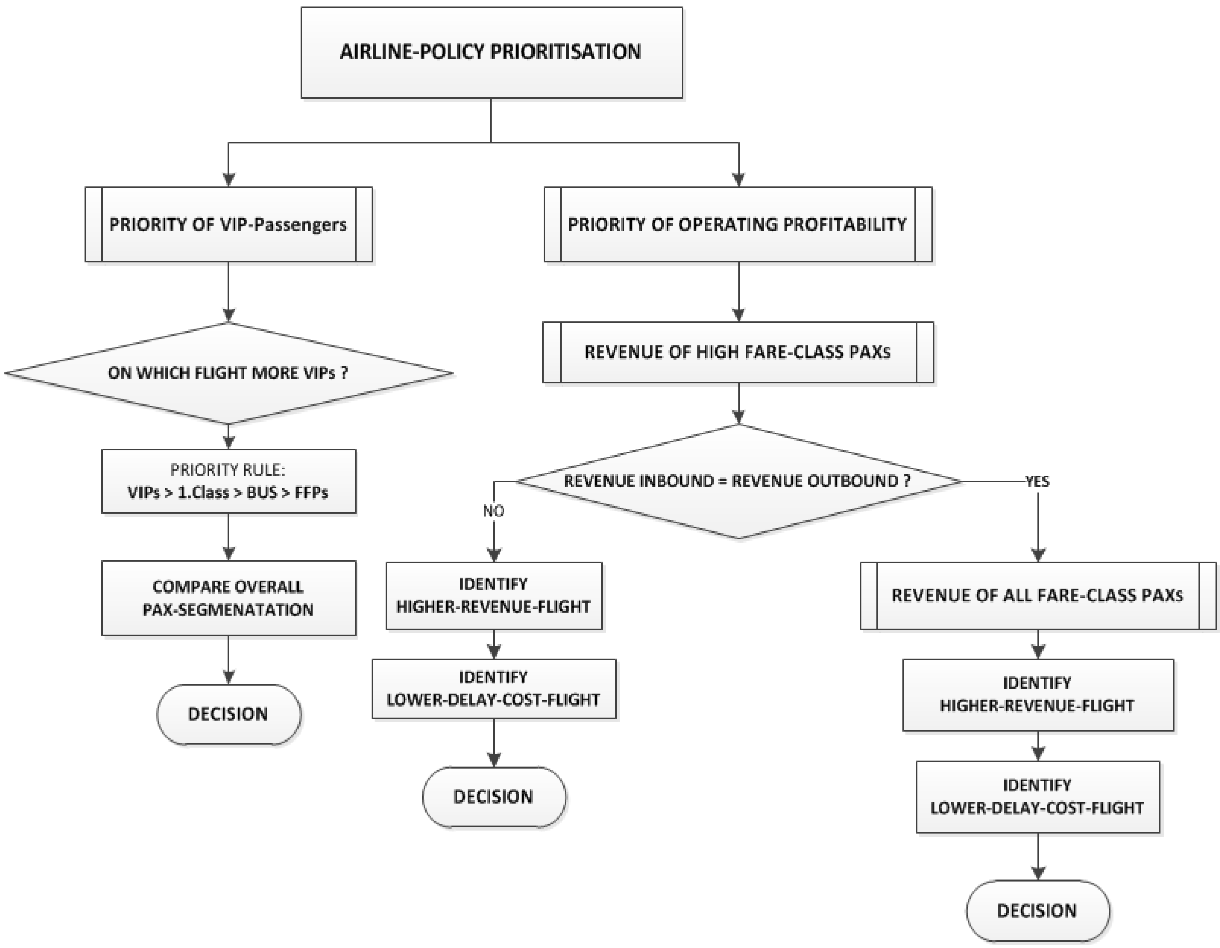


Figure 5-2: Airline Prioritisation Strategies implemented in the DEVOTED DSS Tool

Source: created by the author

Knowing this and having the passenger lists available in their flight charts (i.e. the passengers' names flying on each flight and their cabin or fare class statuses), the operation controllers will take into consideration the airline-prioritisations as follows:

1. The priority of the VIPs or "LOS to the Passengers" - APP1

Since a final decision on whether to wait on departure can also rely solely on this information as one of the main decision-criteria, this priority will be determined in two steps.

First the presence of the very important persons (VIPs) on each flight will be checked, meaning whether there are any VIP passengers on both in-bound and out-bound flights:

(a) Look for their names and/or status on the Gantt Flight-Chart

(b) If there are some VIPs in both aircraft, the number of VIPs flying on the in-bound flight is going to be compared with the number of VIPs on the out-bound-flight

(c) Taking into consideration the passenger-group with the higher number of VIPs in an aircraft, decision priority to the aircraft carrying this passenger-group may be given.

In the second step, checked will be the high-fare passengers' segmentation by taking into account their distribution on considered flights. This is made in the following order: if there are no VIPs, the priority then will be given to the first-class passengers, then after, to the business passengers and FFP-members, considering the following issues in the given order:
(i) Firstly, if there are any first-class passengers on the both flights will be checked;
(ii) Then the number of these passengers on each aircraft/flight-leg will be considered;
(iii) After comparing numbers of these passengers, can be decided which aircraft could be handled with the priority (i.e. if to wait for the in-bound flight when there the number of VIPs and/or 1.class-passengers greater is than on the out-bound flight), particularly then, when this remains the main decision-criteria implemented into the decision making process;
(iv) If the same number of the first-class passengers in each aircraft (flight-leg) has been found, then the number and current placing (on inbound or outbound flight) of the business passengers and the frequent flyers will be taken into consideration.

2. The priority of the Operating Profitability - APP2

For this research purposes, this airline-policy prioritisation rule (i.e. to keep the revenue generated per flight higher than the costs) has been implemented in the decision making process in two steps which follows one another, as described:

(i) The priority of higher revenue per flight gained only from high-valuable passengers

It will be identified which flight (i.e. inbound or outbound) generates a higher revenue gained, considering only the high-valuable passengers. Regarding the delay-costs per flight, it will be compared on which flight occurs a lower delay-costs caused by the high-valuable passengers.

If the comparison of the revenues results in *close by* values, not aiming at taking a decision with a higher certainty on to which flight/aircraft to give the decision priority, the next step is implemented in order to give the decision maker an additional information.

(ii) The priority of the overall higher revenue gained from all-class passengers per flight

Taking into consideration corresponding airline’s business policy, the comparison of the revenues from tickets purchased for each flight facilitates taking decision on which flight to give the decision priority i.e. whether to wait on departure for the connecting in-bound passengers causing some delay, or to depart while not waiting for the arrival-delayed high-valuable passengers. Additionally to this, the costs that can occur following this prioritisation are also taken into account within the decision process.

Implemented in the designed tool, both above-described airline prioritisation strategies are designated to be freely combined according to the required/wanted relation while being customized to the given airline’s business policy. This relation of APPs (i.e. the sum of both single priorities APP1 and APP2) can subsequently individually be changed for any business and/or managerial matters.

Upon decision possibilities given in the proposed solution algorithm of the DEVOTED DSS Tool, it can be seen how the airline-policy prioritisation rules may impact each solution possibility in a specific way for each individual option, thus producing different consequences (i.e. outputs).

Table 5-1 shows the APPs with their main characteristics and utilisation, in terms of an individually impacting key factor in the decision making process implemented in the designed support tool.

Table 5-1: Airline-policy prioritisation strategies implemented in the DEVOTED DSS Tool

Airline-Policy Prioritisation	**Priority of VIPs (APP1)**	**Priority of Operating Profitability (APP2)**	
		Revenue of high fare-class Paxs/per Flight	*Revenue of all fare-class Paxs/per Flight*
Rule description	Identify the flight on which more VIP-Paxs are located, comparing the overall passenger-segmentation	Identify which one flight generates (1) a higher revenue, and (2) lower delay-cost caused by the high fare Paxs	Identify the one flight which generates (1) a higher overall revenue, and (2) a lower delay-cost from all class Paxs/flight
Priority description	As most important Paxs VIP, than: 1.Class-Paxs, and finally: BUS and FFPs	Keep the revenue gained from VIPs higher than the Delay-Cost, and/or minimize the losses	Keep the revenue gained from all fare-class Paxs higher than the Delay-Cost, and/or minimize the losses
Taking decision	Priority will be given to the flight on which more VIPs has been identified considering the overall Pax-segmentation per flight	Decision on wait/not wait refers to the higher revenue gained and lower delay-cost per flight/aircraft (i.e. which flight generates a higher ticket revenue)	Decision on wait/not wait is dependent on the location of the higher revenue gained and lower delay-cost occurred per flight/aircraft

Source: created by the author

5.4 Assumptions

For this research purpose assumed is that an airline has already established its priority-strategies in the all-day operations referring to which priority item will be followed and on which route (city-pair). Practically this means that in some cases for the airline can be of vital importance to wait for its premium passengers delaying a particular flight departure, all other

SQ-attributes equal such as: on-time performance, higher revenue than costs, and loss of the given slot-time. Another time, the same airline for the same route may decide to depart on-time not waiting for its late inbound premium passengers (i.e. as if its priority were solely on-time performance), whereby all other service quality features can stay out of the consideration. Regardless of the established strategy, whether following consequently one of these priorities or switching around them (for the same route/city-pair), each of them can be employed for one particular flight and/or on a particular day, if this is going to be of a primary importance for the operational reasons, public relations, and external supervision or for any other internal reasons.

For modelling the given operational disruption situation, the following is assumed:

1. All required resources for the out-bound flight execution are available, meaning, aircraft and the crew, and the origin (i.e. departing) passengers are already put through all airport utilities till the gate which is assigned to the operating aircraft, while they are on board or at least ready for boarding;

2. The ground handling operations for the out-bound aircraft/flight have been completed (i.e. fuelling, cleaning, and catering completed, while baggage, cargo and mail already loaded);

3. The airline's recovery-plan for disrupted passengers of both considered flights (in-bound and out-bound) is performed under the assumption that the passengers are willing to accept the suggested alternate flight or they will not refuse the proposed recovery plan if the recovering has been done under the following conditions:

   a) There is still the travel motivation from the passenger point of view for the proposed solution i.e. alternate flight. Otherwise, it will be supposed there is either a trip mode alternative (i.e. taken another traffic mean) or a trip cancellation (e.g. becoming too late for intended business matters);
   b) The passenger recovering program is made on the same day and/or date;
   c) Attention is paid to assuredness of not causing an upgrading/downgrading, which means that there is no class-degradation (in case of an upgrading, the assigned seat and service are in the higher service class as purchased, whereby by a downgrading an assigned seat/service is in the lower service class as purchased);
   d) Neither refused nor recovering-passengers will be stranded overnight.

4. The aircraft on the flight F2 flying between the airports B and C is not in a danger to be overnight or to be fallen out of network (i.e. airline controllers will not allow a disrupted aircraft to cause a ripple-effect of disruptions affecting the subsequent flights through the network and/or the day of the operations);

5. Considering the possible status issues of a flight in the execution phase (such as delay, deviation, and cancelation), referring to the modelled disruptive situation, the flights can only be delayed or identified possibly as a *disturbance with a risk to result delays*. These flights will not be cancelled or shifted;

6. Considering the status of the passengers, the business-passengers will have the same status to the airline as its Frequent Flyers in terms of the level of handling efforts and/or the quality of the service to be performed;

7. Referring to getting a new slot time for departure (of the flight F2), if the airline requires a new departure-slot, it will get it within the airline's operating time frame prescribed by the airline business-policy. On one hand, this time refers to the defined maximal waiting time for domestic and international flights, while on the other hand, to the decision on whether an issued upon request new-slot is also operationally achievable for the airline (the airline will comply with). If these two aspects are fulfilled, the airline will apply the new-slot proposal to the flight departure. Within consideration of new slot *availability* and therefore possible associated extra costs, the general rules and conditions of the air traffic control for the slot-re-assignment, advantages and utilization or cost-benefit analysis are not subject to this research;

8. If the airline has to handle its one non-priority i.e. not slot-constrained flight and one slot-regulated flight, the priority will be given to the slot-regulated one;

9. The maximum allowed delay per aircraft and/or flight is specified by the business-policy of a particular airline, while depending among others on the aircraft type, flight destination and a served city-pair history;

10. Referring to the airports working-hours, taken is that the minor disruption will be solved within the working time of both origin and the destination airports (i.e. all airports are open within the execution time for the particular airline's operations in the modelled situation);

11. Since the operation controllers are required to consider some general priorities prescribed by the airline business policy when solving the disruptive situations, they have also to respect and to apply all current requirements and/or changes given by the air traffic control (ATC) referring to the air traffic flow management (ATFM) and the current weather conditions. The following issues are already known or given:

    - Airline-policy prioritisations to be applied, referring to the departure-delays due to the arrival-delayed passengers
    - Airline business policy to be applied, referring to the max-allowed-delay beyond the planned departing time per aircraft and/or per flight
    - All (expected) adding costs when to decide to wait
    - All (expected) adding costs when to decide not to wait
    - Overall time constraints in the modelled situation.

5.5 Algorithm Design of the DEVOTED DSS Tool

The proposed multi-criteria algorithm represents the process of making decisions on whether and to which consequences to delay an out-bound flight in order to wait for the high-fare connecting passengers who are delayed on arriving with an in-bound flight. Hereby, into consideration taken are the airline-policy prioritisations (described in Section 5.3) and the modelled satisfaction levels of the SQ-attributes for both, the airline and the considered passengers (Subsections 4.5.4 and 4.5.5).

The designed DEVOTED DSS Tool consists of the airline-policy prioritisation strategy defined and the decision making possibilities presented by the Algorithm Scheme shown in Figure 5-3.

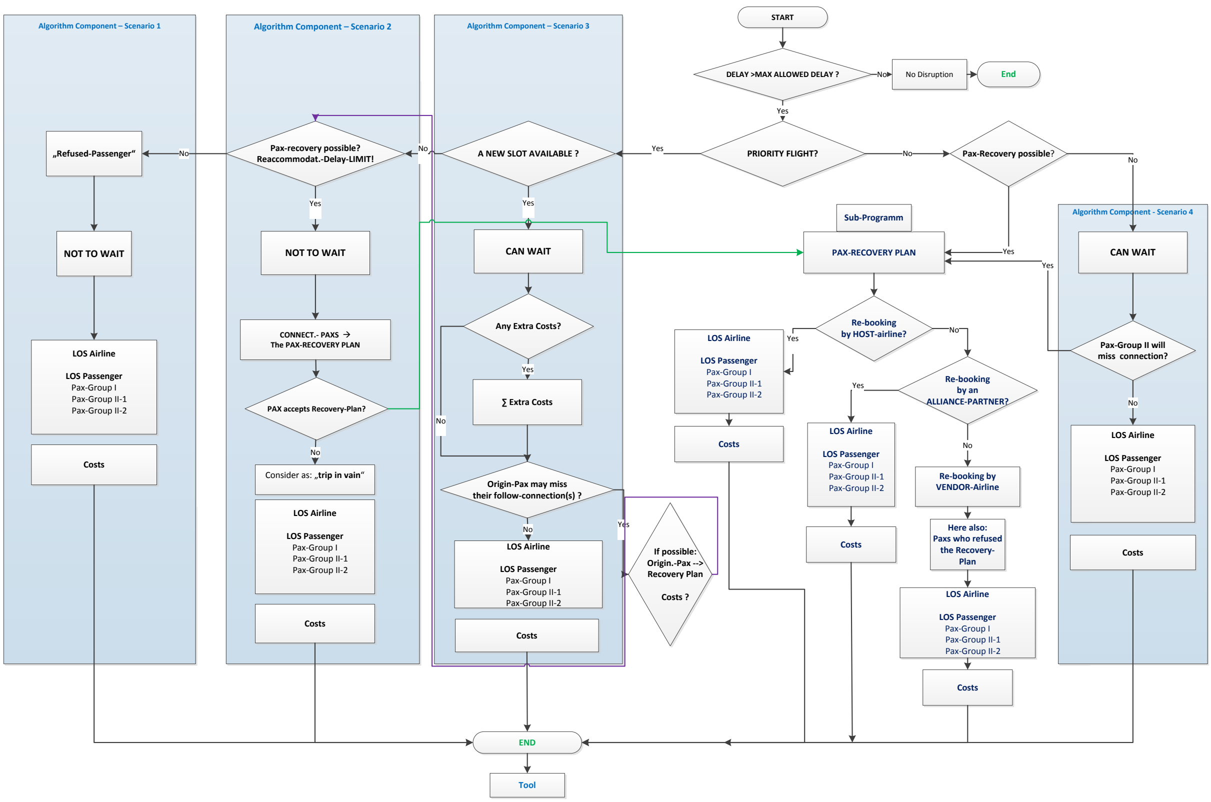


Figure 5-3: Decision making process Algorithm implemented in the DEVOTED DSS Tool

Source: created by the author

Proposed DEVOTED DSS Tool has been created to support the operation controller in the decision making process as soon as has been learnt that a disruptive (as described) operational situation will occur. Referring to the shown algorithm above, this takes place already at the level “start”, where the proposed support tool evaluates the decision options available in the given operational case.

After an airline-policy prioritisation i.e. APP1 or/and APP2 and/or their relation have been determined, the DEVOTED DSS Tool can be employed. The tool runs as follows: taking into account associated consequences in terms of the level of the SQ delivered and delay costs, the tool gives a recommendation to the operation controller which one decision is the optimal one (i.e. whether to wait or not), while still enabling taking of the opposite decision as the recommended one by the tool. In the mathematical formulation will be shown in particular how the DEVOTED DSS Tool evaluates available decision possibilities while providing recommendation for appropriate (decision) solution. The point in time and the way the proposed tool has to be started up within the operational decision making process are depicted in Figure 5-4, showing its employment and the relationship with the multi-criterial evaluating algorithm presented in Figure 5-3 as the 4 Algorithm-Components.

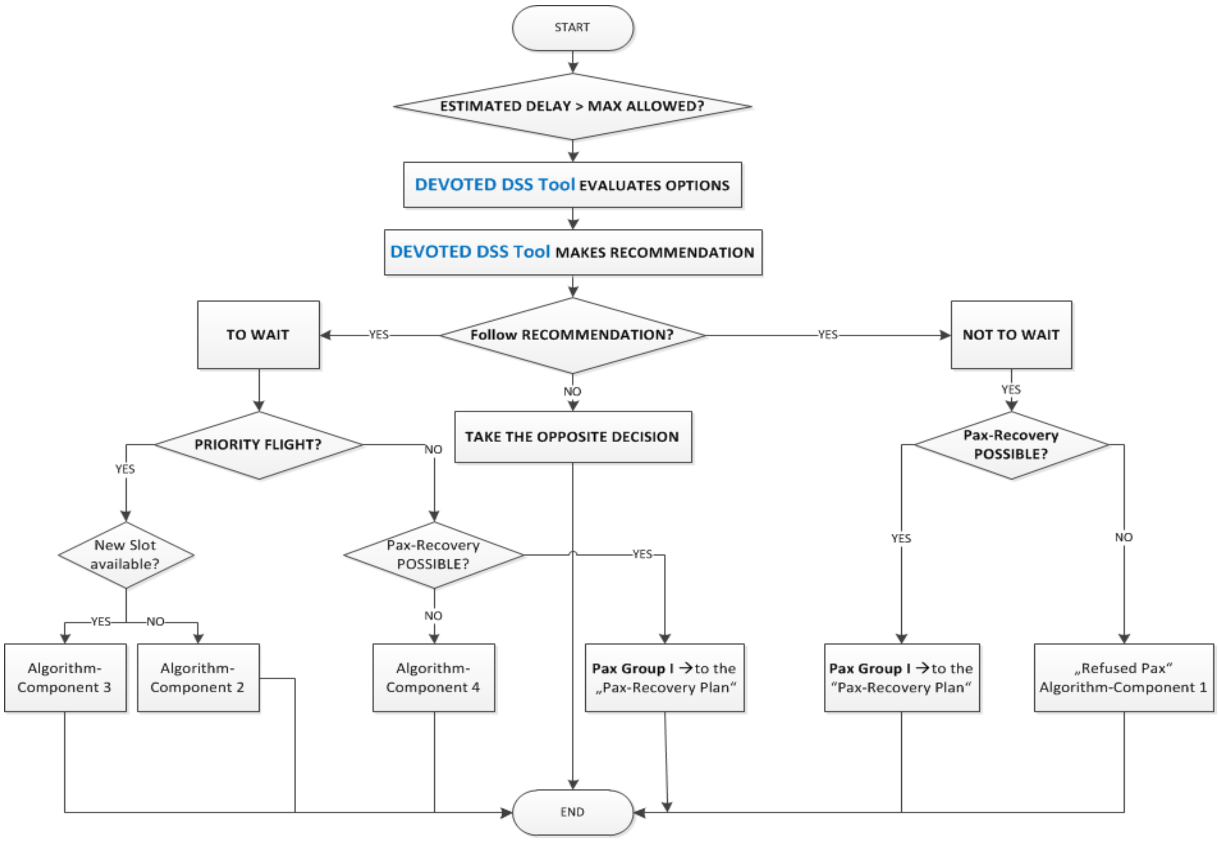


Figure 5-4: Employment of the DEVOTED DSS Tool

Source: created by the author

Figure 5-4 shows the decision possibilities the operation controller being enabled: (i) by approving the option recommended by the DEVOTED DSS Tool, the decision making process follows the algorithm-components shown in Figure 5-3 while (ii) though deciding to take the opposite decision as the recommended one, the operation controller will be still aware of the associated consequences of the particular decision made (i.e. having them displayed on the screen – user interface).

The final decisions remain in this way always in the responsibility of the operation controller, though with the possibility of being saved/stored together with accompanying consequences for the statistical and analysis matters of the airline's businesses.

Figure 5-5 depicts the phases and the way the DEVOTED DSS tool runs, showing the applications of LOS-modelling (Section 4.5) and APPs (Section 5.3). To each decision option (i.e. algorithm-component) applied is the modelled level of service (LOS) for both, passengers and the airline, as well as airline prioritisations, while considering the associated consequences of a particular decision.

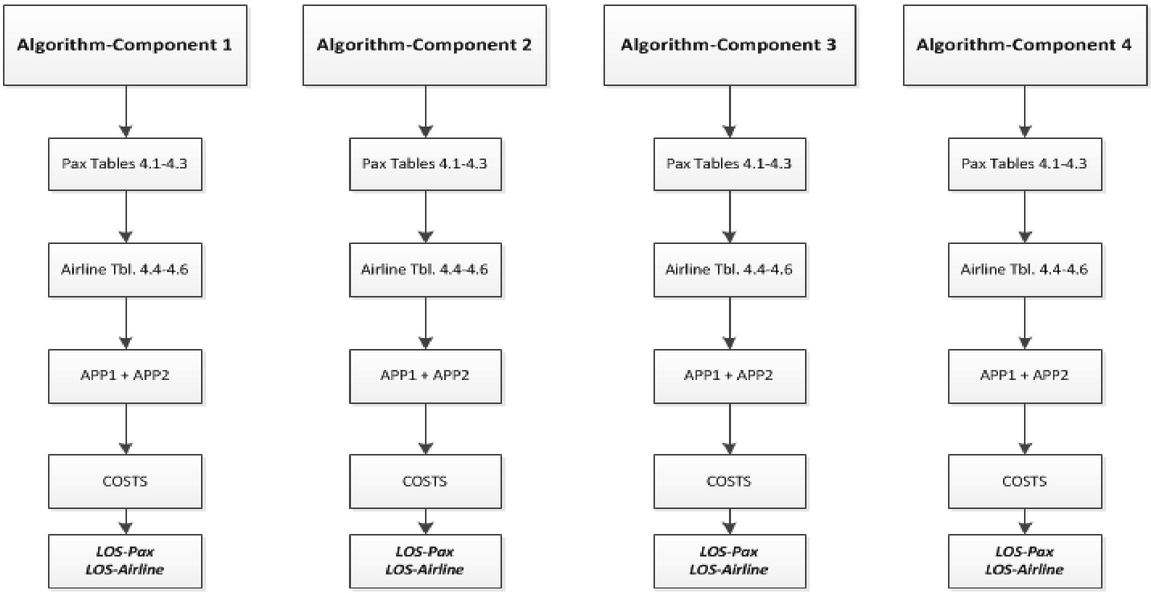


Figure 5-5: Functionality steps of applied modelling and prioritisation strategy

Source: created by the author

5.5.1 The Purpose of the Decision Making Algorithm

The intended purpose of the algorithm (Figure 5-3) when passing through all its elements is to generate, evaluate and monitor possible actions of the airline operation controllers when they are about to make the decisions on delays on departure of out-bound flights for to waiting for the connecting high-value passengers who are late in arriving of an in-bound flight.

Considering the overhead costs to the airline as well, the proposed multi-criteria algorithm estimates the impact of decisions of delaying a outbound flight for waiting for the arrival-delayed connecting inbound passengers on the level of the passengers' satisfaction with the SQ delivered, as well as the impact on the SQ-performance of the airline itself. Solution-algorithm does not (automatically) optimize the decision, retaining the last decision to be made by a dispatcher at the AOCC.

The decision making process algorithm consists of the four algorithm-components. Each algorithm component is equivalent to exactly one decision option when deciding on delays due to arrival-delayed connecting passengers being of the highest value to the airline.

The 4 algorithm-components represent possible and/or available decision options at the moment of decision making. Regarding the ranking order and being seeing from the left to the right, they can be classified from "the worst scenario" case to "the best scenario" case in terms of occurring worst or best case conditions and consequences for both the passengers involved and the airline.

Each algorithm component gives three output-parameters:

(1) The LOS perceived by the passengers (as the sum of all passenger-groups involved)

(2) The LOS quality provided by/and for the carrier

(3) Expected overhead-costs to the carrier that may occur (per a particular decision).

5.5.2 Description of the Algorithm Components

In the following subsections each particular algorithm component i.e. decision option is described. These options are constructed according to the decision conditions available for the dispatchers as well as to the airline performance capability at the moment of the decision making i.e. whether the flight is slot constrained (e.g. regulated by the ATC) and/or the passenger recovery plan is available, etc.

5.5.2.1 Algorithm Component 1

This decision solution might be also named as "The refused passenger", which in terms of this decision consequences also can be seen as "the worst" solution from the view point of both passengers and airline. In the all-day operations this solution option may be often chosen due to the different airline's operational constraints.

The important features of this decision solution can be seen in Figure 5-6.

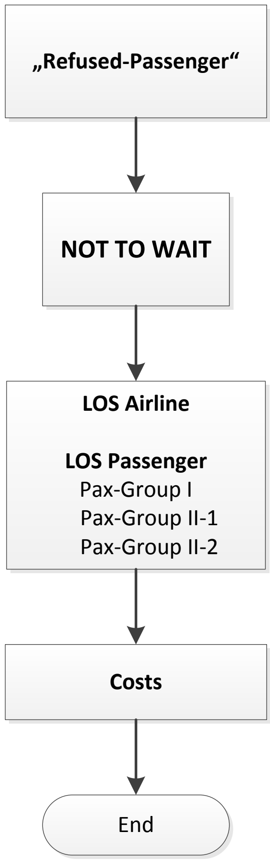


Figure 5-6: Algorithm Component 1

Source: created by the author

In this decision option, the connecting passengers from F1 must be left at the connecting airport (B) for to be overtaken by the Passenger Service in order to be re-accommodated and compensated. Hereby, a lack of available recovery alternatives for these passengers has been identified: either there is no satisfactory re-booking solution (i.e. no efficient recovery flight itinerary which is timely for the day of the travel), or offered neither by the home airline nor by vendor one. Despite, the particular (home) airline can not wait any longer for F1 and has to depart F2 as planned. The denied passengers (as a matter of affairs only for this particular flight) are named *refused passengers*. The refusing of passengers in this research is not only due to a shortage of the airline-seat capacity (including its alliance partners and any competitor airline at that particular market), but also to any other operational constraint. This happens in terms of refusing passengers without any recovery possibility. This economically refers to the so called *opportunity costs* or spilled revenue costs.

If this decision option is taken, being influenced by a possibility that the refused and not-recovered passengers can switch to another carrier for their future air travel, it is to expect that the connecting high-valuable passengers will be disappointed leading to their high dissatisfaction since they will not get the promoted service they have paid for. Even more, with no further travel solution these travellers can lose the travel motivation if the purpose of the trip has not been fulfilled. This may be for example, missing a meeting, closing a potentially lucrative business deal, giving a speech or presence at any time-constrained event, where such a trip may be considered as a “trip in vain”, for which the particular airline may agree to refund the portion of the ticket used, as well as flight back home (Emergency Procedures, Travel-On Ltd. 1996-2012).

If this option is to be chosen, the accomplished consequences defined as outputs are:

(1) ***LOS of the airline*** In this decision solution the costs are usually higher than the revenue generated from ticket purchase (costs for finding other arrangements, ticket-upgrading, accommodating, etc. for the left passengers are included).Therefore, this decision of the airline controllers causes dissatisfaction of the Pax-Group I with a probability of loss of their goodwill (impacting on the switching to the other airline, assumed there is a choice-possibility). In the case, seen from the both origin passenger groups view point, the on-time performance is delivered to the high satisfactory from the airline point of view;

(2) ***LOS to the passenger.*** The left connecting high-value passengers (the *refused ones* of the Pax-Group I) are surely dissatisfied because they don’t get the service quality they paid for. This could lead to a loss of their good impacting their possible switching to another airline for future travelling. Both origin passenger groups (II-1 and II-2) can be satisfied because they get the service level performed they paid for (i.e. an on-time performance);

(3) ***Costs*****.** These costs may be caused to the airline by re-accommodation and compensation made for the refused passenger(s), increased by a so called “spilled cost-revenue” (loss of revenue generated from the tickets purchase).

5.5.2.2 Algorithm Component 2

In this decision option the passenger-recovery for the high-valuable passengers of the flight F1 is possible/available. This means that for these passengers another (later on) connecting flight is available bringing them to their final destinations (i.e. on the same day/date) enabling departing of the out-bound flight (F2) to be executed as planned. Figure 5-7 displays this algorithm component showing the decision made on leaving the late connecting passenger(s) on the airport B to be recovered/re-accommodated by the Passenger Service.

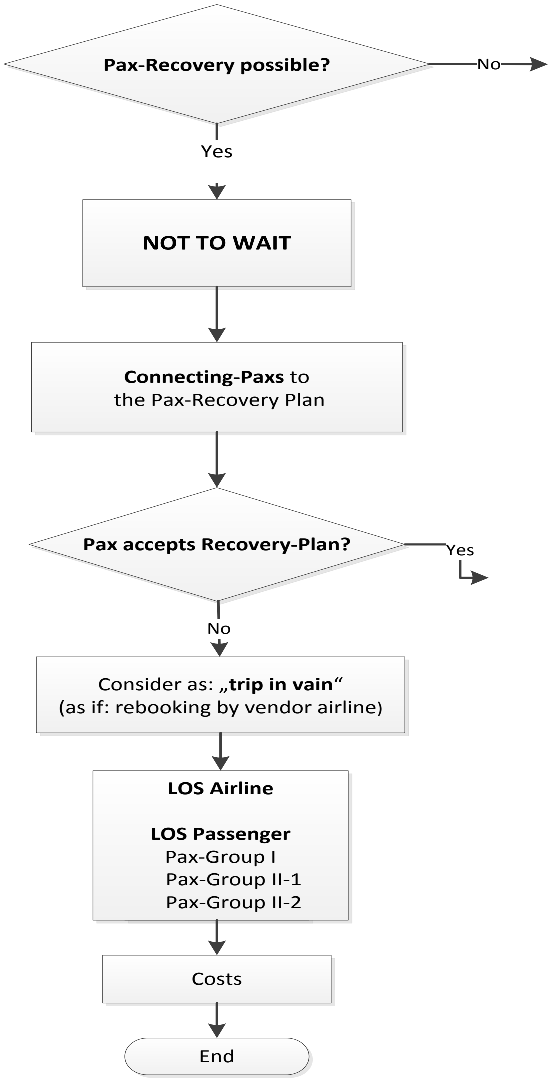


Figure 5-7: Algorithm Component 2

Source: created by the author

Passenger re-accommodation will be separately done in the proposed solving algorithm joined in a subprogram named "Passenger-Recovery Plan", which is an implemented plan of the airline for re-booking of the passengers in cases of disruptions.

However, before this decision can definitely be taken, one more important feature must be taken into account, i.e. whether the high-valuable connecting passenger(s) will accept any recommended recovery plan, or they will lose the travel motivation (the purpose of the trip cannot be fulfilled) and any suggested recovery plan will be refused.

In this research, a recovery plan as a must have i.e. a suitable solution at the same day/date of the trip is taken. Otherwise the passenger(s) can not accept the recovery plan for their further trip which will be considered as the "trip in vain". In this case it will be assumed that the passengers are recovered by a vendor airline causing costs to the home airline for the passenger rebooking while losing the revenue of the purchased ticket.

One more possible consequence of this solution may occur in terms of losing the passenger's goodwill due to the dissatisfaction with the service quality delivered due to fact the ticket is purchased for the whole trip (E.g. the Pax-Group **I** will expect to get the service from the airport A to the airport B, and further on from the airport B to C with the promoted (achievable) connectivity and as an on-time performance).

If the operation controllers choose this solution, this means that the airline will not wait for the connecting passengers from the late in-bound flight F1 and the aircraft of the out-bound flight F2 will depart as planned by leaving the late connecting passengers to get the re-accommodation from the passenger-recovery plan.

The associated consequences of this decision solution defined as outputs are:

(1) LOS of the airline:

- If the connecting passenger(s) accept the recommended recovery-plan by home airline, the airline achieves the revenue (meaning from the ticket purchase), which is higher than its costs having thereby no adding costs. Connecting passengers will not be dissatisfied with the service quality delivered (since they will get their final destination at that day/date). As taken in this case, there is no reason for a dissatisfaction of passengers which could lead to the loss of their goodwill. The airline's on-time performance will lead to the satisfaction of both origin passenger groups.
- If the connecting-passengers from the Pax-Group I refuse the proposed recovering plan to reach the destination airport (C), the Passenger-Service of the home airline has to bring them back home, while recovering and re-accommodating them if required. In this research this is considered as the recovery made by a vendor airline, causing the home airline some extra costs but not risking the loss of the Pax-Group I goodwill (this decision is made by the passengers themselves). Of course, this will influence the overall airline SQ level performance to all passengers, reducing the satisfaction achieved.
- The airline's on-time performance delivered to the both origin Pax-Group II-1 and II-2 will prove satisfactory with the LOS of airline.

(2) ***LOS to the passengers.*** With the decision on *not to wait* beyond the departing time, the airline achieves delivering of its performance to each passenger group to the following satisfaction-levels:

- In the case of the Pax-Group I, the airline delivers the performance to the satisfactory-level neutral, bringing these passengers by applying the recovery-plan to their final destination but not losing their goodwill for their future travelling

- In the case of the Pax-Group II-1, the airline delivers the promoted service departing on-time, whereas this performance leads to their satisfaction
- In the case of the Pax-Group II-2, the airline's promised and delivered an on-time performance, which leads to their satisfaction is achieved

(3) ***Costs***. Since the airline departs F2 on-time offering the recovery-plan for the late high-valuable passengers, the accompanying additional costs could be expected in the phase of the execution of the passenger recovery-plan, especially if it has to be executed by a vendor airline. Hereby, the possible difference in the ticket prices should be considered when rebooking has to be made by the airline alliance partner (interline). In the case of the passenger recovering by a vendor airline, the cost may arise from the difference in the ticket prices, as well as the lost revenue of the purchased ticket by the home airline.

5.5.2.3 Algorithm Component 3

The Algorithm Component 3 illustrates the decision solution which can be seen as the most constrained one in the modelled disruptive situation. The airline controllers have first to accumulate some adding information on possible further actions which might be undertaken.

Figure 5-8 depicts this decision solution showing the necessary conditions for gaining of the situation awareness while taking into consideration all three passenger groups and all the regulated times (slots) given for the airline's operations execution.

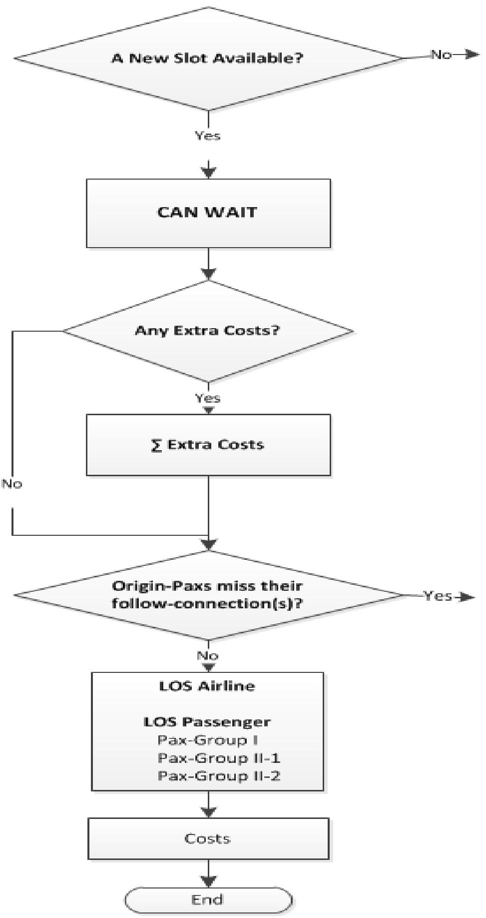


Figure 5-8: Algorithm Component 3

Source: created by the author

At this stage of the decision making process, the controllers are about to handle a priority flight F2 which is slot-regulated. For gaining a better overview of possible solutions and an improvement of the situational awareness, the very first thing that must be cleared up is whether there is a new slot available which at the same time must be achievable and convenient from the airline operations point of view. This time is needed for enabling of a better predictability of the Target Off-Block Time (TOBT) of the particular aircraft/flight as the very last chance within the turn-around phase for a possible still boarding of the late high-valuable passengers from F1. According to the definition, the TOBT is the time that an aircraft operator or ground handler estimates for an aircraft to be ready to start up (all doors closed, boarding bridge removed, push back vehicle available) while push back starts immediately upon reception of clearance from the Aerodrome Control Tower (Eurocontrol 2012, p. 17). Afterwards, a ready for take-off aircraft is required to start its movement on the runway for the take-off sequence procedures. Sometimes, for the airport and particularly for the gate management purposes, after the ground handling operations and boarding of the origin passengers are fully completed, the particular aircraft can be required to be removed onto another assigned (or regulated) free position on the apron area. Parked at a dedicated so called remote bay (i.e. pushed/pulled-back away from the gate/finger position), the particular aircraft can also wait to be assigned a better new slot time for its departure. *Though, it is still in a position to potentially take the late connecting high-valuable passengers who will be transported to this remote standing position.*

Taking into consideration dependency of a new-slot assignment on the current air traffic flow situation (possibly causing a limit of slot availability) and the time limits which are set up by the airline management for its operational and/or business matters, the maximum waiting time beyond the defined maximum allowed delay in the modelled situation is set up on that point of time from which on the origin passengers from the Pax-Group II-2 might miss their follow-up flights (F3/F4) departing from the airport C. The operation controllers have to make trade-offs between this limit border and new assigned slot time when they are about to take the decision on how long to wait on connecting passengers from the flight F1. This means that the airline can not accept (from its operations' side point of view) a new proposed slot which would be beyond this time. There are two possibilities of the decision making process at this stage:

1. In the case that the requested new-slot is not (timely) available and/or for the airline not convenient, the decision making process goes along the Algorithm Component 2
2. In the case that a new-slot is available and also convenient for the airline (i.e. to be applied), the airline can decide to wait for its late connecting passengers. However, this waiting time is, as above explained, the *limit border* constrained with the flight connecting time needed for the origin passengers of the Pax-Group II-2

The first following step needed in this decision option is to clear up whether the origin passengers from the Pax Group II-2, who have to continue the travel with one of the follow-up flights (F3/F4) departing from the airport C, can retain the ability to get their connecting-flights. If they might miss the connections due to late arriving at the airport C, the passengers of the Pax Group II-2 should have an appropriate recovery plan available. Hence, if these passengers can be recovered i.e. there is an alternate flight for bringing them to their final airport(s), the limit time border will be the latest time for enabling of their recovering.

If this decision solution is chosen, the associated consequences of F2 waiting on departure beyond the actual ready time of the particular aircraft/flight are the following:

***(1) LOS* of the airline.** In this decision solution (can wait) the airline has delivered the performance to its satisfactory, since it is not required to leave its late passengers (Pax Group I) and after waiting an amount of time beyond the allowed maximum delay time it will carry on-board all its passengers who purchased tickets for travelling on these flight-legs (from A to B, and from B to C). This performance will lead to the airline's satisfaction with its SQ delivered.

***(2) LOS* to the passengers**. The level of SQ delivered in this decision solution is expected to be differently perceived by each passenger group as follows:

- Pax Group I: in spite of their late arriving on the flight F1 at the airport B, they are enabled to get their follow-up flight F2 which can be expected to lead to their high satisfaction with the SQ delivered
- Pax Group II-1: these passengers are rather neutral-to-dissatisfied with the SQ delivered, since they end their travel at the airport C, though expecting the promised level of service they paid for
- Pax-Group II-2: since these passengers become connecting passengers at the airport C, they are rather dissatisfied with a delayed flight F2, because they could become disenabled to get their connections at the airport C; they do expect too, to get the service quality they paid for (an on-time performance)

(3) Costs. Due to postponing the departure of the flight F2 beyond the prespecified maximum allowed delay, the airline could suffer some extra costs such as costs for crew extra duty times, any ramp-staff (ground handlers) costs, costs for possibly extra personnel for a fast putting through and baggage transferring, as well as any costs for an aircraft standing on a remote holding position (if it takes longer than contractually agreed with the particular airport).

5.5.2.4 Algorithm Component 4

This decision option might also be named “the best solution”, since this solution is the best possible from the viewpoint of both airline and passengers.

At this stage of the decision making process it is already well-known that the operation controllers deal with the flight which is not slot constrained. This means that the departure time of this aircraft could be postponed beyond its actual *ready time* theoretically until the connecting passengers who are late on arriving are also on-board of this flight (F2). In this case, the time the late connecting-passengers have been arrived and bordered in F2 would be the earliest departure time possible for F2 aircraft at which it is ready for start departure.

This algorithm component, showing the operational and/or tactical constraints which lead to this decision solution as well as its accomplished consequences, is displayed in Figure 5-9.

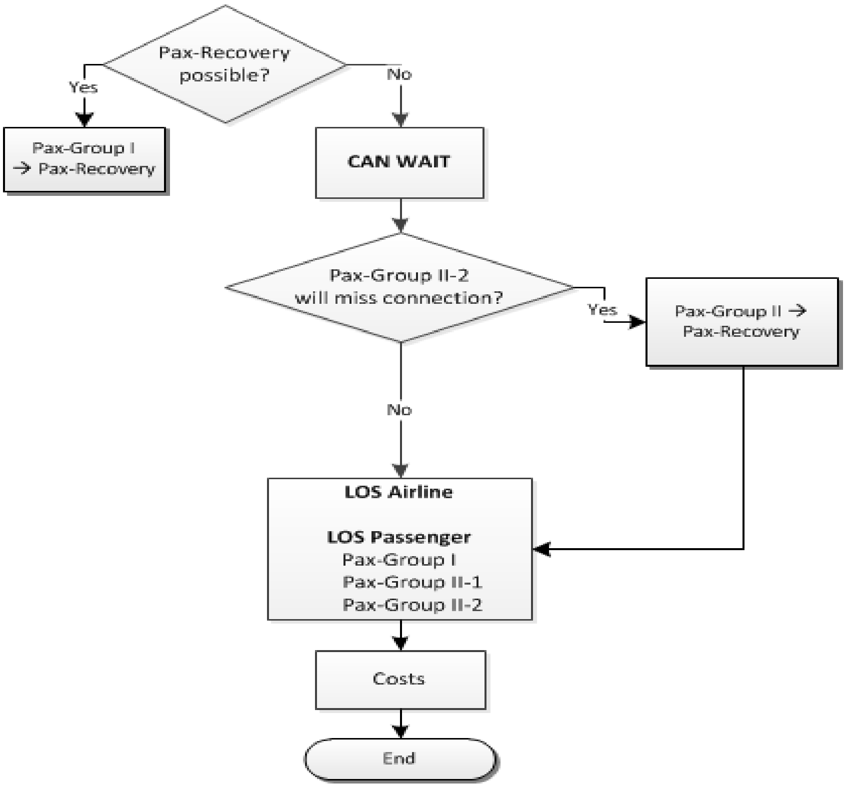


Figure 5-9: Algorithm Component 4

Source: created by the author

Since the origin passengers of F2 are already on board (they *are* on-time), they do expect the airline departure as scheduled, i.e. on time, as a performance of the promoted (and paid for) service quality. Hence, there are origin passengers that do not end the travel at the destination airport C (Pax Group II-2) but are continuing their travel with the follow-up flight(s) e.g. F3 or F4. The operation controllers will take into consideration this possibly new connectivity-disruption within the decision making process as well. Therefore, the very last departing time for the flight F2 shall be the time limit set-up to ensure that the departing passengers from the Pax Group II-2 will not miss the connecting flight(s) at the airport C. In case the flight F2 might arrive late at the airport C, these passengers must be enabled a proper recovery plan i.e. ensured re-accommodation possibility.

However, the operation controllers will first check whether the arrival-delayed passengers i.e. connecting passengers of the Pax Group I from the in-bound flight F1 can be suitably re-accommodated within the passenger recovery program onto the one of the following flights departing from the origin airport B. If the recovery possibility is available, the flight F2 can depart on-time, being not required to wait on the late connecting passengers. As it is well known, most airlines will try to rebook/re-accommodate the disrupted passengers onto their own flights first (Cook 2014).

This decision option involves two possible end-solutions. The first one is: if the airline has a suitable recovery plan that is available for the late in-bound passengers, then the flight F2 can depart on-time being not required to wait. The second one is: if there is no suitable recovery possibility for the late in-bound passengers, then the aircraft will wait (however, only to the time point when the departing passengers from the Pax Group II-2 might be in danger to miss their connecting flight(s) at the destination airport C), departing at the earliest departure-time which is possible i.e. when it is ready for.

Associated consequences of both solutions in this decision scenario are similar. However, they differ only in costs that are arising from the possible passenger recovering by a vendor airline or/and to some extent if recovered by the alliance partner, as showed in the following:

(1) LOS of the airline. Since the airline has succeeded in delivering the promoted LOS quality (getting all its passengers who have purchased the tickets for the particular flights to their final destination(s)), this service will improve satisfaction

(2) LOS to the passengers may be individually perceived as follows:

- Pax Group **I** can be satisfied, because they get the promoted and promised service, meaning they will get their connecting flight with some delay and reach the destination at their full satisfaction with the SQ delivered
- Pax Group **II-1** will be at least not dissatisfied i.e. the level of their satisfaction is rather neutral, because they will end their travel at the airport C with some delay on departure. They may be also not explicitly satisfied, since they do expect an on-time performance as the promoted level of SQ they paid for
- Pax Group **II-2** in the case of waiting on the Pax Group I will be dissatisfied, in spite of the fact that they will be not disabled to get their follow-up flights at the airport C. This is because they do expect the SQ they paid for (i.e. an on time performance). In the case of not-waiting for the late Pax Group I, these passengers will be rather neutral, meaning the SQ of the airline (its on-time performance) was expected (as well as a promoted one) SQ-attribute. In this model this is classified as a *reverse quality* which does not lead to satisfaction if fulfilled, but for sure to the dissatisfaction if not fulfilled.

(3a) Costs for the case of not-waiting. These come from the passenger-recovering by a vendor airline in the case when a home airline and/or its alliance partner are not able to recover the late connecting passengers from the flight F1. Recovering by a vendor airline can lead not only to the loss of the ticket revenue gained from these passengers, but also to some extra costs due to the difference in the ticket fare and/or costs associated with a possible accommodation. This is evident from the well-known price-structure of the purchased tickets which has to be implemented for a gathering the operating revenue (while on the other hand, has to proportionally cover operating expenses);

(3b) ***Costs for the case of waiting***. These are costs that may arise from waiting for the delayed connecting premium passengers including any costs for extra working time of the ramp-personnel (or ground handlers), any aircraft marginal maintenance costs, and finally

the passenger delay-costs. However, the passenger delay-costs occur if the waiting time causes recovery of the passengers from the Pax Group II-2 by another airline for their further travel at the destination airport C.

5.5.2.5 Algorithm Component: Subprogram for the "Passenger Recovery Plan"

Each scheduled airline will have its own system how the disrupted passengers will be re-accommodated and compensated, according to the defined airline business policy, taking into consideration its position (or its reputation) on the particular market as well as whether the airline belongs to an airline alliance or not.

This is the way of how to re-accommodate or to re-book each passenger onto the best flight itinerary on alternative flight-legs within a specified time frame, being either recovered at the home airline and its alliance partner or at a vendor carrier.

Recovering of passengers has to be done according to the business policy of the particular airline and by incorporating relevant factors such as its flight frequencies and schedules as well as system and route load factors (i.e. seat availability for the particular day/date for the required flight destination). At the best this is done by the home airline or by its alliance partner (referring to the passenger re-accommodation based on interlining hierarchies), whereas the worst solution (from the airline viewpoint) would be the passenger-recovery which has to be done by a vendor airline.

At most airlines still today the passengers are only rebooked onto the originated carrier or a co-member of an alliance network (Cook, Tanner et al. 2013). Nevertheless, most airlines will always try to rebook disrupted passengers onto their own flights first. However, on successful re-accommodation the fare of remaining legs is transferred to the new carrier according to principle laid down by IATA (*ibid.*, p. 98).

Hereby, the airline(s)-seat capacity which is available for that particular flight-leg (i.e. between the origin and destination airports), as well as the difference between the daytime and evening limits which can create a significant difference in the overall accompanying costs for the passenger recovery will be taken into consideration. Examining causes and costs for passenger travel disruptions Barnhart, Fearing et al. (2010) detected the difference in influence of the day and evening time factor which can create an arbitrary jump in distribution of disruptions.

In accordance with the re-allocation of the recovering passenger(s), an important accompanying factor is a sum of associated costs incurred to the home airline. This can be in terms of e.g. difference-cost for upgrading/downgrading by the home airline's own flights or by the new carrier, and/or possible returning to home if there are no suitable recovery possibilities available to offer to the recovering passenger(s). Following the financial analysis reported by IATA (2011), the biggest item of the "Transport Related Expenses" comes from payment of major air carriers to their code-share partners for transporting the code-share passengers (i.e. coming from the passenger-recovering and accommodation by other carriers of the same airline alliance).

In practice, an airline will be always trying to avoid offering a seat in another service class (i.e. other than specified in the ticket) in the process of the passenger-recovery planning. In this manner, it will be not forced to deal with additional consequences of delays within the recovery-plan such as downgrading/upgrading problems, which are dependent on the capacity of the substitute aircraft and could lead not only to additional dissatisfaction of the passengers, but also to the revenue-losses of the airline.

At this place, for the airline controllers' decision making process as the most important item is whether the late connecting passenger(s) can feasibly be recovered by the home airline or its alliance partner(s), or the recovery must be made by a vendor airline.

Referring to the decision making process of the modelled situation, it has to be solved at which airline will be the late passenger(s) recovered. According to the chosen re-accommodation option (i.e. at which airline is the recovery plan possible), the associated delay- and recovery-costs, especially in case of recovering by a vendor airline, will be taken into account.

This component of the proposed solution algorithm is shown in Figure 5-10 displaying all solution options available within the passenger recovering-plan process.

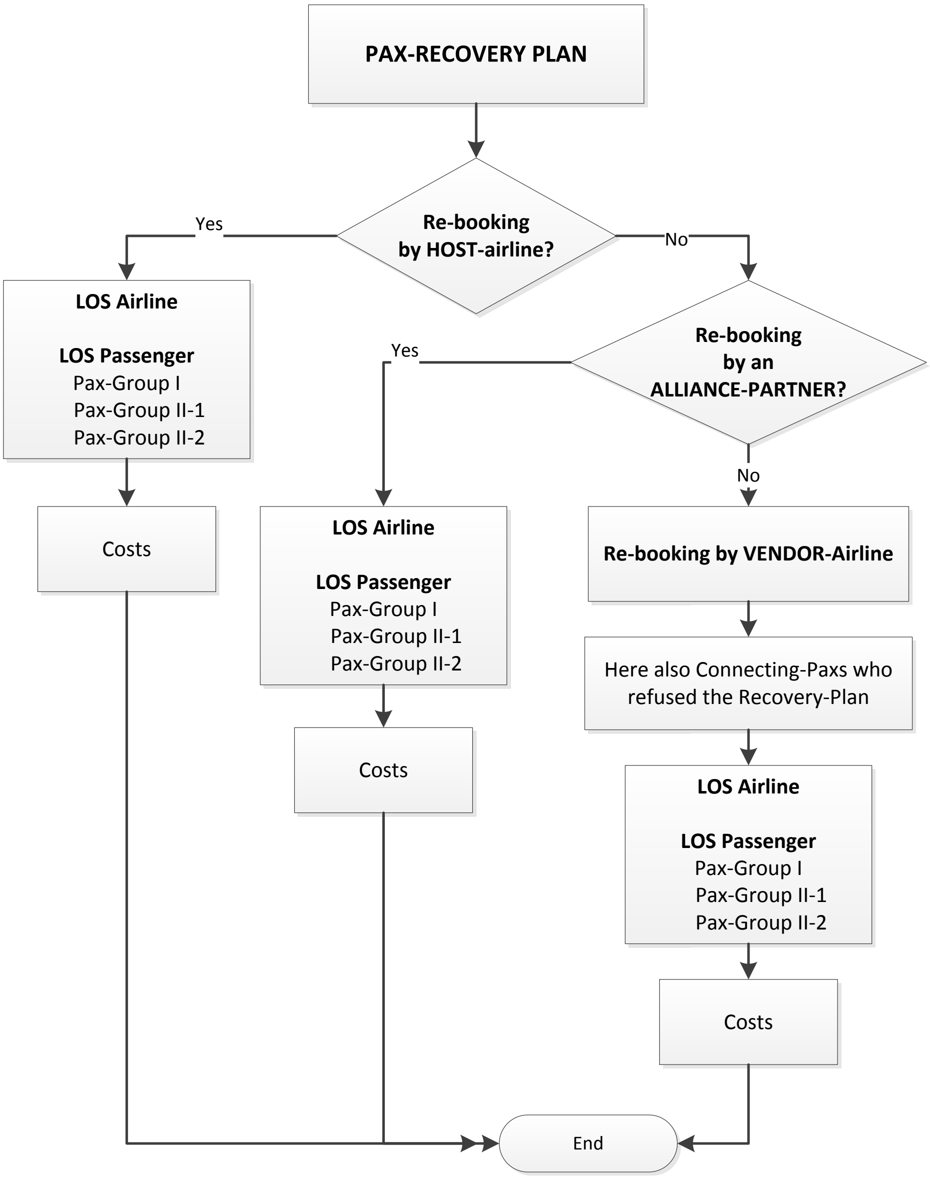


Figure 5-10: Algorithm Component - Subprogram for the Passenger-Recovery Plan

Source: created by the author

Accordingly to the found solution, possible accompanying costs are expected to be the highest if the passenger(s) is/are recovered by a vendor airline. In the latter case, the home airline loses not only the ticket revenue of the particular passenger(s), but it is possible that some extra costs can arise from the difference in the ticket price purchased by a vendor airline. For this purpose each scheduled airline will have its own “price list” referring to the compensation and re-accommodation including all costs relating to delay incurred by the airline. This particularly refers to the cases with business passengers’ delayed baggage.

5.5.3 The Algorithm Output

Aiming predominantly at monitoring of decision solutions and their quantitative and qualitative consequences as its main objectives, the DEVOTED DSS Tool allows the final decisions to be made by humans (i.e. operation controllers) since they have not only the responsibility for, but they are also accounted for consequences of the decision(s) taken.

Respecting the key elements of Human-Centred Design (HCD), since the DEVOTED DSS tool incorporates the user's perspective within the considering disruption situation conditions, as well as the organizational requirements such as the airline-policy prioritisation strategies, the two output components are reflected on the user interface in form of the 3-colour-bar, consisting of three colours indicating an option as *good, neutral* or *bad* one.

Including the delay-costs expected per each decision made, the two tool output-components are defined as:

- The level of service quality delivered by the carrier named as "*LOS Airline*", and
- The level of service quality perceived i.e. afflicted by the passengers named "*LOS Passenger*"

Both described output-components can be displayed: (i) separately as the values achieved as Figure 5-11 shows (each output-component value – represented by the blue line – onto one 3-colour-bar), or (ii) as both output components displayed on the one/same 3-colour-bar.

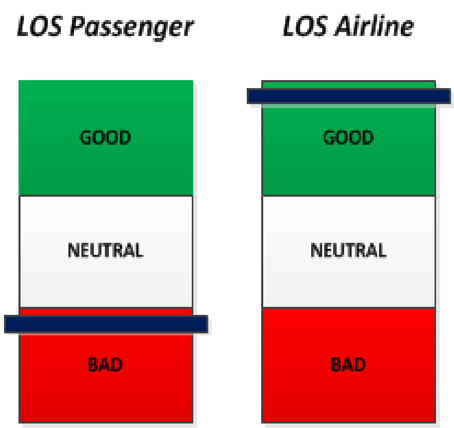


Figure 5-11: Graphical illustration of the DEVOTED DSS Tool Output Components

Source: created by the author

Following the displayed outputs, the satisfaction level achieved by all considered passengers is in the "red" field which indicates their very low satisfaction level with the service quality perceived (dissatisfied), while the value of the airline's LOS performed (displayed as the blue line on the upper "green" field) indicates a very high level of SQ delivered by the carrier.

5.6 Mathematical Background of the Decision Making Process

In this section mathematical formulation of the decision making process which is based on human centred approach (referring to the respected environment and conditions of the decision making for operation controllers and the airline policy prioritisations) is presented.

Each decision solution of the proposed mathematical algorithm gives two outputs adapted for the user interface in form of the above shown two 3-coloured bars. These are designed including the summarized levels of the achieved SQ attributes of both delivered by the carrier and perceived by the all involved high-valuable passengers, and the expected delay costs. Herewith, the decision maker (i.e. operations controller) is supported in the decision making process for solving the minor disruptions (i.e. delays) through enabled direct visualization of the main decision key drivers fitted for each decision solution.

5.6.1 Design of the Coloured Bar of the DEVOTED DSS Tool

The coloured bar of the support tool has been designed for displaying of decision solution possibilities, or precisely, consequences of the decision solutions into the user interface. It consists of a rating scale of the satisfaction levels, shown as the bar of the three coloured fields: red, white, and green.

To enable placing of the achieved satisfaction levels with the service quality performed into one of the three colour fields of the bar, a conversion of the qualitative levels to the quantitative values is necessary.

For this purpose a mathematical scale lying between the border values $\frac{1}{4}$ and $\frac{7}{4}$, enabling the value 1 to be the midpoint for representing the satisfaction level “neutral” is introduced.

To each qualitative-level modelled in Section 4.5 ranging from the level “very dissatisfied” to the “very satisfied”, assigned is a corresponding quantitative-value of the mathematical scale for to be in accordance with the set of defined values L as follows:

$$L = \left\{\frac{1}{4}, \frac{3}{4}, 1, \frac{5}{4}, \frac{7}{4}\right\} \tag{1}$$

According to this, qualitative border-level named “very dissatisfied” corresponds with the border-value $\frac{1}{4}$, while the “very satisfied” border-level corresponds with the border-value $\frac{7}{4}$.

For mapping of equation-values onto the ranked fields of the designed 3-coloured bar, the converting function ω is applied:

$$\omega\,(x) = \frac{3}{4}x + 1, \;\; x \in [-1, 1] \tag{2}$$

Hereby x represents a value of a decision solution which shall be converted onto the 3-colour-bars. In this way the decision-solution-values will be mapped onto the 3-colour-bar, which is reflected on the interface to be seen by the decision maker i.e. operation controller.

In this way, each decision option value can be mapped onto one of the positions on the coloured bar within taken border values by applying the given converting function ω.

Each bar displays the three colours: red, white and green. They are defined as follows:

(1) The *green coloured field* displays the rating scale of the "*satisfied"*-satisfaction level achieved (i.e. performed and/or perceived), being defined by the weight values which lie between $\frac{5}{4}$ and $\frac{7}{4}$, or: $\omega \in \left(\frac{5}{4}, \frac{7}{4}\right]$ (3)

Lying on the green field of the bar, it takes one of the positions within the frame defined between lower bound named "satisfied", and the upper one named "neutral-satisfied", indicating a "good" decision taken or, *satisfied with*. Hereby, the closer the weight value to the border value $\frac{7}{4}$, the greater is the influence of the decision solution on the satisfaction level.

(2) The *white coloured-field* displays the rating scale of the "*neutral"*-satisfaction level achieved (i.e. performed by the carrier and/or perceived by the passengers), which is defined by weight values lying between $\frac{3}{4}$ and $\frac{5}{4}$, or: $\omega \in \left[\frac{3}{4}, \frac{5}{4}\right]$ (4)

It indicates that a value is close to 1. It signifies that a certain decision option has little influence on a satisfaction-level i.e. considered as an "indifferent" or "neutral" satisfactory level lying between the satisfactory levels denoted as "dissatisfied" and "satisfied" ones.

(3) The *red coloured-field* displays the rating scale of the "*dissatisfied"* satisfaction-level achieved i.e. performed and/or perceived, being expressed by the value which takes one of the weight values between $\frac{1}{4}$ and $\frac{3}{4}$, or: $\omega \in \left[\frac{1}{4}, \frac{3}{4}\right)$ (5)

The closer the value to $\frac{1}{4}$, the greater is the influence of that decision solution on the satisfaction level defined as the lower bound of the red-filed denoted as the "very dissatisfied" one, since the level of the dissatisfaction increases. The value which closes to $\frac{3}{4}$ implies that a certain quality of service has less influence on a satisfaction level, defined as its upper-bound denoted as "dissatisfied".

The way the mapping function $\omega\,(x)$ converts any $x \in [-1, 1]$ to any position on the scale between the border values $\frac{1}{4}$ and $\frac{7}{4}$ can be seen in the following example:

For $x = 1$, the mapping function $\omega(1)$ converts x to the position $\frac{7}{4}$ on the scale which corresponds to the position of the “very satisfied” satisfaction value which on the other hand lies in the “green” coloured domain of the bar.

5.6.2 Mathematical Formulation

To express mathematically the above-shown process of decision making on whether to wait on departure for the late connecting high-valuable passengers, it is first necessary to emphasize the different airline-policy prioritisation decision drivers i.e. prioritisation scenarios. In this study two main prioritisations are considered: 1) the level of SQ delivered to the passengers and 2) keeping revenue higher than the costs in order to operate profitably.

Particularly, it is the LOS quality performance which has been influenced by the airline-policy prioritisation. This is one of the tool outputs (*LOS Airline*). The other tool output is the LOS quality perceived by the considered passengers (*LOS Passenger*), both reflected on the designed 3-colour-bars on the user interface (introduced in the previous subsection).

For mathematical expression following terms and conditions are taken into consideration:

(i) The number of all high-valuable passengers involved is defined as: n which is the number of all high-valuable passengers arriving on the inbound flight F1, and m which represents the number of all high-valuable passengers departing on the outbound flight F2;

(ii) If $n = 0$ and $m = 0$, then an airline’s decision on whether to wait or not on departure for its late-arriving high valuable passengers will follow its all-day operation-execution path which is determined by the airline business policy considering no more exceeding passenger-related requirements;

(iii) In accordance to the previous, assumed is that there are some high-valuable passengers on the arriving flight ($n > 0$) and/or on the departing flight ($m > 0$) which is necessary when making a decision on whether to wait or not for the late inbound flight;

(iv) The high-valuable passengers on the arriving-flight (ARR) and departing-flight (DEP) are determined by the following:

- The function $VIP_{ARR,i}$, determining whether or not the arriving passenger i at F1 is a connecting VIP passenger, is defined by

$$VIP_{ARR,i} = \begin{cases} 1, & connecting\ VIP\ Pax \\ 0, & other\ i\ Pax \end{cases} \tag{6}$$

- The function $VIP_{DEP,j}$ determining whether or not the departing-passenger j at F2 is a VIP passenger, is defined by

$$VIP_{DEP,j} = \begin{cases} 1, & a\ VIP\ Pax \\ 0, & j\ not\ a\ VIP\ Pax \end{cases} \tag{7}$$

In the same way functions, for determining whether or not the arriving connecting passenger i and the departing passenger j are ones of the high-valuable passengers, are defined.

- Functions for the first-cabin class connecting arriving passengers ($1.C_{ARR,i}$) and first-cabin class departing passengers ($1.C_{DEP,j}$) are defined in the same way.
- Accordingly to the same rule, the functions for connecting business passengers $BUS_{ARR,i}$ and frequent flyers $FFP_{ARR,i}$ on the arriving flight are defined.
- Likewise the functions $BUS_{DEP,j}$ and $FFP_{DEP,j}$ for determination of the departing business-passengers and frequent flyers are defined.

The Importance Grade of the Airline-Policy Prioritisation strategies

Into the DEVOTED DSS Tool the two main airline-policy prioritisations (APPs) have been implemented, which mathematical expression is presented in the next following steps. APPs influence directly the particular airline behaviour in the execution of its operations as well as its making decisions, and especially the ones on whether to delay an outbound flight in order to wait or not for connecting high-valuable passengers of an in arriving delayed inbound flight.

For this research purposes, a coefficient for denoting the importance (grade) of each airline-policy prioritisation individually has been introduced, which an airline may determine in accordance with its business policy and economic interests.

Also any combination of both presented APPs for constituting of the airline's priority strategy, as a whole, can be achieved by assigning the appropriate coefficients, given as follows:

1) β_1 denotes the importance grade of the *LOS delivered* to the (high valuable) passengers in the airline prioritisation strategy (see Section 5.3)
2) β_2 denotes the importance grade of *the operating profitability* in the airline prioritisation strategy (see Section 5.3)

The use becomes clearer through the following example: an airline can determine its prioritisation strategy as a relation of, for example, 25% importance grade of the LOS delivered to the high-fare passengers (β_1) and 75% importance grade of the operating profitability (β_2) in its APP strategy as a whole, whereby having a possibility enabled in the designed tool to arbitrarily change the given relation (i.e. 25%:75%) as perhaps might be required/wanted for a particular flight/city-pair for any managerial or business matters.

5.6.2.1 Decision Making Based on the Priority of LOS to the Paxs (APP1)

The mathematical value of the decision making at the AOCC based on this airline prioritisation strategy, when it is about to decide whether to wait or not on departure for the late connecting high-valuable passengers, is denoted as value a, mathematically is expressed as follows:

$$a = \frac{\propto_1}{n+m}\left(\sum_{i=1}^{n} VIP_{ARR,i} - \sum_{j=1}^{m} VIP_{DEP,j}\right) + \frac{\propto_2}{n+m}\left(\sum_{i=1}^{n} 1.C_{ARR,i} - \sum_{j=1}^{m} 1.C_{DEP,j}\right) +$$

$$+ \frac{\propto_3}{n+m}\left(\sum_{i=1}^{n} (BUS_{ARR,i} + FFP_{ARR,i}) - \sum_{j=1}^{m} (BUS_{DEP,j} + FFP_{DEP,j})\right) \quad (8)$$

Coefficient α_i in Eq. (9) denotes the weight of the *value* of the passenger to the airline based on the ticket purchased and/or the flyer status at the carrier, whereby α_1 is the *weight* of the VIP passengers, α_2 is the *weight* of the first-class (1.C) passengers, and α_3 is the *weight* of the business-passengers (BUS) and FFP-members.

$\alpha_i \in [0,1]$, while $1 \le i \le 3$, $\sum_1^3 \alpha_i = 1$, where: $\alpha_1 > \alpha_2 > \alpha_3$ (9)

The use of the coefficient α_i (importance value) relies on the plausible reasoning about purchasing the passenger seats according to the seat configuration actual and factual used in the airline operation practice. On the other hand, this is in accordance with the IATA recommendations made for the ratios of costs that need to be charged, and therefore of fares for 3 cabin classes. This recommendation is based on seat space required i.e. seat pitch and seating layout in different cabins taken for the relationship between the first-, business and economy cabin classes to be in relation: 271:187:100 (Doganis 2002, p. 289). Herewith, accordingly to the importance values of the first-class passengers (α_2) and of the business passengers and Frequent Flyers (α_3), the ratio of the ticket prices for these passengers have been already predetermined. The value to be given to the coefficient of the VIPs (α_1) will be aligned with the given airline-policy prioritisation, determining directly *how much important* the VIPs to that particular airline are.

The value a of the Eq. (8) may take a value: $a \in [-1, +1]$ (10)

Making decision on whether to delay an out-bound flight departure (in order to wait for high-value arriving delayed passengers from an in-bound flight) can be expressed according to Eq. (8) as follows:

(i) The value of a is higher than zero: $\boldsymbol{a} > \mathbf{0}$

The value of a greater than zero indicates that the aircraft will wait for the late in-bound high-value passengers, with the accompanying consequences which will be shown in the model outputs;

(ii) The value a is smaller than zero: $\boldsymbol{a} < \mathbf{0}$

The value of a less than zero indicates that the aircraft of the out-bound flight should not wait for the late in-bound passengers, departing as planned in the flight schedule.

(iii) The value $\boldsymbol{a} = \mathbf{0}$

The value of a equals zero, though almost extremely seldom to experience in practice, indicates an operation situation where the juxtaposition of the difference of all high-fare cabin classes between the inbound and outbound flights including the given importance values of the high-fare passengers will remains indifferent, and the airline or its operation controller can make a decision as if would have been taken without high-fare passengers at all (i.e. being dependent on the economy class passengers according to the usual practice).

A) Transforming the decision-value into the coloured-bar of the proposed tool

In order to convert the value of the Eq. (8) into one of the 3 defined coloured fields (red, white or green) the converting function ω (Eq. (2) (Subsection 4.4.1)) is applied giving

$\omega\,(a) = \frac{3}{4}a + 1.$

It transforms each equation value gained $a \in [-1, 1]$ into the coloured fields of the bar, placing it between the values $\frac{1}{4}$ and $\frac{7}{4}$.

B) Prioritisation-Ranking of the high valuable passenger groups applied

Making decision while complying with the airline policy prioritisation named as “The priority of VIPs or *LOS to the (high-fare) passengers*” includes also the prioritisation ranking of the passengers according to their cabin-classes, while being one of the decision making criteria:

(i) The VIPs are the most valuable passengers to the airline in the proposed model. Therefore, in the very first step it will be checked up whether there are to be found some of VIP-passengers. Accordingly, this one flight will be considered as prioritised i.e. either the inbound could be waited for, or the outbound flight can depart without arrival delayed connecting passengers, if VIP-paxs fly only on the outbound flight.
If some VIP-passengers are found on both considered flights, the number of these passengers on each flight will be taken into account. After comparing the results, the priority can be given to the flight (inbound or outbound) whereas more of those

passengers fly with. In this manner, if more of VIPs fly on the inbound flight, the outbound flight will wait for late connecting passengers in arrival while making some feasible delay. If not so, the outbound flight could depart as planned without arrival delayed passengers (leaving them to the Passenger Service for to be recovered).

(ii) If there are *no VIPs* on both considered flights, the very next important passenger or passenger group considered will be *the first-class*. The aircraft on which more of these cabin-class passengers fly with can become prioritised in the decision model. This means, if there are more delayed connecting passengers of the first cabin-class arriving with the inbound flight F1, it may be waited for. If there are more first-class passengers more on the out-bound flight F2, the inbound flight F1 may not be waited for. In any case additionally, the sum of FFP-members and business passengers flying on the inbound and outbound flight will be calculated. Into consideration will be also taken onward flight connectivity i.e. if the passengers of the outbound flight become connecting-passengers on following flight(s) at the destination airport C.

(iii) If there are no first class passengers on the both flights, than the priority will be given either to the *Frequent Flyer Program (FFP) members and/or the business passengers, or to their sum*, and to that one flight on which these passengers fly in a majority (if this is on the inbound flight, it could be waited for; if it is not so, the outbound flight may depart as planned, not waiting for the delayed inbound flight).

5.6.2.2 Decision Making Based on the Operating Profitability (APP2)

Making decision on whether to wait on departure of an out-bound flight for the arrival-delayed high-value passengers coming late from an in-bound flight, whereby the business strategy of the airline is attempting to maximize the ticket revenue by minimizing its losses caused by disruptions, for the purpose of this research it can be expressed as an *attempt at keeping the revenue higher than the costs* thus ensuring the operating profitability (Doganis 2002, p. 8).

The model scenario where the airline’s revenue shall be higher than the costs (i.e. per taken decision), will be separated into two considering issues: (i) the revenue gained only from the high-valuable passengers, and (ii) the one gained from all passengers per an aircraft. The latter one will be used as an adding determining pointer within the same airline-policy prioritisation (i.e. revenue higher than the cost), if the prime one can not give the distinct answer (i.e. result) and/or not leading to the final decision on whether to wait on departure for arrival-delayed passengers (by applying some delays).

These are presented separately in the following subsections, considering the accompanying costs.

The Revenue gained only from the High-Fare Passengers

After the comparison of the revenues gained from purchased tickets by the high-valuable passengers on each flight, the priority to the flight with the higher generated revenue will be given in terms of:

- If this is the in-bound flight (F1), then the flight F2 will wait for the connecting passengers
- Otherwise, the out-bound flight (F2) will depart as planned without its connecting arrival-delayed passengers (in this case, it is the outbound flight, which contains higher number of the high-valuable passengers).

The issue is an extended case of the above introduced *priority of VIPs* (*LOS to the passengers).* When this prioritisation strategy of decision making is applied, *the value of the tickets* these passengers purchased, instead of *only* their personality and/or their *status* with a particular carrier, is taken into consideration.

Mathematical expression for generation of ticket-revenues coming only from the high-valuable passengers from both flights is:

$$TP = \sum_{i=1}^{n} TP_{ARR,i} + \sum_{j=1}^{m} TP_{DEP,j} \quad (11)$$

Whereby $\mathrm{m} + \mathrm{n} > 0$, and:

1) If the ticket price is $TP = 0$, which can mean that there is, for example, only one high-valuable passenger (on the arriving or the departing flight) but who got the flight ticket as a redeemed coupon or bonus/gift as guest of honour, not paying money for it to the airline, then the decision making will be made according to the rules given in the next step, taking effect of the decision making in case of the generated revenue from all-class passengers per flight;
2) If the ticket price is $TP \neq 0$, then the values y and z are defined as follows:

$$\mathrm{y} = \frac{1}{TP}\sum_{i=1}^{n} TP_{ARR,i}\ ; \quad \mathrm{z} = \frac{1}{TP}\sum_{j=1}^{m} TP_{DEP,j} \quad (12)$$

as the revenue gained from the arriving flight (y) and the revenue gained from the departing flight (z), both taken as a proportion of the total (overall) ticket revenue gained from both considered (in-bound and out-bound) flights.

Hereby, n is the number of the all high-fare passengers on the inbound flight (F1), m is the number of all high-fare passengers on the outbound flight (F2), $TP_{ARR,i}$ is the ticket price purchased by the i^{th} high-fare Passenger on the in-bound flight, $TP_{DEP,j}$ is the ticket price purchased by the j^{th} high-fare Passenger on the out-bound flight.

The comparison of y and z values given in the Eq. (13) to show whether

$$(\boldsymbol{y}-\boldsymbol{z})>\mathbf{0} \text{ or } (\boldsymbol{y}-\boldsymbol{z})<\mathbf{0} \quad (13)$$

gives the following information into the decision process:

- $\boldsymbol{y}>\boldsymbol{z}$ means that the airline has gained a higher revenue from the high-valuable passengers on the arriving flight (F1)
- $\boldsymbol{y}<\boldsymbol{z}$ means that the airline has targeted a higher revenue from tickets purchased by the high-valuable passengers of the departing flight (F2).

After applying an individually determined relation of both APPs of a particular airline by giving the importance ratios of each one, the DEVOTED DSS Tool evaluates the considered consequences in available decision options while suggesting a possible solution as follows.

After the values of Equations (8), (12) and (13) have been calculated, while being based on the determined ratios of the airline's single APPs, in terms of their combination given by the coefficients β_1, β_2, the designed tool will suggest the decision maker whether to wait on the departure of the out-bound flight F2 for the delayed high-fare passengers of the in-bound flight F1.

The airline policy prioritization (APP) strategy as the whole is mathematically expressed as:

$$\beta_1 a+\beta_2\,(y-z)\in[-1,\ 1] \quad (14)$$

Whereby: $\beta_1,\ \beta_2 \epsilon\,[0,1]$ and $\beta_1+\beta_2=1$

The final decision solution being recommended by the designed tool will be dependent on the final result gained for both prioritisations in their given relation-ratios as follows:

- For the final result: $\boldsymbol{\beta_1}\,\boldsymbol{a}+\boldsymbol{\beta_2}(\boldsymbol{y}-\boldsymbol{z})<0$, the airline should not wait on departure of the out-bound flight F2;
- For the final result: $\boldsymbol{\beta_1}\,\boldsymbol{a}+\boldsymbol{\beta_2}(\boldsymbol{y}-\boldsymbol{z})>0$, the airline should wait on departure of its out-bound flight F2 for taking the high-fare passengers of the in-bound-flight F1.

As already explained before and given in the illustration in Figure 5-4, the airline controller can still decide whether to follow the suggested solution given by the DEVOTED DSS Tool or to take the opposite one. Herewith, the operation controller is fully aware of accompanying consequences of the decision made/taken in terms of LOS and expected adding costs.

Together with the suggested decision solution, the tool generates another output component, expected delay costs for that particular decision solution.

Delay costs per flight due to high-fare passengers can be mathematically expressed as follows:

$$Cost_{ARRvips} = \frac{1}{TOCs}\left[\sum_{i=1}^{n}(Cost_{ARRpax,i}) + Cost_{ARRcrew} + Cost_{ARRairport}\right] \quad (15)$$

$$Cost_{DEPvips} = \frac{1}{TOCs}\left[\sum_{j=1}^{m}(Cost_{DEPpax,j}) + Cost_{DEPcrew} + Cost_{DEPfuel} + Cost_{DEPaircraft} + Cost_{DEPairport}\right] \quad (16)$$

Hereby, the delay-costs $Cost_{ARRvips}$ and $Cost_{DEPvips}$, occurring on the arriving and departing flight respectively due to high-fare passengers, are expressed as a proportion of the TOCs, including the following expenses:

$Cost_{ARRpax,i}$ and $Cost_{DEPpax,j}$ which denote the passenger-delay costs occurring by the i^{th} arriving passenger and the passenger-delay costs occurring by the j^{th} departing-passenger respectively, consist of following items:

$$Cost_{ARRpax,i} = \sum_{i=1}^{n}(C_{recov\ Pax,i} + C_{comp\ Pax,i} + C_{care\ Pax,i} + C_{VOTPax,i}) \quad (17)$$

$$Cost_{DEPpax,j} = \sum_{j=1}^{m}(C_{recov\ Pax,j} + C_{comp\ Pax,j} + C_{care\ Pax,j} + C_{VOTPax,j}) \quad (18)$$

In the proposed model the passenger costs are designed to express the sum of all expenses related to the passengers which can occur due to the flight delay, regardless the recovering made whether onto the home-carrier's alternate flights or, either the flights of its alliance partner or another airline. Hereby included are all care and compensations costs, as well as the cost of value of time of the delayed high-value passengers. These are expressed as:

- $C_{recov\ Pax,i}$ and $C_{recov\ Pax,j}$ the cost of the re-accommodation of the i^{th} passenger of the inbound flight (Pax, i), and of the j^{th} passenger of the outbound flight (Pax, j) which can be made at both home airline or another airline. This cost can be in terms of a potential ticket fare refund in the whole ticket price purchased, if the passenger is refused and/or has to be brought back home, or in terms of putting through the fare-part of the remaining flight leg to the new carrier, if the passenger is re-allocated within the passenger recovering plan, mathematically expressed as:

$$C_{recov\ Pax,i} = \begin{cases} 0, & if\ Pax_i\ recovered\ by\ home\ airline \\ TP_{ARR,i} - TP_{cshare,i}, & if\ Pax_i\ recovered\ by\ alliance\ partner \\ TP_{ARR,i} + TP_{i,diff}, & if\ Pax_i\ recovered\ by\ a\ vendor\ airline \end{cases} \quad (19)$$

$$C_{recov\ Pax,j} = \begin{cases} 0, & if\ Pax_j\ recovered\ by\ home\ airline \\ TP_{DEP,j} - TP_{cshare,j}, & if\ Pax_j\ recovered\ by\ alliance\ partner \\ TP_{DEP,j} + TP_{j,diff}, & if\ Pax_j\ recovered\ by\ a\ vendor\ airline \end{cases} \quad (20)$$

Whereas $TP_{i,diff}$ and $TP_{j,diff}$ denote the differences in ticket-prices between the one purchased at the home airline and the one by a vendor airline for i^{th} and j^{th} passenger respectively; while $TP_{cshare,i}$ and $TP_{cshare,j}$ denote the code-share ticket-prices (of alliance-partner) for the i^{th} and j^{th} passenger respectively.

- $C_{comp\ Pax,i}$ and $C_{comp\ Pax,j}$ denote the cost of compensation for the case when the passenger recovery for the i^{th} passenger of the inbound flight (Pax, i), and for the j^{th} passenger of the outbound flight (Pax, j) is done more than 3 hours after the planned flight-departure (according to the European Regulation 261/2004 for air passenger compensation and assistance scheme, February 2005) (see in the Annex C)
- $C_{care\ Pax,i}$ and $C_{care\ Pax,j}$ denote all costs coming from the care expenses for the i^{th} passenger on the inbound flight (Pax, i), and the j^{th} passenger of the outbound flight (Pax, j). For example, this cost can be for the business passengers arriving late with no time to wait for their late delivering baggage (because there was no sufficient time for a baggage transfer in time) who may receive separately a sum of money for a buying a new shirt and refreshing at the airport, and/or any communication-connection expenses, etc. Or, this can be offered within the airline's lounge as the full-care-service for its premium passengers, as it has been doing an Asian airline)
- $C_{VOTPax,i}$ and $C_{VOTPax,j}$ denote a monetary Value Of Time (VOT) of the delayed i^{th} passenger on the inbound flight (Pax, i) and of the j^{th} passenger of the outbound flight (Pax, j)

$Cost_{crew}$ denotes crew flight-hour overtimes and any crew on-going costs, on each flight, i.e. the inbound and the outbound one.

$Cost_{fuel}$ denotes extra expenses for additional fuel consumed, also within a possible re-routing when it is accompanied with the new slot applied for avoiding congested or whether-violated areas which has to be overtaken for the ground-delay savings (meaning, in time).

$Cost_{aircraft}$ denotes any extra aircraft maintenance expenses occurred within the time before it departs (i.e. which are not included in a regular pre-flight maintenance)

$Cost_{airport}$ involves any airport and/or ground handling operation extra charges (e.g. extra costs for a ramp agent, baggage transfer/handling, or any adding standing charges).

In the multi-criteria algorithm of tool, for creation of the output-component *LOS-Airline* needed data will be generated by getting the revenues gained on both flights i.e. inbound and outbound, (see: Eq. (12) and Eq. (13)). Expected costs which can occur due to delays (Eq. (15) and Eq. (16)) due to high-fare passengers will be displayed.

The tool is set in the frame of the airline's seeking to operate profitably since the ticket prices are generally determined in order to cover all expected costs while gaining an amount of revenue. This is under the conditions which can be mathematically expressed as a positive difference between the overall ticket revenue gained on both flights and expected extra delay costs on both flights, as shows the following equation:

$$TP - (Cost_{ARR} + Cost_{DEP}) \geq 0 \quad (21)$$

Finding out to which one flight a priority shall be given, while facilitating making decision on whether to wait for the arrival-delayed passengers or to depart the outbound flight without them, the output-component *LOS Airline* has been created. The other one, *LOS Airline* output-component, consists of the modelled qualitative levels (see Subsection 4.5.5).

The Revenue Gained from All Passengers per Aircraft/Flight

If the comparison of Eq. (12) made in Eq. (13) under the above-described conditions results in the same or *close by* values for both aircraft (i.e. the case therewith not aiming at taking a decision with a higher certainty on to which flight/aircraft to give the priority, additional information may be required. This is given in the following step.

Though such one flight operation situation in practice, where the ticket revenue gained from the high-fare passengers of an in-bound flight exactly equals the one gained from the high-fare passengers of the out-bound flight (i.e. $\boldsymbol{y} = \boldsymbol{z}$), may rather highly seldom occur, for enabling an usage of the designed tool in such extreme cases too, in this thesis research established is such *"close by* zero" value: γ. It is defined as the lowest ticket price purchased on both considered flights, being divided by double ticket revenue gained from all passengers and expressed as shown:

$$\gamma = \frac{\min(\min_i TP_{ARR,i},\ \min_j TP_{DEP,j})}{2\, TP_{all}} \quad (22)$$

Where: $TP_{all} = \sum_{i=1}^{N} TP_{ARR,i} + \sum_{j=1}^{M} TP_{DEP,j}$, and $TP_{all} \neq 0; M + N > 0$ (23)

Hereby, N is the number of the all-class passengers on the inbound flight (F1), M is the number of all-class passengers on the outbound flight (F2), $TP_{ARR,i}$ denotes the price of the purchased ticket by the i^{th} passenger of the in-bound flight, $TP_{DEP,j}$ the price of the purchased ticket by the j^{th} passenger of the out-bound flight, and TP_{all} the sum of the ticket prices generated from passengers of both flights.

The purpose is to introduce making of comparison of the overall revenues generated per flight/aircraft (i.e. coming from all passengers, not only from the high-valuable ones), in cases where the difference in the revenue gained on the in-bound flight (i.e. y) and the one gained on the out-bound flight (i.e. z) is smaller than the denoted value γ, expressed by:

$$|y - z| \leq \gamma \quad (24)$$

This complies with the airline *prioritisation of Operating Profitability* by seeking to keep the overall revenue gained from both flights higher than its costs.

The *overall revenue* shared by the total TP_{all} gained from the arriving flight is:

$$y_1 = \frac{1}{TP_{all}} \sum_{i=1}^{N} TP_{ARR,i} \tag{25}$$

The *overall revenue* shared by the total TP_{all} gained from the departing flight is:

$$z_1 = \frac{1}{TP_{all}} \sum_{j=1}^{M} TP_{DEP,j} \tag{26}$$

The comparison of the Eq. (25) and Eq. (26) will give the information, on which flight an overall higher ticket-revenue (from all passengers) has been gained.

Expected extra costs in this case (i.e. all passengers included) which can occur on each flight by considering this airline-policy prioritisation are mathematically expressed as follows:

$$Cost_{ARRall} = \frac{1}{TOCs} \left[\sum_{i=1}^{N} (Cost_{ARRpax,i}) + Cost_{ARRcrew} + Cost_{ARRairport} \right] \tag{27}$$

$$Cost_{DEPall} = \frac{1}{TOCs} \left[\sum_{j=1}^{M} (Cost_{DEPpax,j}) + Cost_{DEPcrew} + Cost_{DEPfuel} + Cost_{DEPaircraft} + Cost_{DEPairport} \right] \tag{28}$$

For this research purpose, the delay-costs of the high-fare passengers, of the crew-overtimes, possible extra airport charges (e.g. for extra ramp-agent, baggage transfer/handling, etc.) are taken into consideration for calculating the delay costs of the inbound flight ($Cost_{ARRall}$), taken as a share of the total operation costs (TOCs).

To additionally require, for the delay-costs of the outbound flight ($Cost_{DEPall}$) also the cost of any extra aircraft maintenance (if required while standing at the gate) as well as extra fuel costs for recovering from a departure ground-delay (but also if associated with a re-routing and therefore an extra fuel consummation) are considered. These are also calculated as a share of the total operational costs (TOCs).

In other words, the airline with this prioritisation policy will deal with the minor disruptions (i.e. delays) always respecting *first* the overall revenue and cost per flight (in this research, per decision) and then after and only when these requirements are already fulfilled, will consider the level of the service to the passengers.

These results constitute one component of the model-output *LOS-Airline* which is created for to be seen by the decision maker (operation controller) as one of the values on the 3 colour-bar, being transferred into the coloured fields by applying the converting function ω (see Subsection 5.6.1).

And finally, as this airline-policy is based on its efforts to keep the overall revenue gained from both flights (the inbound F1 and outbound F2) to be higher than the sum of the costs caused by extra expenses occurred on both considered flights due to delay(s), this can be checked up as it is shown:

$$\sum_{i=1}^{N}\left(TP_{ARR,i}\right) + \sum_{j=1}^{M}\left(TP_{DEP,j}\right) > [Cost_{ARRall} + Cost_{DEPall}]\ TOCs \quad (29)$$

5.6.3 DEVOTED DSS Tool Output

Following the description of the solving algorithm given above, there are two outputs which express consequences of each decision solution individually. The two tool outputs named "*LOS Airline*" and "*LOS Passenger*" are defined as follows:

- *"LOS Airline"* is the level of the service quality performed by the carrier. This output has been developed for the carrier's use and designed from the carrier's point of view. It denotes the measure of the ones key factors that are important for the carrier's operations and its overall business matters, influencing its reputation on the particular market.

  There are two approaches for obtaining this Tool-Output-Component. *The first one* is directly the airline's input, giving the relation of the LOS performance to the paxs and Operating Profitability i.e. $\boldsymbol{\beta_1}$ and $\boldsymbol{\beta_2}$, while respecting the Table 4-4 for to be then directly mapped onto to the 3-colour-bar. This one is taken for this thesis research testing.

  The other one is: the carrier's SQ-attributes have to be taken from the given literature findings for to be modelled according to Tables 4-4 to 4-6 (Subsection 4.5.5) and therewith mathematically computed. Then after, as foreseen, it has to be mapped onto the 3-colour-bar.

- *"LOS Passenger"* is the level of the perceived SQ from the passengers' point of view. The SQ-attributes required by the passengers as well as the level of their impact on the passengers' satisfaction have been modelled and shown in Tables 4-1 to 4-3 (Subsection 4.5.4). For their creation, integration of the basic categorization rules from the Kano's quality model has been made.

  There are two approaches for calculating this Tool-Output-Component. *The one* is enabled through the input taken from the airline passenger data bank for fulfilling the LOS modelling of the passengers' sensitivity to the required/expected SQ-attributes according to Tables 4-1 to 4-3. *The other one*, which has been taken in this research, is defining the passengers' SQ-requirements according to the chosen literature findings (see Subsection 4.5.4) for to be modelled in the created LOS model for the (high-fare) passengers (as shown in Tables 4-1 to 4-3).

Both Tool-Outputs are reflected on the user interface in the form of 2 bars, each consisting of 3 colours which can be seen by the decision maker (i.e. operation controller) on the user interface.

The one 3-colour-bar shows the SQ level of the airline achieved with its service performance (i.e. decision made). The other 3-colour-bar shows how the delivered level of the carrier's service quality may impact the passengers of both considered flights, i.e. inbound and outbound. In this way, given the airline-policy prioritisation strategy nearby the other required inputs, the operation controller gets evaluated decision solutions through the visually displayed output-components on the 3-coloured-bar(s) of the designed support tool.

5.6.3.1 The Output Component "*LOS Airline*"

The main key features of the LOS quality applied in this research (Subsection 4.1.2) are *on-time performance* and efforts to keep the *ticket revenue higher than the delay costs due to high-fare passengers* occurring in this kind of disruptions. Therewith, the level of performance of the service quality seen from the airline view point is specified.

The model-output *LOS-Airline* is constructed under the consideration of the possible airline-policy prioritisation strategies, and consisting of two main components:

1. *The Quantitative Component* (cost of SQ performed or the decision taken).

   It has been designed by comparing the revenues gained from both considered flights: in the first step, generating the revenues coming only from the high-valuable passengers, highlighting all corresponding extra costs that can occur on both flights caused within each decision that can be taken. In the following step, the overall revenues generated from all-class passengers on the both considered flights can be calculated. Accordingly, the occurring delay-costs will be calculated. All extra costs have been determined in relation to the Total Operation Costs (TOCs).

2. *The Qualitative Component* (Level of SQ performed to the passengers).

   It has been designed by taking the airline's overall SQ requirements displayed in Table 4-4. The airline's SQ requirements are individualized in its performance to each Pax-Group individually (Table 4-5), the airline's SQ requirements performed to each Pax-Group (Table 4-6) and finally, by applying the set up prioritisation-rankings referring to the high-valuable passengers of both flights considered.

The final structure of the tool output component *LOS Airline* has been constructed as the sum of both consisting APPs (APP1 and APP2), to be mapped onto the 3-coloured-bar on the user interface. As determined in the mathematical formulation, the output *LOS Airline* is calculated by satisfying of the following:

$$LOS\ Airline = \begin{cases} \omega\ (|APP|),\ the\ Airline\ follows\ the\ tool - recommendation \\ \omega\ (-|APP|),\ \ the\ Airline\ \ won't\ follow\ the\ tool - recommendation \end{cases} \tag{30}$$

This means, if the airline (its operation controller) decides to follow the tool recommendation, this will be mathematically considered as the absolute value of the computed sum of the airline's APPs (given by importance ratios of the two defined prioritisations). If the controller decides to take the opposite decision, the tool calculates also these output-values (i.e. decision consequences) for to be shown on the user's interface and for being saved for the statistical matters.

5.6.3.2 The Output Component "*LOS Passenger*"

With the airline's decision made, whether or not to wait on departure of the outbound flight, each passenger-group will be affected according to the designed SQ satisfaction levels of the passengers which are modelled in LOS model of passengers given in Tables 4-1 till 4-3.

However, it should be emphasized that this output heavily depends on (as much as possible) precise information about each passenger individually, which heavily remains the property of airlines. Therefore, two approaches to the calculation and expression of this output-component are feasible. One is, to take one achieved but someway determined satisfaction level (as for example, the best one i.e. "very satisfied" or "satisfied", or the worst one i.e. "very dissatisfied" or "dissatisfied" level) and apply the same level on the whole considered passenger group. The other (better) one is, an application of the data given by the airline, for getting in this way a much higher precision in the decision making process.

In any case, the output *LOS Passenger* is defined as the level of the satisfaction of the high-valuable passengers with the service quality delivered by the carrier.

Let be:

The arriving passengers of the Pax-Group I: $Pax_{ARR,i}$, for $i \in \{1, \dots\dots, n\}$

For $j \in \{1,..,m\}$, whereby $m = m_1 + m_2$ (31)

- The departing passengers of the Pax-Group II-1: Pax_{DEP,j_1}, for $j_1 \in \{1, \dots\dots, m_1\}$

- The departing passengers of the Pax-Group II-2: Pax_{DEP,j_2}, for $j_2 \in \{1, \dots\dots, m_2\}$

Let the satisfaction level weights of the SQ performed by the carrier to the Pax-Group I, Pax-

Group II-1 and Pax-Group II-2 respectively, taken from the proposed LOS model (see Tables 4-5 and 4-6), being expressed as:

$$c_1, c_2,\ c_3 \in \left[\frac{1}{4}, \frac{7}{4}\right] \tag{32}$$

Then the following mathematical expression

$$\frac{n \cdot c_1 + m_1 c_2 + m_2 c_3}{n + m_1 + m_2} \tag{33}$$

initiates the overall satisfaction level achieved with the particular decision made by the airline (whether to wait or not), showing to which quality level i.e. weight c (in Eq. (32)) the carrier has performed its service, while herewith gaining a much closer information about each of its decision solutions and the accompanying consequences individually.

This output component of the DEVOTED DSS tool may be of a notable importance for those airlines which operations are based on the *LOS* airline-policy prioritisation strategy. Though being less important for the airlines which operate with the airline-policy prioritisation based on the *revenue maximizing* rule, this output-component enables a deeper insight into the decisions and their consequences.

The passengers' satisfaction level on the user interface of the decision support tool displayed as the *LOS Passenger* is one of the outputs of each decision solution in the proposed algorithm. *LOS Passenger* output shows the level of the satisfaction achieved by the passengers on both flights considered. For that purpose, all high-valuable passengers i.e. inbound connecting passengers and both outbound passenger-groups (origin-connecting ones and origin-one-flight-leg passengers) are taken into account. The sum of all satisfaction levels achieved with the SQ delivered (here with the particular decision taken) generated from all passenger groups involved in the modelled situation (Pax-group I, Pax-group II-1 and Pax-group II-2) and applying the Eq. (32) will give the qualitative value of the decision.

This value is multiplied by the defined correlation coefficients individually tailored for each satisfaction level representing the quantitative value of the output *LOS-Passenger*. For its creation taken is the denoted mathematical scale (see Section 5.6.1), being introduced as the Equation (1): $L = \left\{\frac{1}{4}, \frac{3}{4}, 1, \frac{5}{4}, \frac{7}{4}\right\}$.

Then, the overall high-fare passengers' satisfaction level $c \in L$ achieved on both flights can be computed as:

$$[\frac{1}{m+n} \sum_{c \in L} c \left(\sum_{i=1}^{n} Pax_{ARR,c,i} + \sum_{j=1}^{m} Pax_{DEP,c,j}\right)] \epsilon \left[\frac{1}{4}, \frac{7}{4}\right] \tag{34}$$

In this way, the sum of satisfaction levels achieved by each passenger individually can be computed in accordance with the satisfying of the service level attributes required (e.g. if every one passenger gets the foreseen connection(s) within an on-time carrier's performance).

Hereby the passengers on the arriving flight and the departing flight are determined by the functions $Pax_{ARR,c,i}$ and $Pax_{DEP,c,j}$ defined as:

$$Pax_{ARR,c,i} = \begin{cases} 1, & if\ i^{th}\ arriving\ passenger\ perceives\ satisfaction - level\ c \\ 0, & otherwise \end{cases} \tag{35}$$

$$Pax_{DEP,c,j} = \begin{cases} 1, & if\ j^{th}\ departing\ passenger\ perceives\ satisfaction - level\ c \\ 0, & otherwise \end{cases} \tag{36}$$

They determine if the i^{th} arriving passenger and the j^{th} departing passenger are *satisfied* with the SQ delivered with a satisfaction level $c \in L$, which modelling has been shown in Tables 4-1 to 4-3.

Herewith reflected is the sum of the satisfaction levels generated from all considered passengers on both flights (inbound and outbound) with the service quality perceived, i.e. with the particular decision taken. Its value will be expressed (i.e. graphically shown) to the operation controller after it has being transferred on the 3-coloured bar.

The final decision whether to wait or not on departure will consist of two output issues, i.e. *LOS Passenger* and *LOS Airline*, which values, after being converted on the 3-colour-bar, can be found on *two* 3-colour-bars, but also as both outputs on the *only one* (i.e. the same) 3-colour-bar.

Since the DEVOTED DSS Tool also includes the expected costs as the associated component of the particular decision solution, being saved individually per decision taken, it enables generating these data for the economic and/or statistic matters of the airline's businesses. Herewith is the airline management enabled the opportunity for analyzing the taken decisions and their accompanying consequences shown in LOS performed and perceived, and costs, needed for more exact controlling and potentially adjusting the APP or flights scheduling and planning for the particular market (i.e. city-pair).

6 Testing the DEVOTED DSS Tool and Discussion of Results

6.1 Background

The core objective of this thesis work was to explore how much and in which terms a passenger-segmentation (i.e. the passenger-structure) per flight plays an influencing role in the airline's operational decisions on departure delays due to its in arriving delayed high-fare passengers and therefore on the service quality (SQ) level and the accompanying additional costs due to this kind of operational decisions in its all-day operation execution.

Exploring particularly the influence of delayed connecting high-fare passengers on making decisions on onward delays in the carriers' striving to deliver a better service quality to these passengers, into account have been taken the passenger segmentation per flight and the associated consequences in terms of the LOS performed by the carrier and the one perceived by the passengers. The research focus was on an identification of a causality of the high-fare or premium passengers' (i.e. VIPs, FFP- and Golden-/Silver-/Platinum card members, first-class and business passengers) importance to the airline and a conceivable influence of this importance on decisions on delays within its operation execution and disruptive situations.

Based upon an examination made from the airline's operational point of view for a defined prioritization strategy, a knowledge-based decision support tool named Delaying VIPs Oriented Decision Support System (DEVOTED DSS) Tool was designed. Within the tool's operating framework, in its process of making decisions on whether to delay an outbound flight in order to wait for arriving-delayed high-fare passengers of an inbound flight, the level of service (LOS) quality delivered by the carrier and the one perceived by its passengers as well expected delay costs associating these decisions have been taken into consideration.

Aiming at supporting the airline operation controllers in their all-day dealing with departure delays caused by its arrival-delayed connecting premium passengers, the proposed tool evaluates decision options recommending the best available solution, while calculating the consequences. This is made for both cases, if following the decision solution recommended by the tool as well as if taking the opposite decision as recommended one. In both cases the tool provides a visualization of the consequences in terms of the LOS of both, the airline (performed) and the passengers (perceived), and the additional expected costs.

In this chapter the testing of a function, aim and contribution of the DEVOTED DSS Tool with focus on gained final outputs and obtained results will be shown. After the testing operational scenarios have been introduced, each decision solution recommended by the DEVOTED DSS Tool to each airline individually for each scenario separately together with the associated consequences will be presented and discussed.

6.2 Testing Scenarios

Since an airline can choose one of, or to combine both, priority prioritisations in the desired relation according to its own business policy (see Chapter 5), for the testing purposes are two scheduled airlines are taken with two different prioritization strategies while operating on the same flight route between the same origin-destination airports i.e. city-pairs (in this research between A-B with the inbound-flight F1 and B-C with the out-bound flight F2).

Referring to the flight operation situation introduced in Section 4.2.2, in order to expose the functionality and a tangible aim of the designed tool, the testing scenarios are intentionally constructed to reflect specific borderline operational situations while emphasizing occurring conflicting key criteria.

The testing is based on real-world data belonging to the statistical data bank - property of the institute where this research has been completed. Due to strong confidentiality agreements, the names of the airlines, the airports and information about passenger-segmentation per flight as well as the actual configuration of the high cabin-classes per flight have been changed and adjusted to the testing scenarios. Ticket prices are taken firstly in terms of average prices, for to be then adjusted to the high-fare cabin-classes in accordance with the price index ratios recommended by the IATA, worked up by Doganis (2002). Therefore, referring to this thesis work, the importance value-coefficients of two from all three high-fare passenger-groups are determined as: the coefficient $\propto_2$ for the first-class passengers and the coefficient $\propto_3$ for the business passengers and frequent flyers. This will be emphasized in the testing scenarios description.

The two examining airlines are named **Air1** and **Air2**. Both are legacy or full service network carriers. Differing in their prioritisation policies which can be observed on the APPs-share i.e. on their given ratios (β_1 for the APP1 and β_2 for the APP2), these are taken to be:

- The prioritisation strategy of the airline *Air1*: 0,1 of APP1 + 0,9 of APP2
- The prioritisation strategy of the airline *Air2*: 0,8 of APP1 + 0,2 of APP2

However, of a particular importance for the carrier’s economic matters is the role of its operational status at the particular airport, especially referring to the overhead costs that can occur within the aircraft turnaround phase. This status can be either in terms of a home-airline (if the particular airport is its hub or base), or a guest-airline (where it can operate either as an alliance-partner of the corresponding home-airline or as a vendor carrier).

In order to avoid the complexity that can overwhelm the main target of this research but enabling the emphasizing of the differences in their operational statuses at the connecting airport B, the carrier *Air2* is taken to be the *home-airline* whereby *Air1 its alliance partner*. Herewith the associated overhead costs for ground handling operations (GHOs) and the airport charges to the home-airline *Air2* will be around a minimum for the majority of such kind of delay-costs at its hub, while to the airline *Air1* the same costs will be as high as the median value of the extra costs. Given in terms of the airline *cost-trends* adopted from relevant literature findings, for this research purposes these extra costs are presented in a relation to the Total Operational Costs (TOCs) per flight.

Deployment of the designed tool: after the given prioritisation strategy has been applied onto each testing scenario, the DEVOTED DSS Tool-algorithm can be activated for the evaluation of possible decision options. The tool background-processing relies on the flight plan updating, well known Minimum Connecting Time (MCT)[3] of the connecting airport B (here this is 35min), the maximal allowed delay for the particular flight/aircraft and the airline-policy prioritisation strategy (applying the APP1 and/or APP2)[4], as well as the passengers segmentation (i.e. fare-classes sharing) per a particular flight.

The seat-configuration and accordingly to that the passenger-segmentation per flight/aircraft taken for the testing is based on presumptions presented in the following paragraphs, while excluding the economy cabin-class since this is not subject to this research. Taken is:

a) For the flight F1 (between the airports A and B) a typical configuration for an A340-fleet aircraft usually flown on the examined flight destination by the examined airline, the following seat-configuration has been taken:

   0-8 seats for the VIPs and first-class, 0-64 for BUS+FFPs, and 258 economy-class

b) For the flight F2 (between the airports B and C) an A330-fleet aircraft which has usually been flown on this flight destination by the airline examined, has a typical seat-configuration as follows:

   0-8 sets for the VIPs and first-class, 0-60 seats for BUS+FFPs, and 156 economy-class.

Testing scenarios comprise of several chosen operational situations which decision solving solutions are directly affected by varying the following four influencing criteria:

I. The defined airline-policy prioritisations (APPs) and the relation among them - expressed by using two different combinations of the coefficients β_1 and β_2;
II. The importance-values of each cabin-class passenger to the airline expressed by using the different values of the coefficients $\propto_1$ (weight for VIPs), $\propto_2$ (weight for 1.Class), and $\propto_3$ (weight for BUS+FFPs)
III. Ticket prices per cabin-class have been either *space*- or *cost-based* determined by adopting:

[3] Published by airport authorities, MCT is the shortest feasible time required for passengers/baggage to connect between flights at an airport.

[4] Introduced in Section 5.3: APP1 (the priority of LOS delivered to the Paxs) and APP2 (the priority of Operating Profitability).

a) The IATA (2000)[5] recommendations which emphasize to take the ratio of costs/fares for the first-class paxs and (BUS+FFPs) to be in relation: $\mathbf{1{:}1{,}45}$; Hereby, the ticket prices for the VIPs are taken to be in accordance with an assumed *very high* importance of the VIPs to the airlines;

b) Findings of Doganis (2002)[6] which recommend to take the ratio of costs/fares for the first-class paxs and (BUS+FFPs) to be in relation: $\mathbf{1{:}1{,}76}$;
Hereby, the ticket prices for the VIPs are taken to be in accordance with an assumed *not so very high* importance of the VIPs (i.e. a VIP-passenger is not so much higher important to the airlines than the first-class and BUS/FFP ones)

IV. The segmentations of the high-fare passengers and their distribution on both flights (i.e. in-bound and out-bound)

V. The ticket revenue per flight gained only from the high-fare passengers on each examined flight.

This is presented in. Figure 6-1.

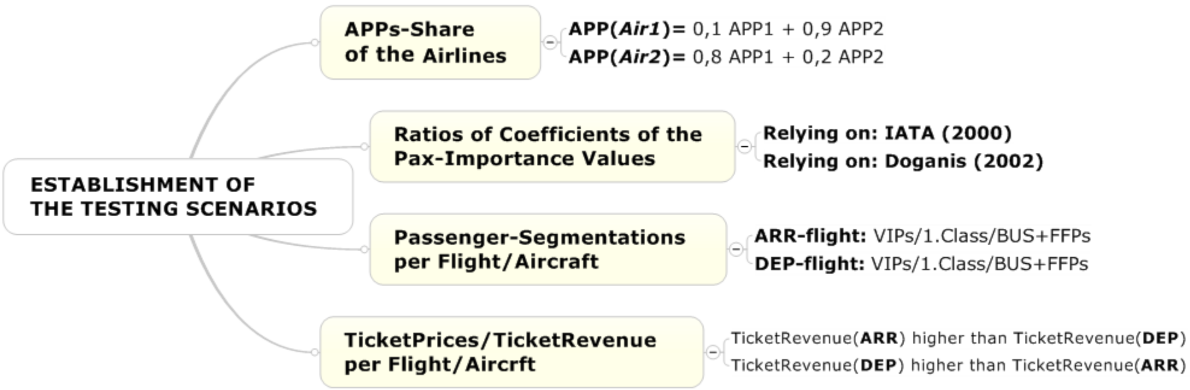


Figure 6-1: Key influencing factors varying for creation of the testing scenarios

Source: created by the author

Combining above-described key influencing factors (Figure 6-1) (i.e. varying their values), five main scenarios have been created. These are then enhanced by exchanging the ticket-prices per flight (having higher ticket prices once on the in-bound, than after on the out-bound flight) and varying the sizes of the high-fare passenger-groups examined (3 Pax-Groups as introduced in Section 4.5.1):

Pax-Group I (delayed in arriving connecting passengers), Pax-Group II-1 (departing passengers who end their trip at the destination airport C) and Pax-Group II-2 (departing

[5] Based on *space required* and varying between airlines, aircraft-types and routes, an IATA analysis (see: Doganis 2002) come to the conclusion that the ratio of costs/fares in the 3 cabin-classes (1.class, business and economy) should be: 2,71:1,87:1

[6] If purely *cost-based*, after adding the passenger-specific costs (e.g. in-flight services and cabin-crew for the high-fare passengers) to the IATA generally recommended fare ratios, the final ratio of relative fares in the 3 classes comes to: 5,7:2,5:1.

passengers who do not end their trip at the airport C). Each scenario has to be applied to each examining airline, *Air1* and *Air2*. Hereby, important to mention is that the impact of the Pax-Group II-2 on making decision on waiting or not for the Pax-Group I, depends explicitly on the main output of the subprogram "Passenger Recovery Plan", i.e. $Cost_{DEPpax,j}$, being computed by employing the Eq.(18) introduced in Subsection 5.6.2.2, particularly in the case when these passengers (are in dangerous to) lose their flight-connections at the airport C. In order to avoid further complexity in the testing, this passenger group (i.e. Pax-Group II-2) will not be let to take any impact on the tool making decision process made in each scenario, since the subprogram-output is not available without having it already programmed in one of the suitable computational programs.

- **Computing of LOS quality perceived by the Passengers**

The level of SQ perceived by each single passenger individually, needed for obtaining the output component *LOS Pax* (foreseen to be calculated by the equation Eq.(34)) can not be entirely used in this testing, since such precise data remain property of the airlines being unavailable for a public and/or research use. Therefore, for this thesis testing purposes in order to show the main functionality of the tool, the worst satisfaction level assumed to be perceived within one passenger group (i.e. "satisfied", "neutral", or "dissatisfied") will always be taken for to be applied on the whole passenger group on the particular flight-leg (e.g. within the Pax-Group I, or Pax-Group II-1, or Pax-Group II-2).

This means that after the tool has evaluated and recommended the best (operationally) possible decision on whether to wait for the Pax-Group I arriving with the in-bound flight, the tool output-component *LOS Pax* can be calculated by applying the equation Eq.(34) but taking the worst level perceived within one Pax-Group, being read from the Tables 4-1, 4-2 and 4-3. Obtained satisfaction level will be applied on all passengers from the same Pax-Group, assuming as if the whole passenger group perceives the same level of satisfaction.

It should be understood that, as knowing more details about its passengers who purchased tickets for the flights considered, airlines can take advantage of a full use of the tool's formula given by the Eq.(34) which takes into consideration each passenger individually, gaining therefore more precise decision-recommendation that can be given by the tool.

6.2.1 Types of Costs considered

Considering the expected costs in the described scenarios for the tool-testing purposes, the following costs will not be included in testing calculations:

(i) the *crew extra duty times* for which Cook and Tanner (2009) argued that *a delay experienced by an individually flight may have no immediate effect on the amount paid by the* *airline to the delayed crew;* but over a period of time such as 28 consecutive days, over the calendar year, delays are likely to affect crew's remaining flight and duty hours,

(ii) *any airport extra charges,* and

(iii) departing *aircraft maintenance costs* within the time period of waiting for arriving flight.

This is because, at this stage of the tool usage (i.e. testing), they are not going to influence the choice of a decision solution.

Since the observed airline *Air1* is taken to be the alliance-partner of the home-airline *Air2*, their expected delay-costs in the testing scenarios will differ in accordance with their status at the intermediate (i.e. connecting) airport B. Therefore, the airline *Air1* will not have as many passenger-recovery possibilities on its own downstream flights as the airline *Air2*. The latter one has its operations basis at the airport B and consequently more alternate flights (and therefore more appropriate for the passenger-recovering) departing from its hub on the day of operation execution.

On one hand, *it is for an airline virtually impossible to provide the accurate cost issues in a real time* in order to put them in use through the whole operation decision chain, as emphasized by Thengvall, Bard et al. (2003, p. 397) and the overhead costs that can occur *have to be estimated*. For this research purposes, the cost-composition trends from the work of Doganis (2002) and estimations made by Cook, Tanner et al. (2013) have been adopted.

On the other hand, the delay costs caused by waiting for the delayed high-fare connecting passengers, although being implemented as a decision affecting criterion into the decision making process of the DEVOTED DSS Tool, have been taken into consideration for the testing scenarios only as associated consequences but not as the decision-driver. This signifies the proposed tool and its implemented modelled LOS quality to be understood as a LOS- *and* Ticket Revenue-driven (or -based) decision making model.

From the delay driven costs implemented in the tool-design, for the testing purposes, only several but most dominant costs have been extracted as the highest or, at least, likeliest occurring ones. The purpose is to show how this one tool output may influence an airline which is cost-driven (here this is the airline *Air1*) in its decision making process when such disruptions occur. These costs are selected in accordance with the decision solutions (i.e. the tool algorithm-paths tracked) within the evaluation process.

The *costs due to the passenger recovering* may arise from the difference in the ticket prices when this has to be made by an alliance partner, while by a vendor airline also the lost revenue of the purchased ticket by the home airline could be added. This calculating process is implemented in the designed tool as its subprogram for the passenger-recovery proceeding (Subsection 5.5.2.5). Considering the costs at this place, the airline operational cost analysis report given by the IATA (2011, p. 4) suggests that the biggest item of the Transport Related Expenses (amounts up to about 17% of the Total Operation Costs) is the major air carriers payment their code-share partners for transporting the code-share passengers (i.e. coming from the passenger-recovering and accommodation by other alliance-partner carriers).

In order to avoid further complexity in the testing, if following all possibilities given in the tool sub-program for the recovering of disrupted passengers in the Subsection 5.5.2.5, referring to the passenger-recovery costs in the testing the following was assumed:

The airline Air1: If the passenger-recovery is possible/available, this will be made by the home airline *Air2* (its alliance-partner), having to pay passenger-code-share costs for the flight F2. If the passenger-recovery is not possible to be made (even not by a vendor airline), though the airline has been forced to depart without the arriving-delayed in-bound passengers, the costs to be paid are assumed to be:

(i) compensations (for more than 3 hours) 250 EUR/hour/Pax
(ii) the Value of Time (VOT): 50 EUR/hour/Pax
(iii) bringing the passengers back home (by any traffic mean), for which has been assumed to incur adding cost up by half of the ticket purchased (i.e. Ticket Price (TP) purchased + ½ of the TP).

The airline Air2: If the passenger-recovery is possible/available, this will be done at the same airline within its downstream operations on the same day, causing no further costs to the airline. If the passenger-recovery is not possible to be made (and also not by a vendor airline), the costs to be paid in that case are the same as used for the airline *Air1*, above being described under (i), (ii), and (iii).

This can be seen in the Annex B implemented in each scenario tested (as, for example, particularly in Scenario 1-5a) for computation of expected costs, while all obtained results will be later described and discussed in more details (shown in Table 6-11 and Table 6-12).

- **The other extra costs considered**

Separately shown are *the opportunity costs* for the delays duration of up to 2 hours, represented as the sum of the *ticket revenue* (lost) and *the value of time* amounting to around 50 EUR/Pax/hour which is adopted from (Cook, Tanner et al. 2013, p. 101). However, when the delay is 3 hours or longer, the compensation according to the EU Regulation 261/2004 (see in the Annex C) is required to be added. However, for this testing purpose into consideration taken is *the compensation expenses for the recovering* in duration maximum up to 2 hours (this time period is set up for the execution of the pax-recovery, since *the high-fare* pax-recovery has to align with the *high* Value of Time of these passengers).

For the simplicity of the calculations in the testing, the Total Operation Costs (TOCs) of the outbound flight F2 (between the airports B and C) is taken to be up to EUR 100.000.

6.2.2 Description of the Testing Scenarios

In order to test and show the DEVOTED DSS Tool design capabilities, in total 12 specific scenarios have been created among which there are five main scenarios which introduce and describe the flight operation situations explored emphasizing denoted main decision drivers, while the other seven scenarios have been created to show the changes which occur by varying these decision drivers. They are presented pairwise: as the main operational situations i.e. *Scenario 1, 2, 3, 4, 4b* and *5* (with a lower ticket revenue gained from the arriving high-fare passengers than from the departing ones), while their variations shown in *Scenario 1a, 2a, 3a, 4a, 4c*, and *5a* represent the same flight situations, whereby the ticket revenue generated from the arriving (inbound) high-fare passengers is here higher than the ticket revenue generated from the departing (outbound) ones.

Each testing scenario in more details (e.g. number of each passenger cabin-class on each flight considered, ticket prices and ticket revenues, passenger importance values, etc.), with calculations as well as the tool recommendations and the final output, has been done in Excel and presented in the Annex B.

On behalf of the detailed presentation of the testing settings and calculations in the first - Scenario 1, shown will be how the testing of all created scenarios has been done.

6.2.2.1 Scenario 1 and Scenario 1a

Both scenarios (*1* and *1a*) describe the same operational situation with the same sizes of the high-fare passenger-groups and their segmentation, differing only in the ticket prices per flight and accordingly to that the ticket revenue per flight.

The flight operational situation to be tested is described as follows: *The number of VIPs on the in-bound flight is taken to be higher by only a 1 VIP-passenger than on the out-bound flight, while the sum of all other high-valuable passenger-groups together on the out-bound-flight is taken to be higher by 48 passengers than on the in-bound flight, mathematically being expressed as:*

$$\boldsymbol{VIP_{ARR} = VIP_{DEP} + 1}$$

$$\boldsymbol{\sum_{i=1}^{n}(1.C_{ARR,i} + BUS_{ARR,i} + FFP_{ARR,i}) = \sum_{j=1}^{m}(1.C_{DEP,j} + BUS_{DEP,j} + FFP_{DEP,j}) - 48}$$

Ticket prices are computed in accordance with the IATA recommendation (see: Section 6.2, II/a). The importance-values of the high-fare passengers $\alpha_{1,2,3}$ in these 2 scenarios are determined by taking into consideration the VIPs with a very high importance (i.e. value) to both airlines, expressed as follows: $\propto_1 = \mathbf{0,8}$ for the VIPs, $\propto_2 = \mathbf{0,1184}$ for the first-class passengers, and $\propto_3 = \mathbf{0,0816}$ for the business passengers and the frequent flyers.

- **Computing the Tool-Recommendation and the final Tool-Output**

All input-data are presented in Excel-tables being created to show the decision key-features (displayed in Figure 6-1) for to be prepared for computation of the DEVOTED DSS Tool-outputs. Table 6-1 shows all relevant inputs for Scenario 1 (see also in the Annex B).

Table 6-1: Scenario 1: DEVOTED Tool Inputs

ARRIVING FLIGHT			
Pax-Group I	**Pax-Number**	**Ticket Price**	**Ticket-Revenue**
VIPs	2	4.873 €	9.746,00 €
1. C	1	3.625 €	3.625,00 €
BUS+FFPs	16	2.500 €	40.000,00 €
Summe	**19**		**53.371,00 €**
DEPARTING FLIGHT			
Pax-Group II	**Pax-Number**	**Ticket Price**	**Ticket-Revenue**
VIPs	1	6.500 €	6.500,00 €
1. C	2	5.200 €	10.400,00 €
BUS+FFPs	63	3.590 €	226.170,00 €
Summe	**66**		**243.070,00 €**
m1 (Pax-Group II-1)			60
m2 (Pax-Group II-2)			6
m + n			**85**

Presented data in the table above show the main playing features needed for the computation of the tool decision-recommendation. According to the table, there are 85 high-valuable passengers on both considered flights, which configuration has been represented by: 19 these passengers are on the in-bound flight, 66 on the out-bound one. These are divided into three passengers groups according to their final destinations as follows:

(i) 19 passengers in the Pax-Group I,
(ii) 60 passengers in the Pax-Group II-1 (ending their travel at the airport C)
(iii) 6 passengers in the Pax-Group II-2 (do not end their travel at the airport C)

- On the *arriving* (in-bound) flight (F1)*:*

a) there are 19 high-fare connecting passengers
b) the pax-segmentation: 2 VIPs, 1 first-class, and 16 business and frequent flyers;
c) ticket prices purchased in EUR: 4.873/VIP, 3.625/first-class, and 2.500/(BUS/FFPs)
d) ticket revenue gained from arriving high-fare passengers is: EUR 53.371

- On the *departing* (out-bound) flight (F2):

a) there are 66 high-fare origin passengers
b) the pax-segmentation: 1 VIPs, 2 first-class, and 63 (BUS + FFPs)

c) ticket prices purchased in EUR: 6.500/VIP, 5.200/first-class, and 3.590/(BUS/FFPs)
d) ticket revenue gained from departing high-fare passengers is: EUR: 243.070
e) 60 of these passengers will end their air travel at the destination airport C: *m1*
f) 6 of the departing passengers are connecting passengers from the airport C: *m2*

- **Mathematical background of the DEVOTED Tool**

It computes the best (operationally) achievable decision solution, calculating the accompanying consequences, while making recommendations to each airline in accordance with the denoted prioritisation policy (i.e. for the airline *Air1:* 0,1APP1 + 0,9APP2; for the airline *Air2:* 0,8APP1 + 0,2APP2).

The main calculaitons include the following items:

- Quantifying the influence of importance of all passengers involved on flights, taking into calculation their given values of the coefficients $\propto_1 = 0{,}8$ (for VIPs), $\propto_2 = 0{,}12$ (for 1.Class), and $\propto_3 = 0{,}08$ (for BUS+FFPs), by setting these passengers into the juxtaposition per flight-leg and their cabin-class, by applying the equation Eq.(8).
The results obtained in this way gave the equation-value $a = -\ 0{,}0371$ which is below the zero indicating the tool-recommendation to *not waiting* for the arriving passengers (the Pax-Group I). Being left to the Passenger Service to be re-accommodated by using the sub-program *Pax-Recovery Plan*, the arriving-delayed passengers will get the best possible or available flight-alternative. In its output, the subprogram gives the valuable information regarding the pax-recovering costs incurred, and these are needed to be considered together with the ticket revenues gained on both flights. Since this step was hardly enabled by Excel, taken are only expected pax-delay costs for both solution-options, i.e. if *having* and *having not* the pax-recovery available.

- Calculation of the Ticket-Revenue gained on both flights considered while comparing them by using the equation Eq.(13). This gives an input into the decision making support system indicating on which flight a higher ticket-revenue has been generated. In this scenario, given data make the difference obvious: on the flight F2 the ticket revenue is significantly higher than on the flight F1, therefore (in this matter) the priority the tool decision making system will give to the departing flight F2.

- The DEVOTED tool gives a decision-recommendation taking into consideration the chosen airlines' prioritisation policies, denoted as:
    - *Air1*: 0,1 of APP1 + 0,9 of APP2
    - *Air2*: 0,8 of APP1 + 0,2 of APP2

  In *Scenario 1* the recommendation given to the both airlines is: *to not waiting.*
  To *Air1* – because the ticket revenue is predominantly higher on the outbound flight, which is its priority in decision making process and therefore should it depart on-time.

To *Air2* – because there are much more high-fare passengers on the outbound flight than on the inbound one and it is worth of departing on time for an higher LOS delivered to and perceived by these passengers, since this is its defined prioritisation policy.

- Calculation of the third tool-output: *Cost*
  For the testing purposes, only the pax-related costs are taken into consideration. In order to avoid further complexities, assumed is that all other costs, such as airport-, crew- and ATC- related costs have not been incurred.
  The passengers-related delay costs are computed as:
  - $\mathrm{Cost}_{\mathrm{ARRpax,i}}$ by using the Eq.(17)
  - $\mathrm{Cost}_{\mathrm{DEPpax,j}}$ by using the Eq.(18)

  These results, obtained for each airline separately, will be graphically shown and more closely commented as the third tool output in the text below.

The tool decision-recommendation depends on (for the airline) operationally possible and/or achievable options as well as on the high-fare passenger-recovering possibilities available (or not) at the moment of decision making.

According to this, the tool will *follow one or more algorithm-paths* (introduced in Subsection 5.5.2) which describe a current flight operational situation of the airline and occurring constraints. Therefore, within the calculations done in Excel, the ones algorithm-components, the tool has followed in its decision making process are displayed for both possibilities: when *having* and *having not* available a passenger-recovery. This is shown in Table 6-2.

Table 6-2: The Tool-Recommendation considering the Algorithm-Paths being followed

Follow the Tool-Recommendation "TO NOT WAIT" OR **Take the Opposite Decision "TO WAIT"**

Pax-Group I go the Recovery-Plan
Follow the Algorithm-Comp. 2

LOS Pax		
Pax-Group I	dissatisf.	14,25
Pax-Group II-1	satisf.	75
Pax-Group II-2	satisf.	7,5
Eq.(32) =		**1,1382**

LOS Airline	
ω (|Air1|)=	**1,4347**
ω (|Air2|)=	**1,1183**

"Refused Pax"
Follow the Algorithm-Comp. 1

LOS Pax		
Pax-Group I	very dissatisf.	4,75
Pax-Group II-1	satisf.	60
Pax-Group II-2	satisf.	7,5
Eq.(32) =		**0,8500**

LOS Airline	
ω (|Air1|)=	**1,4347**
ω (|Air2|)=	**1,1183**

Follow the Algorithm-Comp. 4

LOS Pax		
Pax-Group I	very stisf.	33,25
Pax-Group II-1	neutral	60
Pax-Group II-2	dissatisf.	4,5
Eq.(32) =		**1,1500**

LOS Airline	
ω (-|Air1|)=	**0,5653**
ω (-|Air2|)=	**0,8817**

Solution recommended by the tool ensures the best possible SQ-performance of the airline(s) and therewith best achievable level of the high-fare passengers' satisfaction level at the moment of the decision making.

In searching for the best possible decision option gained in *Scenario 1* for both airlines and according to the displayed results followed were the Alg.-Comp.2 (the pax-recovery is available) and Alg.-Comp.1 (the pax-recovery is not available and arriving-delayed passengers have to "be refused"). The Alg.-Comp.4 will be followed in the case where the operation controller decides to take the opposite decision i.e. *waiting*.

- **Taking the final decision**

Operation controller is the one who makes the final decision on whether to accept (i.e. "to follow") the decision-option recommended by the tool or to take the opposite solution. In both cases the tool will save the decision consequences defined as 3 components of the DEVOTED Tool-Output (LOS Airline, LOS Pax and the Cost). In Scenario 1 this is:

I. The controller can decide **to follow** (accept) the recommended solution ***(not waiting)***, which is presented by applying Eq.(30) (ω ($|APP|$)).
This is required for obtaining the tool output-component ***LOS Airline***. Finally, the one decision option will be taken which is operationally achievable (by following the Alg.-Comp.2 and Alg.-Comp.1 depending on the pax-recovery availability) at the moment of decision making.

The output-component ***LOS Pax*** has been obtained by using the proposed LOS model showing the passenger sensitivity to the SQ delivered. Taking the satisfaction levels modelled for each passenger-group separately (Tables 4-1 to 4-3), for this decision the following values are taken:

(1) Pax-Recovery *available*: in spite of the recovery-availability, 19 paxs from the Pax-Group I may be "dissatisfied" with two SQ-attributes: the "on-time" performance and "getting connectivity" (see Table 4-1), and as the worst one satisfaction-level it will to be applied on the whole arriving group. 60 paxs from the Pax-Group II-1 will be "satisfied" with an (awaited) "on-time" performance of the airline, as 6 paxs from the Pax-Group II-2 too, (they get the SQ delivered as it was promised/promoted, therefore it is not needed to take *more* satisfaction into consideration). The overall paxs' satisfaction level is obtained by applying the equations (33) and (34).

(2) Pax-Recovery *unavailable*: 19 paxs from Pax-Group I are in this case "refused passengers" - who have to be brought back home having no alternate flights to their purchased destination(s). Though getting the whole compensation-program, all these 19 paxs are modelled as "very dissatisfied", since they are disabled to get the SQ they paid for (also, that they accounted with). However, all departing paxs (66) are modelled as "satisfied" with SQ ones, as they "only" perceive exactly the one SQ, they paid for (see in Tables 4-1 to 4-3).

The overall passengers' satisfaction level achieved has been obtained by applying the equations (33) and (34).

II. The controller can also decide to take **the opposite decision** (i.e. *to wait*) which is presented by applying Eq.(30) ($\omega\ (-|APP|)$).
This is needed for obtaining the tool output-component ***LOS Airline***. Although herewith risking an overall worse performance level, it can be achieved somewhat higher satisfaction level of the passengers, which comes from the highest satisfaction level of arriving-delayed passengers that in this case would have been waited for (indeed to the obviously worse overall performance-issue of the airline). The tool will follow in this case the Alg.-Comp.4.

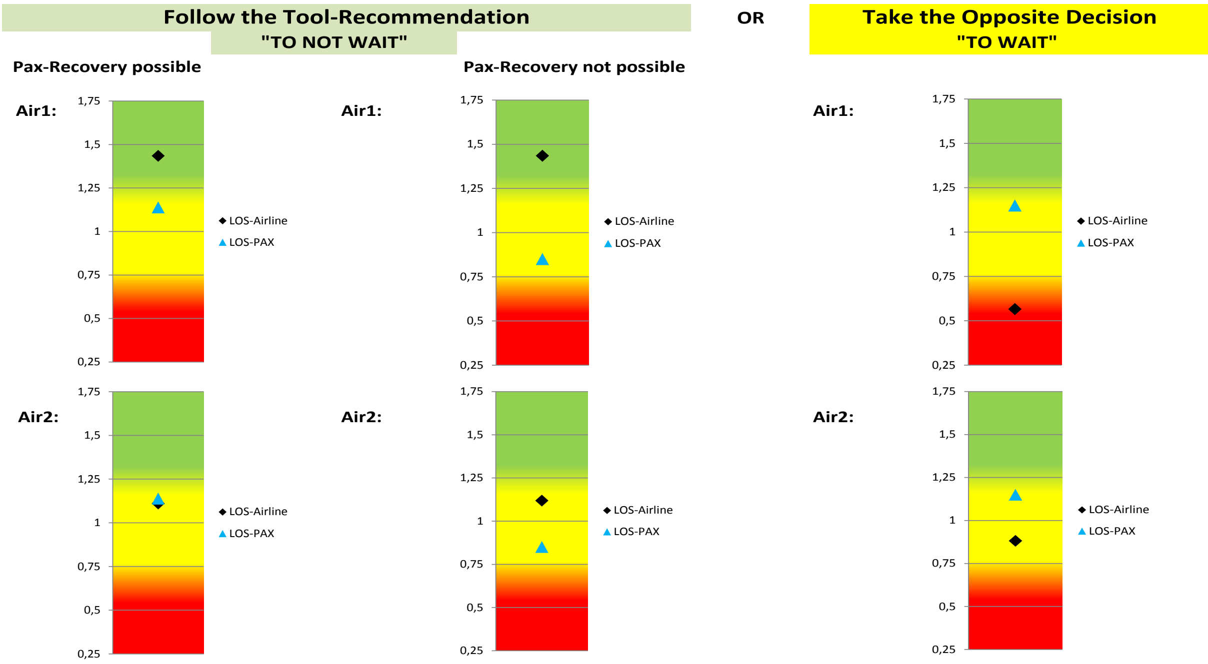
The output-component ***LOS Pax*** has been obtained by using the proposed LOS model for showing the passenger sensitivity to this one SQ delivered (i.e. decision made). Taking the satisfaction levels modelled for each passenger-group separately by using Tables 4-1 to 4-3, for this decision the following values have been taken into account:
19 passengers from the Pax-Group I are assumed to be "very satisfied" with the carrier's SQ i.e. decision made (since in spite of an obvious incurring delay in arriving, they have been waited for!), which may be highly credited to the carrier's account in this case.
60 one-flight-leg originate passengers (the Pax-Group II-1) are assumed to be "neutral" (or "not affected") satisfied aligning with the literature findings that *arriving* on time is the service characteristic most valued by the passengers (Bratu and Barnhart 2006), and as one of the key areas of airline's SQ (Tiernan, Rhoades et al. 2008) categorized as appointed by the passengers i.e. "one dimensional" one. Therefore these passengers have not yet been affected with a delay on the departure.
However, 6 originate-connecting passengers from the Pax-Group II-2 although being themselves on-time, may be "worried" about their own connecting flight(s) at the airport C and therefore are modelled as "dissatisfied" with the perceived SQ (i.e. with departure-delay made for waiting for the inbound flight).
The overall passengers' satisfaction level has been obtained by applying the equations (33) and (34).

The two computed results, *LOS Pax* and *LOS Airline,* must firstly be transferred onto the 3-colour-bar for to be displayed onto the user interface by applying the mapping function (ω) expressed by the Eq.(2).

However, in both cases i.e. following the tool-recommendation or taking the opposite decision the decision-solution and consequently its associated consequences will be displayed on the user interface, being stored for the statistical and managerial matters.

For space savings in this research, the both tool outputs are displayed on one 3-colour-bar. The tool recommendations calculated for *Scenario 1* with their accompanying consequences for both airlines are displayed in Figure 6-2. This would be seen on the user interface of the operation controller (however without the shown mathematical scale and border-lines).

Figure 6-2: Scenario 1: DEVOTED DSS Tool-Outputs for Air1 and Air2



As the figure above shows, the tool recommends, for example, to the airline *Air1* (depending on pax-recovery availability) to not waiting for the arriving-delayed passengers, showing the two main outputs *LOS Pax* and *LOS Airline* placed somewhere on the 3-colour bars. Hereby:

- If *Air1* follows the tool recommendation, it will achieve a highly satisfying SQ-performance (in the “green” field) and an overall “neutral” (or “not affected”) satisfaction level of the high-fare passengers on both considered flights
- If *Air1* takes the opposite decision – waiting for its delayed passengers, it achieves a notably worse SQ-performance (in the “red” field) while the satisfaction level of all high-fare passengers with this (opposite) decision remains “not affected” (it lies in the “yellow” field).

In this way, the decision maker (i.e. the operation controller) is aware of each decision solution taken, being enabled in making rather objective than intuitive decisions when dealing with this kind of operation disruptions.

- **Calculation of the Tool-Output: Cost**

For the thesis testing purposes, the third tool-output - extra costs caused by decisions made in this kind of disruptions has been separately processed.

As already seen above, the final decision-outputs of the recommended solutions differ in their values, since they are dependent on the passenger-recovery availability. E.g., for the case when the recovery of the arriving connecting high-fare passengers is not achievable/possible on that day/date within the assumed 2 hours (by respecting both, the importance (monetary) value of these passengers to the airline and the value of time (VOT) of these passengers), these passengers will be considered as *being refused* with the associated consequences (i.e. recovering- and compensation-costs, and dissatisfying LOS achieved of both, performed by the carrier and perceived by these passengers).

Costs incurred in *Scenario 1* have been calculated according to the assumptions given in the Subsection 6.2.1 being applied on both airlines, in both decision-cases:

- If taken *not waiting* (following the tool-recommendation) – with pax-recovery availability, calculated is that *Air1* (as an alliance partner of the *Air2*) has to pay for its arriving-delayed passengers who have to be recovered in this decision-case by another airline (for example, *Air2*) and therefore is due to pay as assumed the passenger code-share of up to 17% of the TOCs. Contrary to this, the airline *Air2* has more possibilities to recover its delayed arriving passengers, since this airline has been taking the decision at its home-/basis-airport (B) and assumed is that the passenger recovering will not incur extra expenses when made with the same (home) airline.

  In the case of *not waiting* - with an unavailability of a pax-recovery for the arriving Pax-Group I, being forced to refuse and bring them home back, both airlines will have to pay compensation for these passengers in terms of the *Opportunity Cost* which is calculated as: 2 hours multiplied with the VOT of these passengers (adopted to be 50€/h) added to the ticket revenue generated from the refused passengers. According to this, the overall cost incurring to the airlines is the sum of the Opportunity Cost plus ½ of the Ticket Revenue gained from the refused passengers, assuming that the other half of the ticket price purchased has to be refunded. These results are shown in Table 6-3.

Table 6-3: Scenario 1: *expected costs* if following the tool-recommendation

Cost (pax-recovery available)	
Cost (Air1)=	17.000,00 €
Cost (Air2)=	0,00 €

Cost (pax-recovery not available)	
Cost (Air1)=	81.956,50 €
Cost (Air2)=	81.956,50 €
Opport.Cost=	55.271,00 €

- If the decision option *waiting* for delayed in arriving Pax-Group I is taken (which is the opposite decision as recommended by the tool), both airlines are assumed to not suffer any extra pax-delay costs, since in the case of waiting for the inbound flight and the Pax-Group I, all passengers will be brought to their final destination with the same airline *Air1* or *Air2*. Therefore they are not required to pay any extra passengers related delay costs, as shown in Table 6-4. This is under the assumption that the airlines will not exceed 2 hours of waiting-time on departure while respecting the high VOT of this kind of passengers. As introduced and explained in Subsection 6.2.1, other costs (related to the crew flight hours, airport and airspace charges) are not taken into decision calculations as being defined as not notably relevant for this phase of the tool testing.

Table 6-4: Scenario 1: expected costs, if taking the opposite decision

Cost	
Cost (Air1)=	0,00 €
Cost (Air2)=	0,00 €

To keep in mind is the fact that these costs can properly be fulfilled only by the airlines directly in order to take an effectively advantage of the DEVOTED tool.

At this place it must be emphasized the obvious differences between costs which occur in the recommended and the opposite decision solutions in *Scenario1*. As it can be seen from illustrations above, the recommended solution is bounded with some costs (for *Air1*) though ensuring its SQ of a satisfactory performance level and an overall "not affected" passengers' satisfaction level, whereby the opposite decision in this scenario would not be burdened with any extra costs (the Pax-Group I would be waited for and accordingly very satisfied with the SQ i.e. decision made), but the airline's overall SQ-performance would be on the low LOS level field (in the "red" field) as this shows Figure 6-2.

This example indicates the difference in decision making processes between the one relying only on mostly employed cost-driven (i.e. cost-based) models and in this research proposed one - relying on the implemented LOS and ticket revenue-driven model.

As it can also be seen from all scenarios which are pairwise described but separately presented in the Annex B (e.g. "*Scenario 1*" and "*Scenario 1a*"), the ticket prices are exchanged between them to simulate a case of gathering of higher ticket revenue from the in-bound flight than from the out-bound flight. For example in *Scenario 1* the ticket prices of the departing (out-bound) flight are higher than the ones of the arriving (in-bound) flight for the same cabin-class passengers, while in *Scenario 1a* the ticket prices per flight have been exchanged. This is done in order to provoke an influence of ticket prices on a final decision making process output. This can be seen on the case of *Scenario 1a,* shown in Table 6-5.

Table 6-5: Scenario 1a: DEVOTED Tool Inputs

ARRIVING FLIGHT			
Pax-Group I	Pax-Number	Ticket Price	Ticket-Revenue
VIPs	2	6.500 €	13.000,00 €
1. C	1	5.200 €	5.200,00 €
BUS+FFPs	16	3.590 €	57.440,00 €
Summe	**19**		**75.640,00 €**
DEPARTING FLIGHT			
Pax-Group II	Pax-Number	Ticket Price	Ticket-Revenue
VIPs	1	4.873 €	4.873,00 €
1. C	2	3.625 €	7.250,00 €
BUS+FFPs	63	2.500 €	157.500,00 €
Summe	**66**		**169.623,00 €**
m1 (Pax-Group II-1)			60
m2 (Pax-Group II-2)			6
m + n			**85**

In the manner the Scenario 1 in details was described above, all settings and calculations of Scenario 1a as well as the all remaining scenarios in this research have been done, while being presented in more details in the Annex B entitled to refer to the scenario number which has been processed (e.g. Scenario2, Scenario3, etc.).

6.2.2.2 Scenario 2 and Scenario 2a

These 2 scenarios describe the same operational situation as Scenario 1 with the same number and distribution of the high-fare passengers on the in-bound and the out-bound flights, expressed as follows:

$$\boldsymbol{VIP_{ARR} = VIP_{DEP} + 1}$$

$$\boldsymbol{\sum_{i=1}^{n}(1.C_{ARR,i} + BUS_{ARR,i} + FFP_{ARR,i}) = \sum_{j=1}^{m}(1.C_{DEP,j} + BUS_{DEP,j} + FFP_{DEP,j}) - 48}$$

However, the relation of ticket prices of the high-fare cabin classes has now been taken according to the findings of Doganis (2002) (see Section 6.2, II/b).

In these scenarios the importance of the VIP-passengers to the airlines is taken to be not as high as in the previous two scenarios, although still respecting their given ranking order (i.e. $\propto_1 > \propto_2 > \propto_3$). Here they are taken to be:

$\propto_1 = \mathbf{0,448}$ for the VIPs, $\propto_2 = \mathbf{0,352}$ for the first-class, and

$\propto_3 = \mathbf{0,2}$ for the business passengers and frequent flyers.

These two scenarios have been done in the same manner as in detail described in Scenario 1, being presented in more details in the Annex B (“Scenario 2”/”Scenario 2a”).

6.2.2.3 Scenario 3 and Scenario 3a

The number of VIPs on the in-bound and on the out-bound flight is equal, meaning that the difference between the number of the VIPs in arriving and the VIPs on the departing flight equals to zero.

This indicates that these passengers of the highest ranking importance to the airlines do not affect now (at least, not directly) the decision making of the designed tool, while this process will now depend on the two remaining (while also bigger) high-fare passenger-groups, i.e. first-class, and business-/FFP-passengers.

Additionally, there are 3 more First-class passengers on the in-bound flight than on the out-bound flight, because these passengers are the next most important ones according to the ranking set up in this research (see: Section 5.3), in the case where either the VIPs have not been found on both flights or the number of VIPs on inbound flight equals the ones on the outbound flight. Hereby, the sum of the Business passengers and Frequent Flyers on the in-bound-flight is taken to be higher by 10 passengers than on the out-bound flight.

This is mathematically expressed as follows:

$$\boldsymbol{VIP_{ARR} = VIP_{DEP}}$$

$$\sum_{i=1}^{n}(\mathbf{1.}\,\boldsymbol{C_{ARR,i}}) = \sum_{j=1}^{m}(\mathbf{1.}\,\boldsymbol{C_{DEP,j}}) - \mathbf{3}$$

$$\sum_{i=1}^{n}(\boldsymbol{BUS_{ARR,i}} + \boldsymbol{FFP_{ARR,i}}) = \sum_{j=1}^{m}(\boldsymbol{BUS_{DEP,j}} + \boldsymbol{FFP_{DEP,j}}) + \mathbf{10}$$

The importance-values (α_i) are defined so that the VIPs are here (again) very important (i.e. valuable) to the airlines, which is expressed as:

$\propto_{\mathbf{1}} = \mathbf{0,8}$ for the VIPs, $\propto_{\mathbf{2}} = \mathbf{0,1184}$ for the first-class passengers, and

$\propto_{\mathbf{3}} = \mathbf{0,0816}$ for the business passengers and frequent flyers.

Calculations and processing of these two scenarios have been done in the same manner as in detail described Scenario 1, being presented in the Annex B ("Scenario 3"/"Scenario 3a").

6.2.2.4 Scenario 4 and Scenario 4a

This is the same operational situation as described in Scenario 3 and 3a:

$$\boldsymbol{VIP_{ARR} = VIP_{DEP}}$$

$$\sum_{i=1}^{n}(\mathbf{1.}\,\boldsymbol{C_{ARR,i}}) = \sum_{j=1}^{m}(\mathbf{1.}\,\boldsymbol{C_{DEP,j}}) - \mathbf{3}$$

$$\sum_{i=1}^{n}(\boldsymbol{BUS_{ARR,i}} + \boldsymbol{FFP_{ARR,i}}) = \sum_{j=1}^{m}(\boldsymbol{BUS_{DEP,j}} + \boldsymbol{FFP_{DEP,j}}) + \mathbf{10}$$

Hereby, the values of the importance ratios α_i are changed. Here is again assumed that the importance of the VIP passengers to the airlines is not as high as in the Scenarios 3 and 3a, though still respecting their defined ranking order (i.e. $\propto_1 > \propto_2 > \propto_3$). They are presented as follows:

$\propto_{\mathbf{1}} = \mathbf{0,448}$ for the *VIPs,* $\propto_{\mathbf{2}} = \mathbf{0,352}$ for the first-class passengers, and

$\propto_{\mathbf{3}} = \mathbf{0,2}$ for the business passengers and frequent flyers.

Being calculated and processed in the same manner as above described in Scenario 1, they are presented in more details in the Annex B (“Scenario 4”/“Scenario 4a”).

6.2.2.5 Scenario 4b and Scenario 4c

The same operational situation as described in Scenario 4 and 4a, together with the same values of the importance ratios, being expressed as:

$$\boldsymbol{VIP_{ARR} = VIP_{DEP}}$$

$$\sum_{i=1}^{n}(\mathbf{1}.\,C_{ARR,i}) = \sum_{j=1}^{m}(\mathbf{1}.\,C_{DEP,j}) - \mathbf{3}$$

$$\sum_{i=1}^{n}(BUS_{ARR,i} + FFP_{ARR,i}) = \sum_{j=1}^{m}(BUS_{DEP,j} + FFP_{DEP,j}) + \mathbf{10}$$

$\propto_{\mathbf{1}} = \mathbf{0,448}$ for the *VIPs,* $\propto_{\mathbf{2}} = \mathbf{0,352}$ for the first-class passengers, and

$\propto_{\mathbf{3}} = \mathbf{0,2}$ for the business passengers and frequent flyers.

In these two scenarios, the sizes of the two departing passenger groups (on the out-bound flight) have been changed so that the Pax-Group II-1 (which ends its travel at the destination airport C) has now been taken to be much smaller than the Pax-Group II-2 (which has not to end its travel at the airport C). This is undertaken in order to simulate a situation where the connecting passengers on the out-bound flight (Pax-Group II-2) may *feel discomfort* due to threatening possibility of misconnecting at the airport C, which may impact the overall LOS perceived by the passengers, displayed in the DEVOTED DSS Tool output named the *LOS Passenger*.

This can be seen in more details in the Annex B (“Scenario 4b”, “Scenario 4c”) together with the calculations and processing in the same manner done as described in Scenario 1.

6.2.2.6 Scenario 5 and Scenario 5a

These scenarios are created to show the same operational situation as previous one, where the designed tool *recommends* to one airline *to wait* while to the other *to not wait* for the arriving-delayed passengers. Compared to Scenario 4b/4c, here have been exchanged the ticket prices purchased per flight, while both passenger-importance valuing basics have been used (the coefficient $\propto_{\mathbf{1}}$ **-** the importance of VIPs, once being very high, then after, not as high as). This is made as follows:

(1) For the Scenario 5:

$\propto_{\mathbf{1}} = \mathbf{0,8}$ for the VIPs, $\propto_{\mathbf{2}} = \mathbf{0,1184}$ for the first-class passengers, and

$\propto_{\mathbf{3}} = \mathbf{0,0816}$ for the business passengers and frequent flyers;

(*2) For the Scenario 5a:*

$\propto_{\mathbf{1}} = \mathbf{0,448}$ for the VIPs, $\propto_{\mathbf{2}} = \mathbf{0,352}$ for the first-class passengers, and

$\propto_{\mathbf{3}} = \mathbf{0,2}$ for the business passengers and frequent flyers.

In Scenario 5 and 5a, not only the influences of the passenger-importance ratios and a bigger size of the Pax-Group II-2 on the decision making was examined, but at the same time the situation where the ticket revenue gained (only from the high-fare passengers) on the inbound-flight being higher than the one gained on the out-bound flight.

The operational situation for both scenarios here is the same, being presented as:

$$\boldsymbol{VIP_{ARR}} = \boldsymbol{VIP_{DEP}} - \mathbf{7}$$

$$\sum_{i=1}^{n}(\mathbf{1}.\,\boldsymbol{C_{ARR,i}}) = \sum_{j=1}^{m}(\mathbf{1}.\,\boldsymbol{C_{DEP,j}}) - \mathbf{6}$$

$$\sum_{i=1}^{n}(\boldsymbol{BUS_{ARR,i}} + \boldsymbol{FFP_{ARR,i}}) = \sum_{j=1}^{m}(\boldsymbol{BUS_{DEP,j}} + \boldsymbol{FFP_{DEP,j}}) + \mathbf{3}$$

Above introduced scenarios and the corresponding calculations have been done in Excel, in the manner Scenario 1 described, being shown in the Annex B (“Scenario 5”/“Scenario 5a”).

6.3 Results and Discussion

In order to expose a tangible aim of the designed tool, the testing scenarios were constructed to reflect specific borderline operational situations while emphasizing conflicting non-quantifiable key criteria. For this thesis purposes, the testing is completed in Excel for showing the tool’s main functionality possibilities and the way of its processing while presenting the results obtained.

In each described testing scenario, available decision options have been evaluated by employing the DEVOTED DSS Tool while generating always two possible outcomes for a decision maker (operation controller) by enabling: either to follow the decision solution recommended by the tool or to take the opposite decision. In both cases, the tool outputs are visualized to the controller remaining simply and easily to deal with, since being entirely disburden from digits and/or calculations.

Table 6-6 shows the tested scenarios with the main decision criteria and the results obtained (see also Annex B, “Results Overview”, where using the DEVOTED DSS Tool mathematical background (i.e. Eq. 8, 13, 33 and 34) is presented).

Table 6-6: Testing scenarios with testing results

	DEVOTED DSS Tool: Testing Evaluation						
	Key Characteristics of the Testing Scenarios					**The Tool Decision-Recommendation**	
SCENARIOS	***Pax-Value Coeff.***	***Passenger-Groups***	***Relation of Ticket Prices: ARR/DEP***	***Value of the Eq. (8)***	***Value of the Eq. (13)***	***Air1***	***Air2***
Scenario 1	α1=0,8 α2=0,118 α3=0,082	Pax-Group I =19 Pax-Group II-1 =60 Pax-Group II-2 =6	TicketPrices(ARR) **<** TicketPrices(DEP)	-0,0371	-0,6399	to not wait	to not wait
Scenario 1a			TicketPrices(ARR) **>** TicketPrices(DEP)	-0,0371	-0,3832	to not wait	to not wait
Scenario 2	α1=0,45 α2=0,35 α3=0,2	Pax-Group I =19 Pax-Group II-1 =60 Pax-Group II-2 =6	TicketPrices(ARR) **<** TicketPrices(DEP)	-0,1095	-0,6399	to not wait	to not wait
Scenario 2a			TicketPrices(ARR) **>** TicketPrices(DEP)	-0,1095	-0,3832	to not wait	to not wait
Scenario 3	α1=0,8 α2=0,118 α3=0,082	Pax-Group I =70 Pax-Group II-1 =53 Pax-Group II-2 =10	TicketPrices(ARR) **<** TicketPrices(DEP)	0,0035	-0,1385	to not wait	to not wait
Scenario 3a			TicketPrices(ARR) **>** TicketPrices(DEP)	0,0035	0,2169	to wait	to wait
Scenario 4	α1=0,45 α2=0,35 α3=0,2	Pax-Group I =70 Pax-Group II-1 =**53** Pax-Group II-2 =**10**	TicketPrices(ARR) **<** TicketPrices(DEP)	0,0071	-0,1385	to not wait	to not wait
Scenario 4a			TicketPrices(ARR) **>** TicketPrices(DEP)	0,0071	0,2169	to wait	to wait
Scenario 4b	α1=0,45 α2=0,35 α3=0,2	Pax-Group I =70 Pax-Group II-1 =**10** Pax-Group II-2 =**53**	TicketPrices(ARR) < TicketPrices(DEP)	0,0071	-0,1385	to not wait	to not wait
Scenario 4c			TicketPrices(ARR) **>** TicketPrices(DEP)	0,0071	0,2169	to wait	to wait
Scenario 5	α1=0,8 α2=0,118 α3=0,082	Pax-Group I =46 Pax-Group II-1 =**40** Pax-Group II-2 =16	TicketPrices(ARR) **>** TicketPrices(DEP)	-0,0595	0,0083	to wait	to not wait
Scenario 5a	α1=0,45 α2=0,35 α3=0,2		TicketPrices(ARR) **>** TicketPrices(DEP)	-0,0456	0,0083	to wait	to not wait

Source: created by the author

For example, if observing the *Scenario 1*, the main criteria show that the VIP-importance-value (0,8) is much higher than the one in the *Scenario 2* (0,45); though there are the same sizes of the passenger-groups observed, the ticket prices (per same cabin-class) for the arriving flight are lower than the tickets purchased for the departing flight; the values of the equations (8) and (13), since both laying below zero, emphasize that an airline should not wait for its in arrival delayed high-fare passengers. Correspondingly, the DEVOTED DSS Tool does recommend to the both airlines, *Air1* and *Air2: not waiting*.

However, this conclusion may appear almost obvious and predictable, since there is only one VIP-passenger more in the arriving-group of the high-fare passengers which size (17 paxs) is around three times smaller than the departing high-fare passenger group (66 paxs); also for having the ticket prices on the out-bound flight higher (by around 35%) than on the in-bound one. Thus, seeing the decision making process in these operational situations from both points of view, i.e. *LOS delivered to the passengers* (by confronting 1 VIP-more and 16 business passengers and Frequent Flyers on arriving flight, with one 1.class- and 63 (BUS+FFPs)-passengers more on the departing flight) and *Operating Profitability* (where the ticket revenue gained on the departing flight is higher than the one gained on the arriving flight due to higher ticket prices and higher number of the high-fare passengers on the departing i.e. out-bound flight), it would therefore lead to the same final conclusion i.e. decision: *not waiting*.

In opposite to these two rather “clear” random-situations, the tool decision-recommendations made in somewhat *tight* Scenarios 5 and 5a differ in the suggestions given to the airlines *Air1* (should wait) and *Air2* (should not wait). In these two scenarios, the following were varied: VIP-passenger-importance-values (Scenario 5: 0,8; Scenario 5a: 0,45, the difference of the sizes of passenger-groups per flight i.e. in-bound and out-bound is small (arriving Pax-Group I is smaller only by 10 paxs than the departing Pax-Group II) while the ticket revenue gained from the in-bound flight is higher than the one from the out-bound flight (indicating that for an airline it *could be worth* waiting for its delayed passengers). Indeed, the DEVOTED DSS tool recommends to *Air1* to wait for the delayed arriving high-fare passengers, because this airline has its prioritization policy composed of a very low *LOS to the Paxs* ratio (0,1) and a very high ratio for the *Operating Profitability* (i.e. to keep revenue being higher than the cost) set on 0,9. Therefore, for this airline it is worth waiting for its delayed arriving-passengers, since the in-bound flight gains more ticket revenue than the outbound one.

However, for the same flight situations (5 and 5a) to the other airline *Air2* the tool recommends not waiting, since this airline has its prioritization so composed that the ratio for the *LOS to the Paxs* is set to be very high (0,8), and following this for *Air2* is much more lucrative to depart with the greater out-bound group of the high-fare passengers (to gain higher overall satisfaction level of the high-fare paxs), than to wait for the smaller group of the arriving passengers (risking to cause the bigger departing passenger-group becoming dissatisfied, especially the Pax-Group II-2 due to their further connections from the airport C).

6.3.1 Evaluating Paths of the Algorithm that have been followed

The decision making process implemented in the designed tool consists of a process for searching for the best achievable solution being based on evaluation of available solving possibilities. For that purpose, the tool will follow one or more of the Algorithm-Components (see Figure 5-3) corresponding with the operationally available solving options. For the testing purposes, this is simulated by a given decision event environment of a particular scenario.

For each scenario separately and for each airline individually, the tool has to follow required algorithm-paths (i.e. algorithm-components) recommending the final solution(s). The airline can either follow the tool-recommendation (i.e., heeding the advice) or decide to take the opposite decision solution. However, in the latter case, the particular airline will risk delivering of a worse performance, meaning, a worse level of service quality delivered to the passengers and a worse overall level of service quality perceived by all high-fare passengers involved on both flights considered.

Evaluating algorithm paths followed by the tool for the airline *Air1* are presented in Table 6-7, while Table 6-8 shows the ones had been followed for the airline *Air2*.

Table 6-7: Algorithm-Components used for the airline *Air1*

Air1	DECISION MAKING ALGORITHM-PATHS TAKEN							
	If Taking the Tool-Recommendation Decision				If Taking the Opposite Decision			
SCENARIOS	*Alg.-Comp.1*	*Alg.-Comp.2*	*Alg.-Comp.3*	*Alg.-Comp.4*	*Alg.-Comp.1*	*Alg.-Comp.2*	*Alg.-Comp.3*	*Alg.-Comp.4*
Scenario 1	x	x						x
Scenario 1a	x	x						x
Scenario 2	x	x						x
Scenario 2a	x	x						x
Scenario 3	x	x						x
Scenario 3a			x		x	x		
Scenario 4	x	x						x
Scenario 4a			x		x	x		
Scenario 4b	x	x					x	
Scenario 4c			x		x	x		
Scenario 5			x		x	x		
Scenario 5a			x		x	x		

Table 6-8: Algorithm-Components used for the airline *Air2*

Air2	DECISION MAKING ALGORITHM-PATHS TAKEN							
	If Taking the Tool-Recommendation Decision				If Taking the Opposite Decision			
SCENARIOS	*Alg.-Comp.1*	*Alg.-Comp.2*	*Alg.-Comp.3*	*Alg.-Comp.4*	*Alg.-Comp.1*	*Alg.-Comp.2*	*Alg.-Comp.3*	*Alg.-Comp.4*
Scenario 1	x	x						x
Scenario 1a	x	x						x
Scenario 2	x	x						x
Scenario 2a	x	x						x
Scenario 3	x	x						x
Scenario 3a			x		x	x		
Scenario 4	x	x						x
Scenario 4a			x		x	x		
Scenario 4b	x	x					x	
Scenario 4c			x		x	x		
Scenario 5	x	x						x
Scenario 5a	x	x						x

In Scenario 1 the DEVOTED DSS Tool recommends the decision solution to the airline *Air1* when the disruptive situation has to operationally be solved by taking the algorithm paths: Algorithm-Component 1 (pax-recovery is not possible, or “refused passenger”) or Algorithm-

Component 2 (passenger-recovery possible for the delayed Pax-Group I). If *Air1* though decides to take the opposite decision, the decision-making process will then follow the path: Algorithm-Component 4.

Recommending in Scenario 1 the same solution-paths (i.e. Alg.-Comp. 1 and 2) to *Air2*, in Scenario 5 the tool recommends different solutions to the airlines: to *Air1* to take decision-solution following the Alg.-Comp. 3, whereby to the airline *Air2* to follow the Alg.-Comp. 1 and 2. This can be seen in more details in the Annex B (“Tool Algorithm-Paths for Air1/Air2”).

6.3.2 Recommendations from the DEVOTED DSS Tool

After the calculations (i.e. evaluation of possible/available decision solutions) have been completed, obtained results are represented by the tool-recommendations to each airline individually. These are the best achievable decision solutions operationally possible (i.e. available) at the moment of the decision making, if following the tool-recommendations. However, the controller can take the opposite decision as the recommended by the tool, being shown the final outputs for LOS of both, the airline and all high-fare passengers.

Obtained results are presented first in the numerical form being then shown graphically, visualized as the final output on the 3-color-bar for to be seen by the decision maker. Hereby, it is important to notice that obtained results show very small values around zero (somewhat above or below) as consequential effects of the chosen operation situations (above introduced and described), in order to emphasize the particular aim, arbitrary precision and full decision supporting function of the tool. In the presented scenarios (operational situations) it would be difficult for a human in a required short decision making time to consider all the playing features or to oversee, compare and evaluate them, for a reasonably decision making on what to do.

Table 6-9 shows the numerical tool-evaluations of available decision solutions for all tested scenarios together with given tool-recommendations for the airline *Air1*, whereby the resulting tool-recommendations for the airline *Air2* are shown in Table 6-10. See also separately presented in the Annex B (“Test Results for Air1/Air2”).

Table 6-9: The Tool decision-recommendations for the airline *Air1*

Air1	**The DEVOTED DSS Tool OUTPUT**							
	Follow the Tool-Recommendation				**Take the Opposite Decision**			
	Pax-Recovery possible		Pax-Recovery not possible		Pax-Recovery possible		Pax-Recovery not possible	
SCENARIOS	***LOS Pax***	***LOS Airline***	***LOS Pax***	***LOS Airline***	***LOS Pax***	***LOS Airline***	***LOS Pax***	***LOS Airline***
Scenario 1	1,14	1,44	0,85	1,44	1,15	0,57		
Scenario 1a	1,14	1,26	0,85	1,26	1,15	0,74		
Scenario 2	1,14	1,44	0,85	1,44	1,15	0,56		
Scenario 2a	1,14	1,27	0,85	1,27	1,15	0,73		
Scenario 3	0,99	1,09	0,72	1,09	1,38	0,91		
Scenario 3a	1,38	1,15			0,99	0,85	0,72	0,85
Scenario 4	0,99	1,09	0,72	1,09	1,38	0,91		
Scenario 4a	1,38	1,15	0,99	0,85	0,72	0,85		
Scenario 4b	0,9868	1,09	0,7237	1,09	1,2951	0,91		
Scenario 4c	1,2951	1,1469			0,9868	0,8537	0,7237	0,8537
Scenario 5	0,9962	1,0011			0,7857	0,9989	0,6128	0,9989
Scenario 5a	0,9962	1,0022			0,7857	0,9978	0,6128	0,9978

Table 6-10: The Tool decision-recommendations for the airline *Air2*

Air2	**The DEVOTED DSS Tool OUTPUT**							
	Follow the Tool-Recommendation				**Take the Opposite Decision**			
	Pax-Recovery possible		Pax-Recovery not possible		Pax-Recovery possible		Pax-Recovery not possible	
SCENARIOS	***LOS Pax***	***LOS Airline***	***LOS Pax***	***LOS Airline***	***LOS Pax***	***LOS Airline***	***LOS Pax***	***LOS Airline***
Scenario 1	1,14	1,44	0,85	1,44	1,15	0,57		
Scenario 1a	1,14	1,26	0,85	1,26	1,15	0,74		
Scenario 2	1,14	1,44	0,85	1,44	1,15	0,56		
Scenario 2a	1,14	1,27	0,85	1,27	1,15	0,73		
Scenario 3	0,99	1,09	0,72	1,09	1,38	0,91		
Scenario 3a	1,38	1,15			0,99	0,85	0,72	0,85
Scenario 4	0,99	1,09	0,72	1,09	1,38	0,91		
Scenario 4a	1,38	1,15	0,99	0,85	0,72	0,85		
Scenario 4b	0,9868	1,09	0,7237	1,09	1,2951	0,91		
Scenario 4c	1,2951	1,1469			0,9868	0,8537	0,7237	0,8537
Scenario 5	0,7857	1,0344	0,6128	1,0344	0,9962	0,9656		
Scenario 5a	0,7857	1,0261	0,6128	1,0261	0,9962	0,9739		

Observing presented results above, for example for the airline *Air2*, it is suggested that if the airline follows the tool recommendations, its performance expressed as *LOS Airline* and *LOS Pax* will lay either in the field of the best positive (achievable) ones, or, in worst cases, in the neutral or not impacting ones (where the sum of the compounding key factors of the LOS fall not in the frame of neither the worst nor the best ones). Though, if the airline *Air2* decides to take the opposite decisions, its performance will be either in the best case in the neutral field, or, in the worse-dispositioned LOS performance fields.

6.3.3 Costs

Table 6-11 shows the results obtained for the airline *Air1*, while Table 6-12 for the airline *Air2* for each testing scenario separately. Calculations made can be seen in the Annex B ("Costs for Air1/Air2" and under each single scenario appropriately).

Table 6-11: Costs obtained for the airline *Air1*

Air1	The DEVOTED DSS Tool OUTPUT: COST						
	Follow the Tool-Recommendation			Take the Opposite Decision			
	Pax-Recovery possible	Pax-Recovery not possible		Pax-Recovery possible	Pax-Recovery not possible		Ticket-Revenue (ARR+DEP)
SCENARIOS	Cost	Cost	Opportunity Cost	Cost	Cost	Opportunity Cost	
Scenario 1	17.000,00 €	81.956,50 €	55.271,00 €	0,00 €			296.441,00 €
Scenario 1a	17.000,00 €	122.960,00	85.140,00	0,00			245.263,00 €
Scenario 2	17.000,00 €	89.556,50	62.871,00	0,00			296.441,00 €
Scenario 2a	17.000,00 €	122.960,00	85.140,00	0,00			245.263,00 €
Scenario 3	17.000,00 €	307.809,50	216.873,00	0,00			422.223,00 €
Scenario 3a	0,00 €			17.000,00	425.975,00	295.650,00	428.398,00 €
Scenario 4	17.000,00 €	307.809,50	216.873,00	0,00			422.223,00 €
Scenario 4a	0,00 €			17.000,00	425.975,00	295.975,00	428.398,00 €
Scenario 4b	17.000,00 €	307.809,50	216.873,00	0,00			422.223,00 €
Scenario 4c	0,00 €			17.000,00	425.975,00	295.650,00	428.398,00 €
Scenario 5	0,00 €			17.000,00	277.490,00	19.266,00	336.519,00 €
Scenario 5a	0,00 €			17.000,00	277.490,00	19.266,00	336.519,00 €

Table 6-12: Costs obtained for the airline *Air2*

Air2	The DEVOTED DSS Tool OUTPUT: COST						
	Follow the Tool-Recommendation			Take the Opposite Decision			
	Pax-Recovery possible	Pax-Recovery not possible		Pax-Recovery possible	Pax-Recovery not possible		Ticket-Revenue (ARR+DEP)
SCENARIOS	Cost	Cost	Opportunity Cost	Cost	Cost	Opportunity Cost	
Scenario 1	0,00 €	81.956,50 €	55.271,00 €	0,00 €			296.441,00 €
Scenario 1a	0,00 €	122.960,00 €	85.140,00 €	0,00 €			245.263,00 €
Scenario 2	0,00 €	89.556,50 €	62.871,00 €	0,00 €			296.441,00 €
Scenario 2a	0,00 €	122.960,00 €	85.140,00 €	0,00 €			245.263,00 €
Scenario 3	0,00 €	307.809,50 €	216.873,00 €	0,00 €			422.223,00 €
Scenario 3a	0,00 €			0,00 €	425.975,00 €	295.650,00 €	428.398,00 €
Scenario 4	0,00 €	307.809,50 €	216.873,00 €	0,00 €			422.223,00 €
Scenario 4a	0,00 €			0,00 €	425.975,00 €	295.650,00 €	428.398,00 €
Scenario 4b	0,00 €	307.809,50 €	216.873,00 €	0,00 €			422.223,00 €
Scenario 4c	0,00 €				425.975,00 €	295.650,00 €	428.398,00 €
Scenario 5	0,00 €	277.490,00 €	192.660,00 €	0,00 €			336.519,00 €
Scenario 5a	0,00 €	277.490,00 €	192.660,00 €	0,00 €			336.519,00 €

Observing these results and taking into consideration the whole tested situation as being presented in the previous subsection, for example, in Scenario 5 the designed tool recommended *Air1* **to wait** for the arriving-delayed high-fare passengers (since this airline has its APP2-Operating Profitability importance of 0,9), because in this scenario the arriving passengers generate a higher ticket revenue than the departing ones. Looking at the costs displayed in Table 6-11 it can be noticed the following: if the airline follows the tool-recommendation, the airline would suffer no costs and would achieve much better overall LOS performance, while if taking the opposite decision as the one recommended by the tool, it would suffer extra costs achieving an overall worse LOS performance.

In the same scenario, the tool recommends to the airline *Air2* **not to wait** and to depart without the arriving delayed high-fare passengers since in this case its APP1 – LOS to the Passengers is 0,8 high. Accordingly to this, the departing passengers for this airline have a dominant importance (there are 7 VIPs and 6 of 1.class-passengers more on the out-bound than on the in-bound flight) and the satisfaction level achieved by the departing high-fare passengers will drive the decision making of this airline. Looking at the costs obtained in this scenario being presented in Table 6-12, it can be noticed the following: if the airline follows the tool-recommendation departing without the in-bound passengers, it would suffer extra costs only in the case of "refused passenger" (with no possible recovery for these passengers and therefore having extra costs that occur for their compensation and bringing back home), but the overall performance of this airline will be better than in the opposite situation: if taking the opposite decision as recommended one, this airline will suffer no extra (and dominant) costs but its overall performance and the LOS to the Passengers would be worse.

Secondarily, the obtained results for both airlines (i.e. in both given tables) show distinctly the difference between the decision candidate solutions recommended by the proposed tool (as being LOS- and Ticket Revenue-driven) and the ones which would have been chosen in the commonly used only cost-driven models/solutions.

6.3.4 The DEVOTED DSS Tool Output: Displaying on the 3-colour-bar

Obtained results from all testing scenarios presented above as the tool-recommendations for each tested scenario and airline separately, the two defined tool-output parts i.e. the level of service quality (SQ) achieved by the carrier (*LOS Airline*) and the one perceived by the high-fare passengers (*LOS Passenger*), have been transferred on the 3-colour-bar, to be shown on the user's interface. Since overloaded with neither digits nor data or calculations, the operation controller will see only the final positions the values of both defined outputs on the 3-color-bar, having so an easy and simple dealing aid with this kind of disruptions.

Referring to the results obtained by employing the designed tool in terms of its recommendations given to the airline *Air1* (see: Table 6-9) and to the airline *Air2* (see: Table 6-10), Figure 6-3 and Figure 6-4 display final results for *Air1* and *Air2* respectively, showing how these can be seen while being displayed on an user interface/screen, at this place only from Scenario 1 presented. Obtained results gained in each scenario separately with the final tool outputs displayed for each airline individually can be seen in the Annex B ("The Tool-Output").

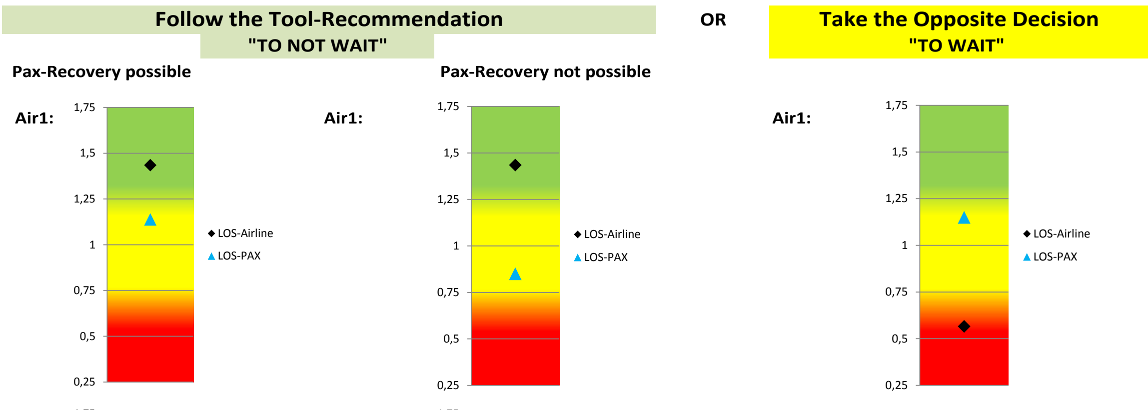


Figure 6-3: The DEVOTED DSS Tool-Output for the airline *Air1* (Scenario 1)

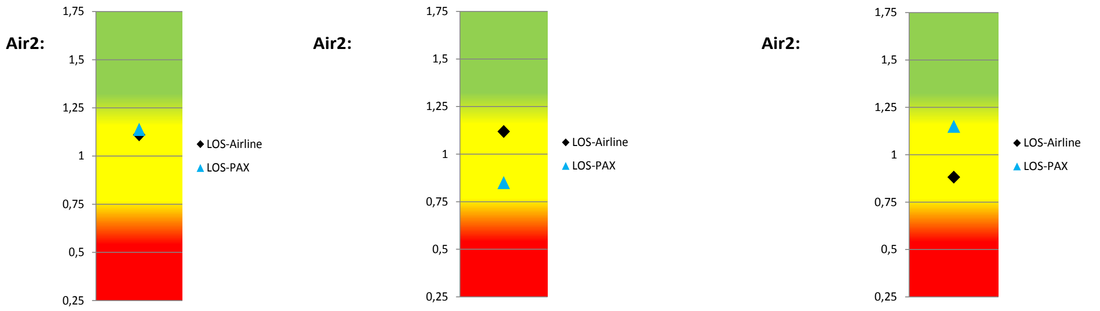


Figure 6-4: The DEVOTED DSS Tool-Output for the airline *Air2* (Scenario 1)

Source: created by the author

As shown in Figure 6-3 for the case of the airline *Air1*, the operation controller would see finally one of two possible decision solutions, depending on the operationally achievable flight situation, recommended by the designed decision support tool for which the airline *Air1* would have an excellent SQ-performance (*LOS Airline* on the "green field") and an overall neutral-to-positive satisfaction level achieved *by its all high-fare passengers* on both flights (*LOS Pax* on the high-third of the "neutral-field" or not impacted).

However, by taking the opposite solution as the recommended by the tool, the airline's SQ-performance level would lie on the "red-field" of the 3-colour-bar, indicating an overall worse level of the SQ performance which can be achieved.

In this way, the operation controller has been enabled "to see" and to follow the decision made together with its associated consequences in terms of the level of the service quality achieved as well as the overall satisfaction of the high-fare passengers involved.

6.4 Discussion

Results obtained from the testing presented in the subsections above (Tables: 6-1 to 6-5), besides demonstrating the aim and proper functionality of the designed support tool, show accurate benefits of its use in the decision making process.

Though compounding of conflicting key figures which directly impact decisions on this kind of disruptions, the tool-output is visualized as a scale-value positioned somewhere on the three color-fields-bar being relieved of any digits, data and/or calculations, where the final values of the level of the SQ achieved and the one perceived by all high-fare passengers involved are shown (see Figure 6-3 and Figure 6-4). This demonstrates that the DEVOTED DSS Tool has been developed within its process system by respecting the human-centered design (HCD).

The final tool-output is a result of the evaluation of available options while being achieved by employment of the appropriate algorithm-paths i.e. its components (shown in Figure 5-3). However, the tool mathematical background and calculations processing beyond the tool-architecture enables a juxtaposition of the relationship between accurate multi-criteria rules. Since they rely on the given airline-policy prioritization, expressed as the ratio of the main prioritizations: *LOS to the Passengers (or APP1, math. denoted as* β_1*)* and *Operating Profitability (or APP2, math. denoted as* β_2*)*, considering the results obtained in all scenarios it can be noticed how much the final decision-solution depends on this influencing input. This can be particularly seen in the discussion given for each airline separately.

6.4.1 The case of the airline *Air1*

Having the status at the airport B of an alliance partner of *Air2* and an APP which consists of: 0,1 of the APP1 and 0,9 of the APP2, for this airline of the highest priority i.e. importance is the *Operating Profitability* (0,9) seeking to keep its revenue higher than its cost per each flight, which will also strongly impact all its operational decisions. Since the satisfaction of its (high-fare) passengers with the level of the SQ performed has much lower importance ratio (0,1), the airline *Air1* will not primarily consider the overall satisfaction level of the passengers involved, when dealing with disruptions with such contradicting criteria. It will rather give the priority in its decision making processes mainly to avoiding extra costs and/or gaining the greater revenue possible.

From the results obtained throughout all scenarios, it can be noticed that the final decision-solutions recommended to *Air1* were higher-revenue-gained per flight oriented. Considering the higher revenue generated by both flights (inbound or outbound), calculating by use of the Eq. (13), those decision-solutions which ensure that *Air1* earns more money from the flight with the justified higher priority were recommended (i.e. if the inbound flight generates a higher revenue than the outbound flight, recommended to the airline has been to wait, since for this airline *is worth* of waiting for these “much expensive” passengers).

6.4.2 The case of the airline *Air2*

The meaning of the prioritization-policy (APP) of this airline composed of the given ratio-relation 0,8:0,2 (i.e. APP1:APP2) is, that the satisfaction level achieved by its high-fare passengers with its SQ performed is of a high-priority i.e. importance (0,8), much higher than the *Operating Profitability* (0,2). Accordingly, it will seek with each its decision made to perform the level of the SQ of the quality level which has been promoted (through the marketing/purchase), and keep trying to cultivate the reputation of a reliable carrier.

Examining the results obtained for the airline *Air2*, it can be noticed that decision options in each scenario strongly depend on the resulting value of the Eq. (8), a, if being above or below zero and in which the passenger-segmentation on both flights (in-bound and out-bound) plays the key role in the searching for the best possible decision solution. This can be seen on the given passenger-ranking prioritization i.e. if the VIP-passengers are of a very high-importance ($\propto_{\mathbf{1}} = 0{,}8$), or not ($\propto_{\mathbf{1}} = 0{,}45$). The designed tool recommended to *Air2* in each scenario exactly those decision solutions that suit this airline’s prioritization satisfying its SQ-requirements set. It proposed always the one solution, which can more of the high-valuable passengers impact with a higher satisfactory level.

6.4.3 Boundary of Decision Solutions

Testing scenarios have shown that the prioritization policy determined by the airline (APP) and passenger-ranking-prioritizations (given by the importance values $\propto_i$) which have to be determined by the airline, play the most influencing roles in the decision making process when it is about to decide whether to delay an outbound flight in order to wait for the arriving-delayed high-fare passengers.

To obtain the border between the two decision options, *to wait* and *to not wait*, it was required to find out under which conditions the results of the equations (8) and (13) will take the zero-value, being presented in the following under-sections for both importance values taken for testing.

6.4.3.1 Decision Zero-Set for the passenger-importance value $\propto_1 = \mathbf{0,8}$

For the testing scenarios with the ranking values of the high-fare passengers: $\propto_1 = \mathbf{0,8}$ for the VIPs, $\propto_2 = \mathbf{0,1184}$ for the 1.-class, and $\propto_3 = \mathbf{0,0816}$ for business-passengers and frequent flyers, it was needed to create the passenger-segmentation relationships, consisting of their number-difference on both flights, i.e. for the case of: *Eq. (8) = 0*.

Figure 6-5 depicts the high-valuable passengers' juxtaposition showing the border between the two decision options: waiting and not waiting (see also Annex B, "a-Zero (0,8)").

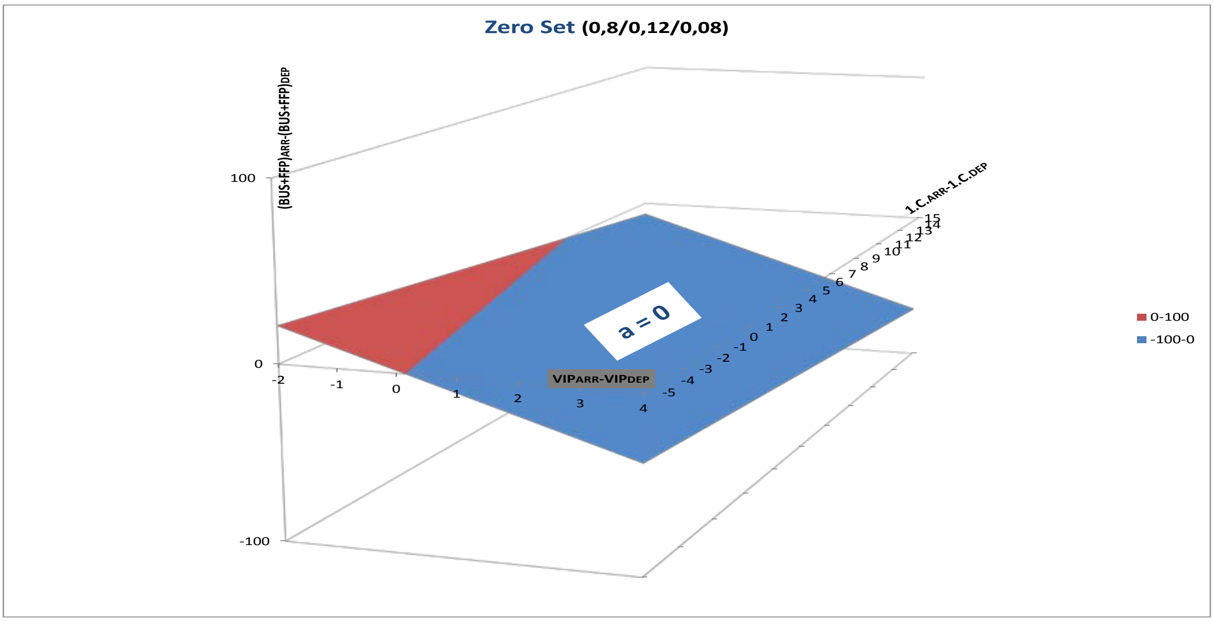


Figure 6-5: Border between the two decision options

Source: created by the author

As Figure 6-5 shows, all values $a = 0$ form the surface "*a=0*", where the "blue" part of this surface lies under the coordinates plane described by: *(BUS+FFP)ARR - (BUS+FFP)DEP = 0,* while the "red" one lies above it. Values lying above the surface "*a=0*" will lead to the tool-recommendation: "waiting" for the delayed in-bound high-fare passengers. Values lying under the surface "*a=0*" will lead to the recommendation: "not waiting". The negative values of any passenger-group-difference between arriving and departing flights indicate that the number of departing passengers is higher than the arriving ones, for the same cabin-class.

The $a = 0$ surface indicates those operation situations which result in an indifferent juxtaposition of all in-bound high-fare passengers with the out-bound ones, for the given passengers ranking importance values (here: 0,8/0,12/0,08). This signifies such occurring differences between the numbers of all inbound and outbound high-fare passengers of the same cabin-class (for the given passengers ranking importance) which would affect the decision drivers of the proposed tool that these would urge the airline (or its operation controllers) to consider the decision on this disruption by taking the one decision solution as if both flights were without any high-fare passengers on board of both flights.

Considering the given importance values (i.e. passenger-rankings) coming from single comparisons done, a *Zero-Line* between the decisions whether *to wait* and *not to w*ait was obtained which enables making some general remarks.

For a very high (i.e. 0,8) importance value of the VIP-passengers to the airline when it is about to make the decision whether to delay an outbound flight in order to wait for the delayed-arriving high-fare passengers, to identify the border between two possible decisions it is first needed to determine the passenger-segmentation (i.e. their configuration) per flight.

This is made by confronting pairwise the differences in numbers of: arriving and departing VIPs, arriving and departing first class passengers, and arriving and departing BUS-passengers and FFPs. These juxtapositions are presented in Figure 6-6, Figure 6-7, and Figure 6-8 giving the following conclusions:

1) For **1** VIP-Pax *more* on the in-bound flight, there must be **6,76 more** 1.-class Paxs on the outbound flight, to come in such an operation situation, where the airline would be on the zero-line between the two decisions. Hereby, having 6 passengers more of the 1.-class on the outbound flight, the airline would wait for the inbound VIPs, whereby for 7 more 1.-class outbound passengers, the airline would not wait for the inbound VIPs (see Figure 6-6);
2) For **1** VIP-Pax *more* on the in-bound flight, there must be **9,8 more** business-passengers and frequent flyers on the out-bound flight, to get the decision making on the zero-line between the two decision possibilities. If having 9 passengers more of the (BUS and FFP) cabin-class on the outbound flight, the airline would wait for the inbound VIPs, while by 10 more (BUS+FFP) outbound passengers, the airline would not wait for the inbound VIPs (see Figure 6-7);
3) For **1** 1.-class passenger *more* on the in-bound flight, there must be **1,45 more** business-passengers and frequent flyers on the out-bound flight for to getting on the decision zero-line between the two decisions, waiting and not waiting. In such an operation situation, having only 1 passenger more of the (BUS and FFP) cabin-class on the outbound flight, the airline would wait for the inbound 1.-class passenger, whereby by 2 passengers more of the (BUS and FFP) cabin-class on the outbound flight, the airline would not wait for the inbound passengers (see Figure 6-8).

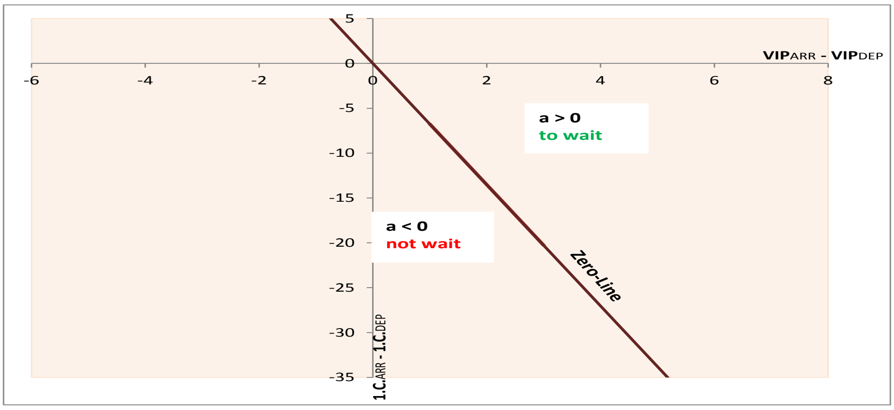


Figure 6-6: Pax-Segmentation Comparison: (VIP_{ARR}-VIP_{DEP}) and ($1.C._{ARR}$-$1.C._{DEP}$)

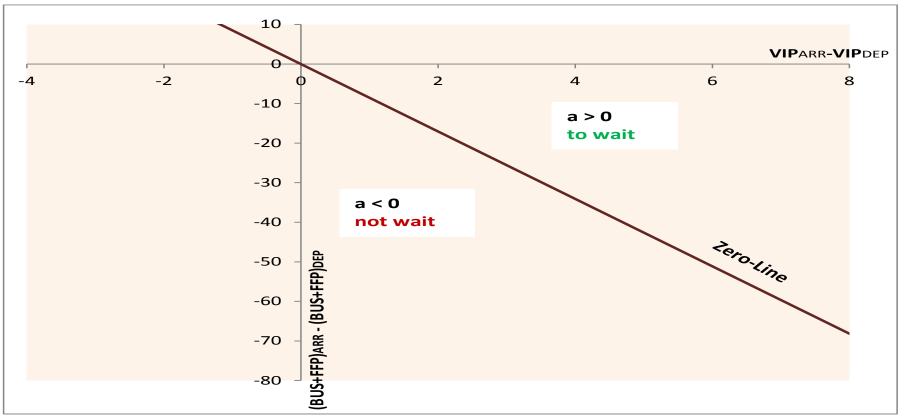


Figure 6-7: Pax-Segmentation Comparison: (VIP_{ARR}-VIP_{DEP}) and [$(BUS+FFP)_{ARR}$ - $(BUS+FFP)_{DEP}$]

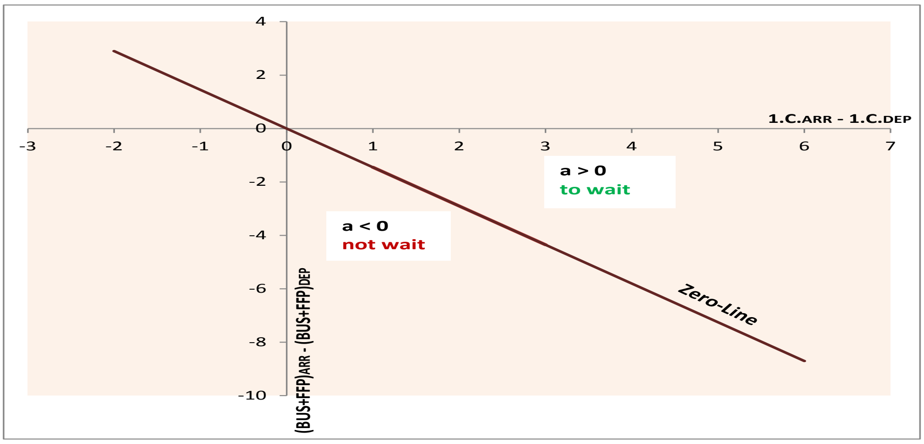


Figure 6-8: Pax-Segmentation Comparison: ($1.C._{ARR}$-$1.C._{DEP}$) and [$(BUS+FFP)_{ARR}$ - $(BUS+FFP)_{DEP}$]

These comparisons and accompanying calculations have been done in Excel, being presented in more details in the Annex B (“a-Zero (0,8)” and “Zero-Line (0,8) - single”).

6.4.3.2 Decision Zero-Set for the passenger-importance value $\propto_1 = \mathbf{0,45}$

For the scenarios where the ranking value of the VIP-passengers is not as high as in the previous example, having them set up: $\propto_1 = \mathbf{0,448}$ for the VIPs, $\propto_2 = \mathbf{0,352}$ for the 1.-Class, and $\propto_3 = \mathbf{0,2}$ for business-passengers and frequent flyers, for obtaining a decision zero-line between the two decision possibilities, it was needed to create the passenger-segmentation relationships, consisting their number-difference on both flights, i.e. where: $Eq.\ (8) = 0$.

Figure 6-9 depicts these juxtapositions showing the final border between the two decisions.

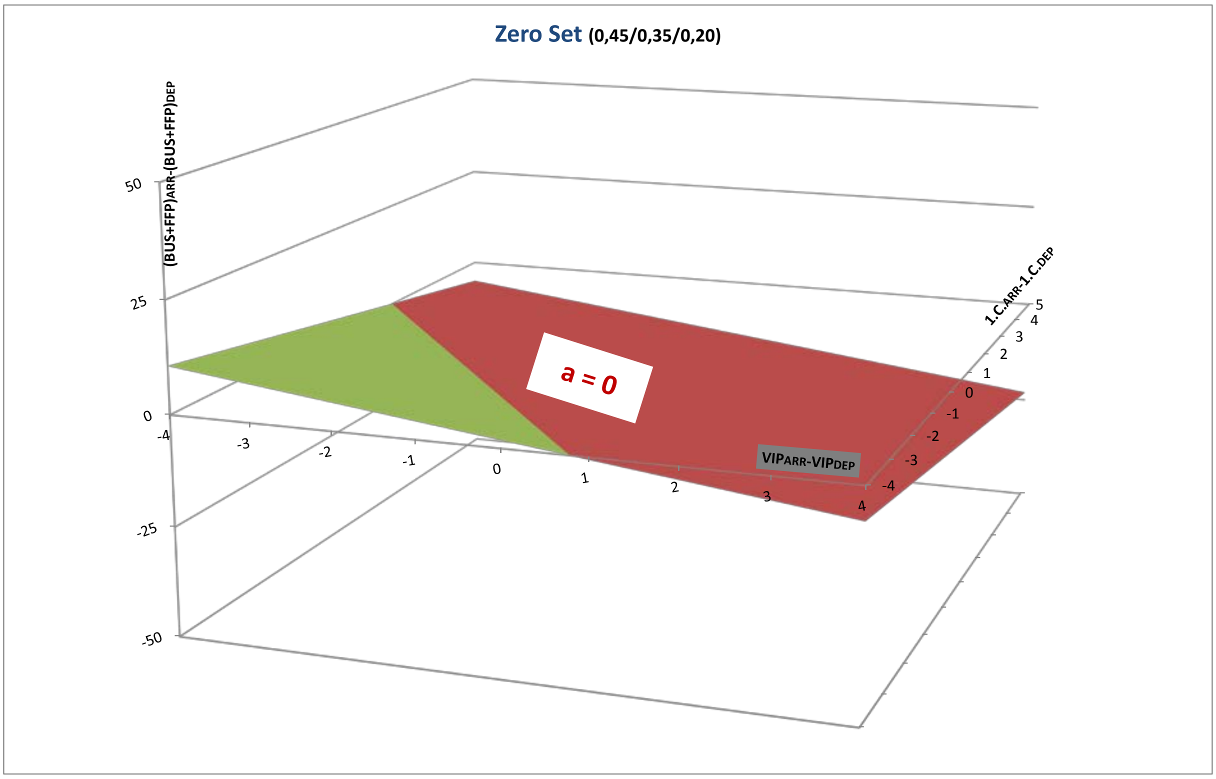


Figure 6-9: Border between the two decision options

According to Figure 6-9, all values $a = 0$ form the surface "*a=0*", where the "red" part of this surface lies under the coordinates plane described by: $(BUS+FFP)_{ARR} - (BUS+FFP)_{DEP} = 0$, and the "green" one lies above it. Values lying above the surface "*a=0*" will lead to the tool-recommendation: "waiting" for a delayed in-bound flight, while the values which lie under the surface "*a=0*" will lead to the recommendation: "not waiting". The negative values of any passenger-group-difference between arriving and departing flights indicate that the number of departing passengers is higher than the arriving ones for the same cabin-class.

The $a = 0$ surface indicates those operation situations which result in an indifferent juxtaposition of all in-bound high-fare passengers with the out-bound ones for the given passengers ranking importance values. This signifies the differences between the numbers of all inbound and outbound high-fare passengers (of the same cabin-class) for the given passengers ranking importance which result in values which would urge the airline (or its operation controllers) to consider the decision on this disruption by taking decision solution as if both flights were without any high-fare passengers on board of both flights.

For a lower importance value of the VIP-passengers to the airline (i.e. 0,45), when it is about to make the decision whether to delay an outbound flight in order to wait for the delayed-arriving high-fare passengers, to identify the border between the two decisions it is first needed to determine the passenger-segmentation (i.e. their configuration) per flight.

Considering the given importance values (i.e. passenger-rankings) coming from single comparisons done, a *Zero-Line* between the decisions whether *to wait* and *not to w*ait could be obtained enabling making some general remarks. This is made by confronting pairwise the differences in numbers of: arriving and departing VIPs, arriving and departing first class passengers, and arriving and departing BUS-passengers and FFPs. These juxtapositions are presented in Figure 6-10, Figure 6-11, and Figure 6-12, for the following situations:

1) For **1** VIP-Pax *more* on the in-bound flight, there must be **1,27 more** 1.-class Paxs on the out-bound flight, to come in such an operation situation, where the airline would be on the zero-line between the two decisions. If having 1 passenger more of the 1.-class on the outbound flight, the airline would wait for the inbound VIP, whereby by having 2 more 1.-class outbound passengers, the airline would not wait for the inbound VIPs (see Figure 6-10);
2) For **1** VIP-Pax *more* on the in-bound flight, there must be **2,24 more** business-passengers and frequent flyers on the out-bound flight to get the decision making on the zero-line between the two decision possibilities. If having 2 passengers more of the (BUS and FFP) cabin-class on the outbound flight, the airline would wait for the inbound VIP, while by 3 more (BUS+FFP) outbound passengers, the airline would not wait for the inbound VIPs (Figure 6-11);
3) For **1** 1.-class passenger *more* on the in-bound flight, there must be **1,76 more** business-passengers and frequent flyers on the out-bound flight for to getting on the decision zero-line between the two decisions, waiting and not waiting. In such an operation situation, having 1 passenger more of the (BUS and FFP) cabin-class on the outbound flight, the airline would wait for the inbound 1.-class passenger, whereby by 2 passengers more of the (BUS and FFP) cabin-class on the outbound flight, the airline would not wait for the inbound first-class passengers (Figure 6-12).

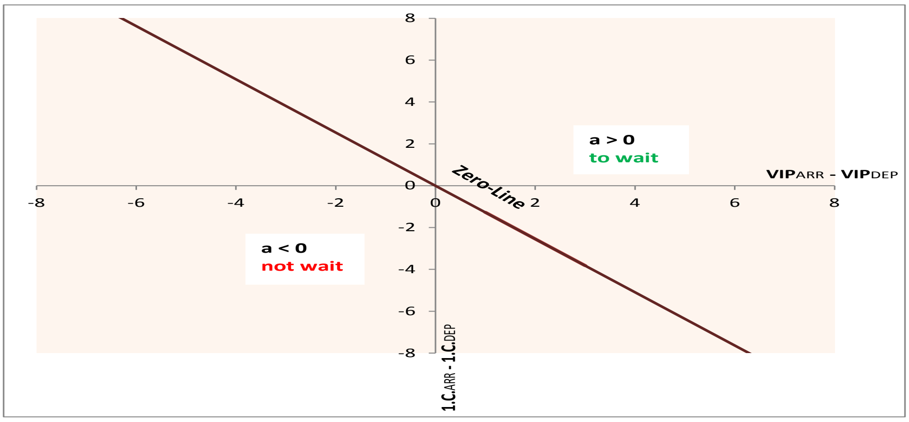


Figure 6-10: Pax-Segmentation Comparison: (VIPARR-VIPDEP) and (1.C.ARR-1.C.DEP)

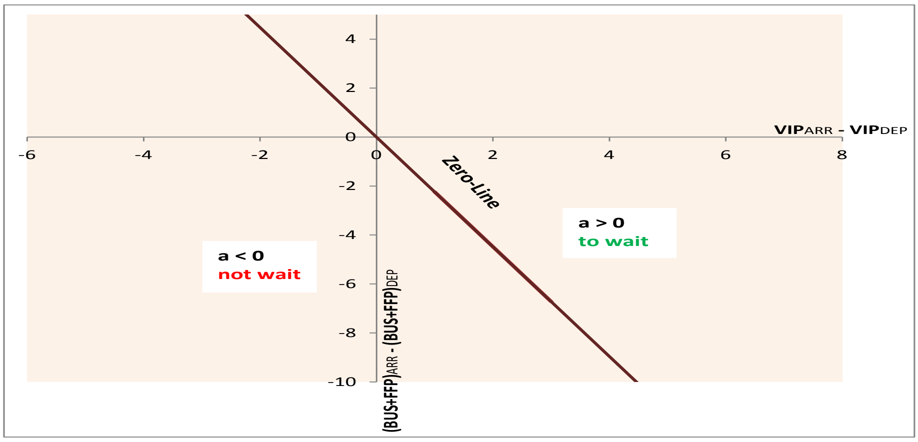


Figure 6-11: Pax-Segmentation Comparison: (VIPARR-VIPDEP) and [(BUS+FFP)ARR - (BUS+FFP)DEP]

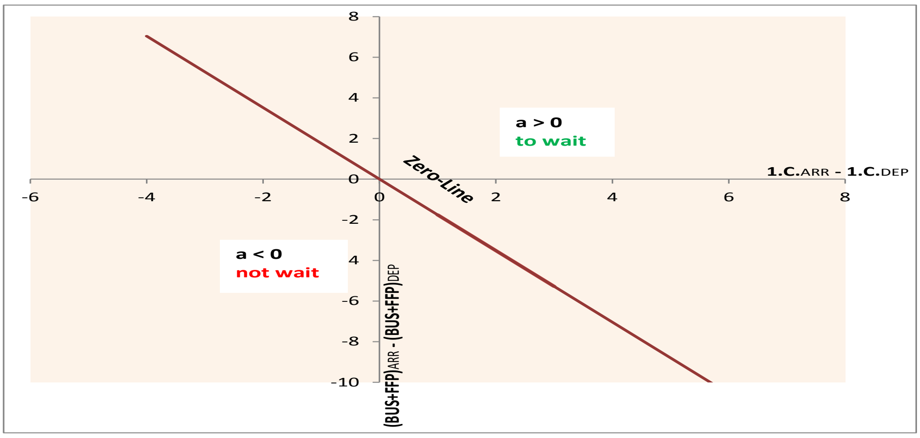


Figure 6-12: Pax-Segmentation Comparison: (1.C.ARR-1.C.DEP) and [(BUS+FFP)ARR - (BUS+FFP)DEP]

These comparisons and accompanying calculations have been made in Excel, being presented in more details in the Annex B (“a-Zero (0,45)” and “Zero-Line-single (0,45)”).

- **Comparison of Decision Zero-Sets for both importance values:** $\propto_1 = 0,45$ **and** $\propto_1 = 0,8$

For a more clear overview of both above presented cases (i.e. for both passenger-importance values applied in: α_1, α_2, α_3) whereby *Eq. (8) = 0*, obtained results from the corresponding testing calculations made are displayed in Table 6-13.

Table 6-13: Zero-Line for both Passenger-Importance Value-Sets applied

	Pax-Groups Configuration	
The Passenger-Importance Value applied	Difference by 1 Pax	Difference by 2 Paxs
α1=0,45; α2= 0,35; α3= 0,2	VIPARR-VIPDEP = 1 --> 1.C.ARR - 1.C.DEP = -1,2727 VIPARR-VIPDEP = 1 --> [(BUS+FFP)ARR - (BUS+FFP)DEP] = -2,24 1.C.ARR - 1.C.DEP = 1 --> [(BUS+FFP)ARR-(BUS+FFP)DEP] = -1,76	VIPARR-VIPDEP = 2 --> 1.C.ARR - 1.C.DEP = -2,5455 VIPARR-VIPDEP = 2 --> [(BUS+FFP)ARR - (BUS+FFP)DEP] = -4,48 1.C.ARR - 1.C.DEP = 2 --> [(BUS+FFP)ARR-(BUS+FFP)DEP] = -3,52
α1=0,8; α2= 0,12; α3= 0,08	VIPARR-VIPDEP = 1 --> 1.C.ARR - 1.C.DEP = -6,75 VIPARR-VIPDEP = 1 --> [(BUS+FFP)ARR - (BUS+FFP)DEP] = -9,80 1.C.ARR - 1.C.DEP = 1 --> [(BUS+FFP)ARR-(BUS+FFP)DEP] = -1,45	VIPARR-VIPDEP = 2 --> 1.C.ARR - 1.C.DEP = -13,51 VIPARR-VIPDEP = 2 --> [(BUS+FFP)ARR - (BUS+FFP)DEP] = -19,6 1.C.ARR - 1.C.DEP = 2 --> [(BUS+FFP)ARR-(BUS+FFP)DEP] = -2,90

Source: created by the author

Comparing the results shown in the table above, when getting the passenger importance values varying (by applying in the first case values: 0,45/0,35/0,2 and in second case the values: 0,8/0,12/0,08, for VIPs/first-class/BUS and FFP passenger cabin-class respectively), the following can be noticed:

(1) The passenger segmentation on each flight is an important influencing factor in the decision making process which can be seen from the comparison of numbers of passengers of the particular cabin-classes needed to affect the decision on whether to wait for the arriving-delayed high-fare passengers;

(2) Also the ranking of the high-fare passengers plays an important role in making decisions on waiting for arriving-delayed high-fare passengers, being evident from obtained results showing the needed number of passengers between different passenger-cabin-classes (i.e. how many passengers, for example, of the departing BUS/FFP passengers are needed for only 1 VIP-arriving passenger to change the decision on waiting/not waiting, etc.);

(3) The passenger-importance values, shown through the values of their coefficients applied, indicate how this importance may directly impact the decision on which passenger an airline would wait and under which conditions (i.e. seen from their segmentation and the configuration, as for example, to make the decision *to wait* for 1 arriving VIP, it is needed to

have on the departing flight either 7 first-class or 10 of (BUS+FFPs) passengers by the VIP-importance value of 0,8; whereby to wait for 1 in-bound VIP in the case of its importance value of 0,45 there are needed on the out-bound flight either 2 first-class or 3 (BUS+FFPs) passengers.

Calculations have been made in Excel, being presented in the Annex B (“Zero-Line for both Passenger-Importance Sets”).

6.4.4 Overall Decision Border-Line

Having yet identified the decision options boundary when considering the passenger-segmentations on both flights by taking into account all given decision conditions in terms of determined passenger-importance values as well as the airline-prioritization policy, it remains to identify one more correlating factor. This is the relationship between the values of the two main airline-prioritizations, *LOS delivered to the passengers* and *Operating Profitability*. They deliver the final judgment in the decision making process of the designed tool resulting in the boundary-line between two decision-options, *to wait* and *not to wait*.

For exploring the relationship between two main information drivers of the decision making processes of the support tool, the Equations (8) and (13) have been confronted in juxtaposition. This is used for the identification of the Zero-Lines of the overall decision options for both airlines, for the given (i.e. already known) value of the Eq. (8), which mathematically expresses the comparison of the high-fare passenger segmentations involved on both flights (inbound and outbound).

6.4.4.1 The Decision Border-Line for the airline *Air1*

In order to obtain the relation between the SQ level which has to be delivered to the high-valuable passengers and an operating profitability by comparing the ticket revenues gained on both flights, a sectioning line between two decision options has been obtained. This is made as a calculated relationship of equations (8) and (13) for the given (determined) relation of both APPs. For the airline *Air1* this relationship has been calculated to be:

APP2= -0,11 APP1 , or: $(y\text{-}z) = -0{,}11a$, for $a \in [-1, 1]$).

This is graphically shown in Figure 6-13.

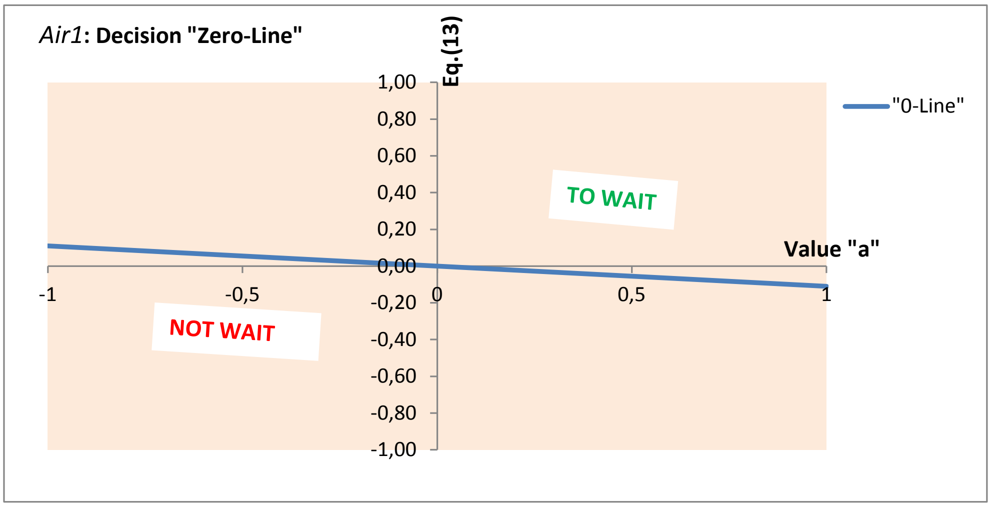


Figure 6-13: Decision “Zero-Line” of the airline *Air1*

As the graphic shows, by taking into consideration that the airline *Air1* has its APP defined as: *0,1APP1 + 0,9APP2*, the following can be noticed:

- with a much higher importance of the priority of the *Operating Profitability* (APP2) than of the *LOS to the Passengers (APP1)*, *Air1* ought to be in such an operational situation when making this kind of decisions, where the value of the APP1 has to be around (i.e. slightly below) the value of the APP2 for getting on the limit line, where the other one (arbitrary) decision can be taken. This means that the airline needs to have up to around 0,11 times smaller value of the ticket revenues difference gained as the calculated importance of the passenger-sensitivity applied for to getting on “the other side” of the decision sectioning line of recommended solutions (e.g. instead “waiting” to take decision solution “not waiting”).

These calculations made in Excel are presented in more details in the Annex B (“Airline Air1: Decision Zero-Line”).

6.4.4.2 The Decision Border-Line for the airline Air2

In order to obtain the relation between the SQ level which has to be delivered to the high-valuable passengers and an operating profitability by comparing the ticket revenues gained on both flights, a sectioning line between two decision options has been obtained. This is made as a relationship of equations (8) and (13) for the given (i.e. determined) relation of the both APPs. For the airline *Air2* this relationship has been calculated to be:

APP2= -4 APP1 (or: $(y\text{-}z) = -4a$, for $a \in [-1, 1]$)

This relationship is shown in Figure 6-14.

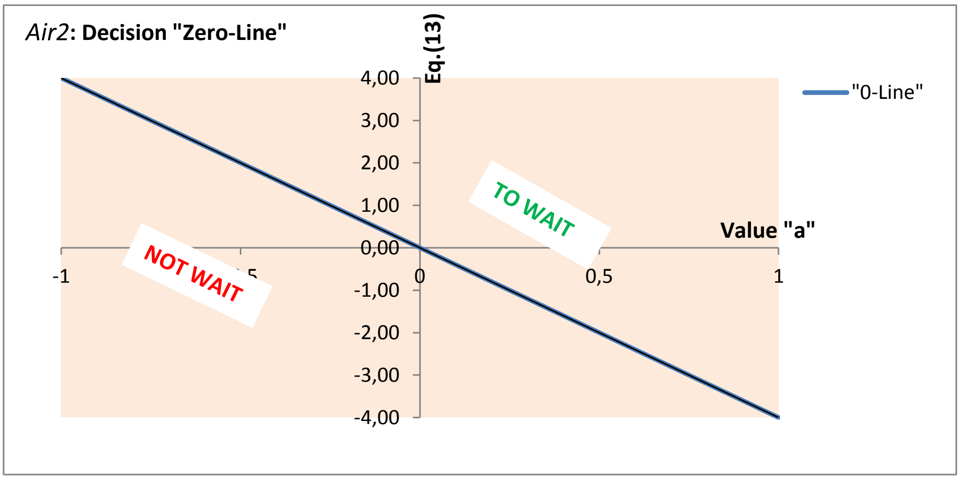


Figure 6-14: Decision "Zero-Line" of the airline *Air2*

As Figure 6-14 shows and by taking into consideration that the airline *Air2* has its APP defined as: *0,8APP1 + 0,2APP2*, the following can be noticed:

- with a much higher importance of the priority of *LOS to the Passengers* (APP1) than of the *Operating Profitability* (APP2) in its business policy, *Air2* ought to be in such one operational situation when making this kind of decisions, where the value of the APP1 has to be 4 times smaller than the value of the APP2 for getting on the limit line, where the other one (arbitrary) decision can be taken. This means that the value of the passenger sensitivity importance has to be 4 times smaller than the value of the ticket revenue difference of both flights for to getting on the limit line, where the opposite decision can be taken (e.g. instead "not waiting" to take the decision solution "waiting").

These calculations made in Excel are presented in more details in the Annex B ("Airline Air2: Decision Zero-Line").

Final discussion words

The testing showed the precise functionality of the designed DEVOTED DSS Tool, which enables its employment at any airline with any set up prioritization-policy. Respecting the rankings and importance-values of its high-valuable passengers denoted by the airline, the tool is capable to make the one decision-solution which is accurately aligned to the airline-policy requirements.

Moreover, considering the tool output - extra costs occurred, it could be recognized the difference in decision solutions when the tool were not LOS- and Ticket Revenue-based, but cost-driven one. This would urge in some tested situations for the same scenario key conditions taking an exactly contraire decisions as recommended by DEVOTED.

7 Conclusions

In this doctoral thesis a knowledge-based Decision Support System (DSS) tool for use in the disruption management of the Airline Operation Control Centre (AOCC) has been designed and presented. Based upon an examination made from the airline's operational point of view for a determined prioritization strategy and to investigate the impact of passenger-structure on operator decisions, *Delaying VIPs Oriented Decision Support System* - DEVOTED DSS Tool was created. Its aim is to assist the airline operation controller in decisions on whether to delay the departure of out-bound flights in order to wait for arriving-delayed high-valuable passengers from an in-bound flight. It accurately evaluates the impact of the decisions in operations disruptions on high-value passengers for aiming at enabling the airline operation controllers' assessment of this important performance issues.

Analysis of a causality of the high-valuable or premium passengers' importance to the airline and a conceivable influence of this importance on decisions on delays within its operation execution and disruptive situations has been done. Particularly the influence of delayed connecting high-valuable passengers on making decisions on onward delays in the airlines' striving to deliver a better service quality (SQ) to these passengers, the passenger segmentation per flight and the associated consequences in terms of the Level of Service (LOS) performed by the carrier and the one perceived by the passengers have been taken into account.

The designed tool comprises of evaluation of decision options and making suggestions which decision process involves the airline's passenger prioritisation policy regarding the high-valuable passengers and the SQ-attributes, both required and perceived. The LOS delivered by the air carrier and the level of service quality expected and perceived by the passengers are determined quantitatively by using a created LOS-model, which relies on the basic categorization rules of the Kano Model of quality.

The tool output is visualized as a scale-value positioned somewhere on the three colour-fields-bar being relieved of any digits, data and/or calculations, where the final values of the level of the SQ achieved and the one perceived by all high-fare passengers are involved. The output consists of the LOS quality delivered by the carrier including the delay-costs (*LOS Airline*), and the level of service perceived by the passengers (*LOS Passenger*). The tool includes the airline's passenger segmentation importance ratio and the emphasis on LOS passenger or operational profitability. Respecting the key elements of Human-Centred Design (HCD), the output components are reflected on the user interface in form of two bars, each consisting of three colours indicating an option as good, neutral or bad. Although the operator may take the opposite decision as recommended one, the tool is enabled to display the evaluation of the consequences in these cases too.

Implementing the (pre-specified) airline prioritisation policy in accordance with the rating of passenger-classes importance, DEVOTED incorporates the LOS which is to be delivered to these passengers, SQ-attributes required by these passengers, number of passengers in each defined passenger-group, and the ticket prices purchased as well as expected costs as its main influencing factors. The consequences of the decision solutions displayed in the designed form are practical in terms of user-friendly utilization of DEVOTED being simple and easy to deal with.

For the first time within a passenger-sensitivity analysis, introduced is confrontation of the in-bound and out-bound high-fare passengers within connecting flights, as an influencing decision making factor in the airline disruption management, investigated and then shown in a juxtaposition of the high-valuable passengers of the same cabin-class.

When it is about to make the choice between a monetary benefit and the retention of the reputation of a reliable service provider, the use of the designed tool can afford rather objective instead the still occurring intuitive decision making in the disruption management.

A decision border-line between the two decision possibilities has been identified. Also the relation between the passenger-sensitivity, passenger-importance and the ticket revenues difference, being gained on both flights (inbound and outbound) have been analysed and graphically shown.

Key Conclusions

From the research carried out in this thesis five key conclusions can be withdrawn:

1. For the first time an introduced confrontation of the in-bound and out-bound high-fare passengers within connecting flights, as an influencing decision making factor in the airline disruption management, was investigated. This is shown in a juxtaposition of the high-fare passengers from an in-bound flight with the high-fare passengers of the same cabin-class of an out-bound flight, respecting their segmentation per flight, their ranking-priorities, and their given/determined importance-value. In the testing, this could be seen on the output *LOS Passenger* which shows for each considered airline the level of passengers' satisfaction with a decision made.

2. When it is about to make the choice between a monetary benefit and the retention of the reputation of a reliable service provider, the use of the designed tool affords *rather objective* instead the still occurring *intuitive* decision making in the disruption management. This is achieved by confronting the relevant decision drivers in a multi-criteria algorithm to be calculated and evaluated in the decision making process of the designed tool. In the testing done this could be displayed on the tool-output *LOS Airline*. The results obtained showed that the designed tool makes the best decision solution-choice for a particular airline by recommending the exactly this one solution

which aligns with the airline's prioritisation policy and determined importance values. The airline's LOS-attributes were asset in terms of their impact on passenger satisfactory level, providing primary inputs into the modelled situation.

3. The both playing decision factors, in this research being also the tool-outputs, the level of service (LOS) performed by the carrier and the one perceived by the high-fare passengers involved (i.e. from both flights considered), are displayed on the user interface on the 3-colour-bar. Aiming at affording much more awareness of the decision maker (operation controller) of the decision consequences, the DEVOTED DSS Tool supports making rather rational than the intuitive/spontaneous decisions.

4. Gaining much more control over appropriate responding to the service quality requirements of the passengers who are of the highest importance to the airline, not only the operation controllers, but also the airline management can take the benefits of the designed tool. This is enabled by giving a visual display of their computed satisfaction level that might be achieved by each decision solution taken for both cases: by following the tool-recommendation as well as by taking the opposite decision, while gaining a possibility to better handling the high-fare passengers. This may, on the other hand, increase yielding more of these passengers due to higher level of the service quality performed and a higher satisfaction level achieved by the premium passengers.

5. Displaying consequences of the decision solutions in the designed form is practical in terms of user-friendly utilization of a supporting tool and a simple and easy dealing with. The operation controllers are not overloaded with any numbers, costs or other similar data, while these have been calculated and evaluated beyond the user interface. The proposed support tool visualizes to the controller (i.e. decision maker) the final recommendation i.e. whether the particular decision leads the airline into the "green" or "red" field of the operation decision consequences (this in terms of the costs and its reliability).

Key advantage

On one hand, there are disruptive operational situations which require making decisions (in a timely manner) on whether to delay or not an outbound flight in order to wait for the delayed-arriving high-fare passengers. On the other hand, in the very little research literature it was argued how *most of airlines nowadays use some kind of rule-of-thumb when they are evaluating the impact of the decisions on passengers while others just assign a monetary cost to each minute of delay and evaluate the solutions taking this value* (Castro and Oliveira 2011, p. 10). Dedicated operation controllers to assist in handling with multi conflicting objectives when making this kind of decisions, the DEVOTED DSS Tool has been designed accurately to aim at solving this problem, resulting in enabling the airline operation controllers assessment of these important performance issues.

The two key model outputs, the level of service performed by the airline and the level of service perceived by the high-fare passengers, provide final information for the decision maker (the airline operation controller), aiming at an easier taking decisions on delays when caused by the arriving-late high-valuable passengers.

The results obtained can be statistically processed for the managerial matters in the airline businesses to be used for a better planning and/or scheduling. On the other hand, conducting statistical analysis of particularly this kind of decisions at the operations control centre aims at gaining more light into the somewhat grey zone of the decision making process of the disruption management of a frill airline.

The main scientific contribution of the doctoral thesis is in:

(1) Providing of a nearer insight into a for the research grey zone of the airlines' decision makings on disruptions caused by its highest-fare passengers,
(2) For the first time, the confrontation of the segmented high-fare passengers per flight and per cabin-class (or ticket purchased) for an evaluation while aiming at measuring the decision solutions and satisfactory level of these passengers, and
(3) Establishing of a LOS model for both, high-fare passengers and the airline, which is based on application of an extended approach to the Kano Model of quality.

Besides, the importance and impact of the high-fare passengers on decisions on delays of outbound flights have been explored in order to find out how much this importance can influence the airline's decisions and its level of service quality performance.

Directions for Future Research

Since not all aspects could be completed in one work, there is still more to know to fully understand the whole mechanism of decision making processes in examined disruptions in the airline all-day operation execution.

With some changes (e.g. priority rankings, importance-values, and occurring costs), the designed tool could be employed in any similar decision making process, where a choice should be made between monetary benefits/advantages and a performance of a promoted quality level for retaining the reputation of a reliable and serious service performer.

Excepting the closest target, the tool computer-programming for to be implemented in a scheduled airline for probations (i.e. for comparing the results of practically taken and the ones would have been recommended by the tool), there is a significant opportunity for further research and comprehensive knowledge on following topics in following areas:

(1) This designed tool could be employed also to the economy-cabin class passengers by excluding the VIPs and accordingly the very high importance value for these passengers. Thus the airlines would have all its cabin-class passengers confronted per in-bound and out-bound flights for the decision making purposes in disruptions;

(2) Taking the time-component into the modelling and evaluating process, the decision solutions and their consequences could be dynamically followed;

(3) Taking (more) actual delay costs occurring instead applied estimated/expected ones, the proposed tool could give more accurate and precise decision recommendations;

(4) Application of economic optimization-models or purposeful cost-models would enable the proposed tool to give more optimal solution-recommendations;

(5) With some adjustments for to be applied in the airport management, the tool could be employed in the decision making processes where the airport management has to decide which airlines shall be prioritized for being served in disruption situations.

Closing Words

This research succeeded not only in stressing the main decision drivers when such disruptive events occur, but also in putting them into the multi- and contradicting-criteria juxtaposition in the solving-algorithm of the designed tool.

Referring to the research questions and hypotheses set in this doctoral thesis the following has been achieved:

- Being not overloaded with nor digits and data or calculations, the designed tool is created on the human-centred-design basis. Therefore the operation controller will see only the final positions of both defined outputs positioned on one of the three coloured fields having so an easy and simple dealing with, which in turn, can minimize still commonly occurring intuitive making decisions.
- Using the designed tool in the decision making process of the disruption management, can aim the airline at improving an increased level of satisfying the Service Quality requirements of the passengers who are of the highest (financial) importance to the airline. On the other side, the usage of the proposed tool can aim at gaining increasing control over appropriate *responding to the SQ-requirements of the high-fare passengers and therewith their confidence and loyalty.*
- The airline management is enabled to analyze and optimize its planning and scheduling adjusting less optimal decisions i.e. flight connections to match the requirements and a higher satisfactory level of its highest-fare passengers, having available data generated and saved about such decisions made.

Herewith the research work succeeded in answering to the specified research questions and hypothesis.

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List of Abbreviations

AI	Airline Industry
AOCC	Airline Operation Control Center
ATC	Air Traffic Control
ATS	Air Traffic System
BUS	Business passenger
DOC	Direct Operational Cost
DSS	Decision Support System
FFP	Frequent Flyer Program
HCD	Human Centered Design
IATA	International Air Traffic Association
ICAO	International Civil Aviation Organisation
LCC	Low Cost Carrier
LOS	Level of Service
MCT	Minimum Connecting Time
OCC	Operation Control Center
Pax	Passenger
SQ	Service Quality
TOC	Total Operational Cost
VFR	Visiting Friends and Relatives
VOT	Value of Time

Annex

Annex A

- DEVOTED DSS Tool Output: 3-colour-bar

Annex B

- Single Testing Scenarios – Calculations and Results
  - Scenario 1
  - Scenario 1a
  - Scenario 2
  - Scenario 2a
  - Scenario 3
  - Scenario 3a
  - Scenario 4
  - Scenario 4a
  - Scenario 4b
  - Scenario 4c
  - Scenario 5
  - Scenario 5a

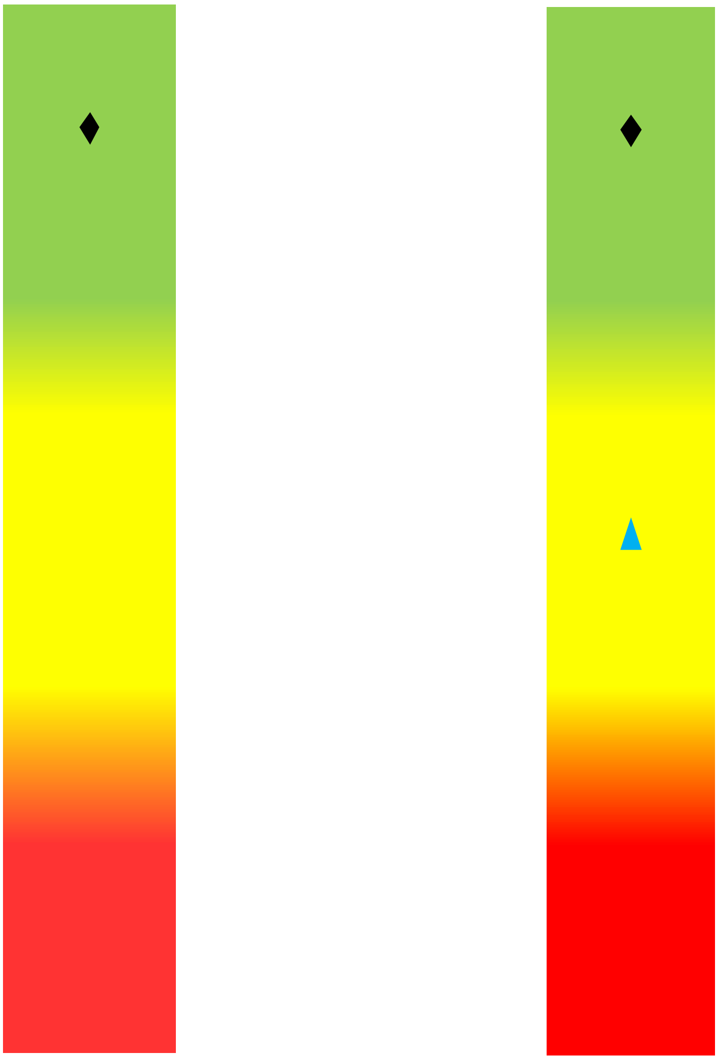
- Results Overview
  - Results: All Scenarios
  - Tool Algorithm-Paths taken for *Air1*
  - Tool Algorithm-Paths taken for *Air2*
  - Test Results for *Air1*
  - Test Results for *Air2*
  - Costs for *Air1*
  - Costs for *Air2*

- a-Zero ($\alpha_1 = 0{,}8$)
- Zero-Line single (0,8)
- a-Zero ($\alpha_1 = 0{,}45$)
- Zero-Line single (0,45)
- Zero-Line for both Passenger-Importance Value Sets
- Decision Zero-Line for *Air1*
- Decision Zero-Line for *Air2*

Annex C

- Example of the EU Regulation 261/2004 in practice

DEVOTED DSS Tool: 3-Colour-Bar



SCENARIO 1

ARRIVING FLIGHT			
Pax-Group I	**Pax-Number**	**Ticket Price**	**Ticket-Revenue**
VIPs	2	4.873 €	9.746,00 €
1. C	1	3.625 €	3.625,00 €
BUS+FFPs	16	2.500 €	40.000,00 €
Summe	**19**		**53.371,00 €**
DEPARTING FLIGHT			
Pax-Group II	**Pax-Number**	**Ticket Price**	**Ticket-Revenue**
VIPs	1	6.500 €	6.500,00 €
1. C	2	5.200 €	10.400,00 €
BUS+FFPs	63	3.590 €	226.170,00 €
Summe	**66**		**243.070,00 €**
m1 (Pax-Group II-1)			60
m2 (Pax-Group II-2)			6
m + n			**85**
ARRIVING + DEPARTING			
TP (all high-fare Paxs)			**296.441,00 €**
Value "y"			0,18
Value "z"			0,82
Eq.(13):			**-0,6399**

The *value of the passenger* **α**		
VIP-Pax	α1	0,8
1.C-Pax	α2	0,1184
BUS/FFPs-Pax	α3	0,0816
	α1+α2+α3=1	1

Eq.(8): **a =** **-0,0371** < 0

Air1: β1*a + β2*(y-z) = **-0,5796** < 0 --> DEVOTED DSS Tool recommends: **to not wait**

Air2: β1*a + β2*(y-z) = **-0,1577** < 0 --> DEVOTED DSS Tool recommends: **to not wait**

Decision Threshold-Value		Not available
For the value of APP1	**β1**	1,06
For the value of APP2	**β2**	-0,06

β1 = -(y-z)/(a-(y-z))

β2 = 1 - β1

SCENARIO 1
DEVOTED DSS Tool Recommendation

Follow the Tool-Recommendation
"TO NOT WAIT"

OR

Take the Opposite Decision
"TO WAIT"

Pax-Group I go the Recovery-Plan
Follow the Algorithm-Comp. 2

LOS Pax		
Pax-Group I	dissatisf.	14,25
Pax-Group II-1	satisf.	75
Pax-Group II-2	satisf.	7,5
Eq.(32) =		**1,1382**

LOS Airline	
ω (|Air1|)=	**1,4347**
ω (|Air2|)=	**1,1183**

Cost	
Cost (Air1)=	17.000,00 €
Cost (Air2)=	0,00 €

"Refused Pax"
Follow the Algorithm-Comp. 1

LOS Pax		
Pax-Group I	very dissatisf.	4,75
Pax-Group II-1	satisf.	60
Pax-Group II-2	satisf.	7,5
Eq.(32) =		**0,8500**

LOS Airline	
ω (|Air1|)=	**1,4347**
ω (|Air2|)=	**1,1183**

Cost	
Cost (Air1)=	81.956,50 €
Cost (Air2)=	81.956,50 €
Opport.Cost=	55.271,00 €
(TicketRevenue)ARR	53.371,00 €
(1/2 TR)ARR	26.685,50 €

Follow the Algorithm-Comp. 4

LOS Pax		
Pax-Group I	very stisf.	33,25
Pax-Group II-1	neutral	60
Pax-Group II-2	dissatisf.	4,5
Eq.(32) =		**1,1500**

LOS Airline	
ω (-|Air1|)=	**0,5653**
ω (-|Air2|)=	**0,8817**

Cost	
Cost (Air1)=	0,00 €
Cost (Air2)=	0,00 €

SCENARIO 1
The Tool-Output

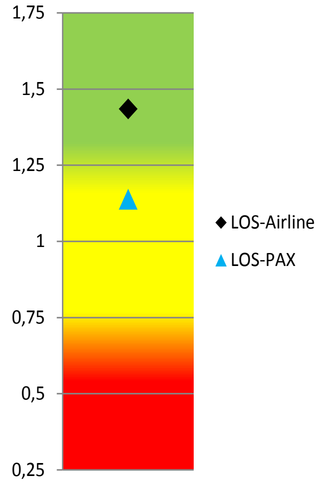
Follow the Tool-Recommendation
"TO NOT WAIT"

OR

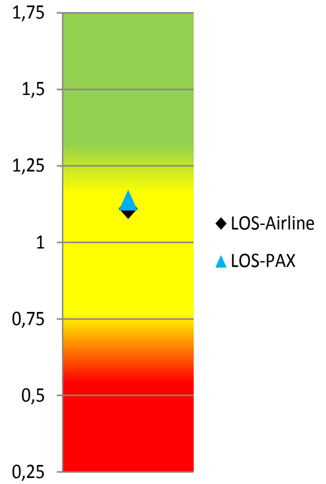
Take the Opposite Decision
"TO WAIT"

Pax-Recovery possible

Air1:

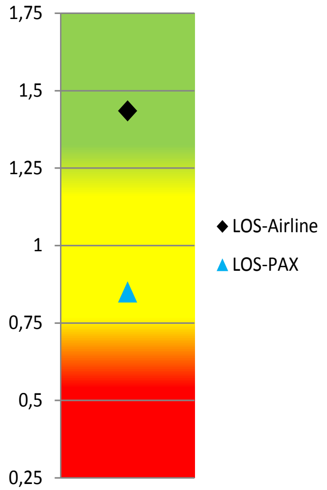


Air2:

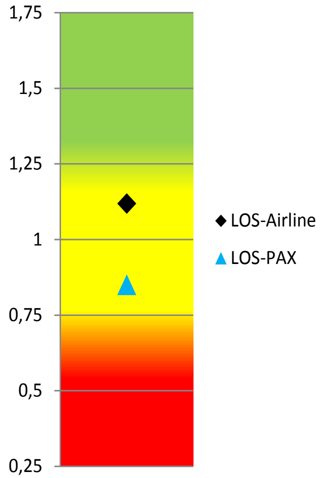


Pax-Recovery not possible

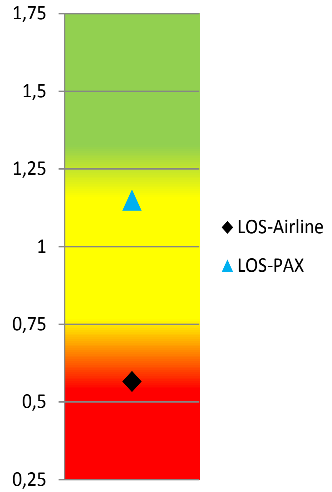
Air1:



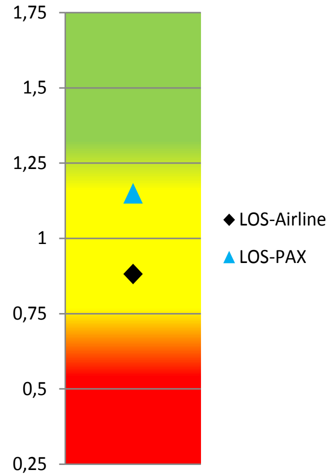
Air2:



Air1:



Air2:



SCENARIO 1a

ARRIVING FLIGHT			
Pax-Group I	**Pax-Number**	**Ticket Price**	**Ticket-Revenue**
VIPs	2	6.500 €	13.000,00 €
1. C	1	5.200 €	5.200,00 €
BUS+FFPs	16	3.590 €	57.440,00 €
Summe	**19**		**75.640,00 €**
DEPARTING FLIGHT			
Pax-Group II	**Pax-Number**	**Ticket Price**	**Ticket-Revenue**
VIPs	1	4.873 €	4.873,00 €
1. C	2	3.625 €	7.250,00 €
BUS+FFPs	63	2.500 €	157.500,00 €
Summe	**66**		**169.623,00 €**
m1 (Pax-Group II-1)			60
m2 (Pax-Group II-2)			6
m + n			**85**
ARRIVING + DEPARTING			
TP (all high-fare Paxs)			**245.263,00 €**
Value "y"			0,31
Value "z"			0,69
Eq.(13):			**-0,3832**

The *value of the passenger* **α**		
VIP-Pax	α1	0,8
1.C-Pax	α2	0,1184
BUS/FFPs-Pax	α3	0,0816
	α1+α2+α3=1	1

Eq.(8): **a** = **-0,0371** < 0

Air1: β1*a + β2*(y-z) = **-0,3486** < 0 --> DEVOTED DSS Tool recommends: **to not wait**

Air2: β1*a + β2*(y-z) = **-0,1063** < 0 --> DEVOTED DSS Tool recommends: **to not wait**

Decision Threshold-Value		Available
For the value of APP1	**β1**	0,91
For the value of APP2	**β2**	0,09

β1 = -(y-z)/(a-(y-z))

β2 = 1 - β1

SCENARIO 1a

DEVOTED DSS Tool Recommendation

Follow the Tool-Recommendation **"TO NOT WAIT"** — **OR** — **Take the Opposite Decision** **"TO WAIT"**

Pax-Group I go the Recovery-Plan
Follow the Algorithm-Comp. 2

LOS Pax		
Pax-Group I	dissatisf.	14,25
Pax-Group II-1	satisf.	75
Pax-Group II-2	satisf.	7,5
Eq.(32) =		**1,1382**

LOS Airline	
ω (|Air1|)=	**1,2615**
ω (|Air2|)=	**1,0797**

Cost	
Cost (Air1)=	17.000,00 €
Cots (Air2)=	0,00 €

"Refused Pax"
Follow the Algorithm-Comp. 1

LOS Pax		
Pax-Group I	very dissatisf.	4,75
Pax-Group II-1	satisf.	60
Pax-Group II-2	satisf.	7,5
Eq.(32) =		**0,8500**

LOS Airline	
ω (|Air1|)=	**1,2615**
ω (|Air2|)=	**1,0797**

Cost	
Cost (Air1)=	122.960,00 €
Cost (Air2)=	122.960,00 €
Opport.Cost=	85.140,00 €
$(\text{TicketRevenue})_{ARR}$	75.640,00 €
$(1/2\ \text{TR})_{ARR}$	37.820,00 €

Follow the Algorithm-Comp. 4

LOS Pax		
Pax-Group I	very stisf.	33,25
Pax-Group II-1	neutral	60
Pax-Group II-2	dissatisf.	4,5
Eq.(32) =		**1,1500**

LOS Airline	
ω (-|Air1|)=	**0,7386**
ω (-|Air2|)=	**0,9203**

Cost	
Cost (Air1)=	0,00 €
Cost (Air2)=	0,00 €

SCENARIO 1a
The Tool-Output

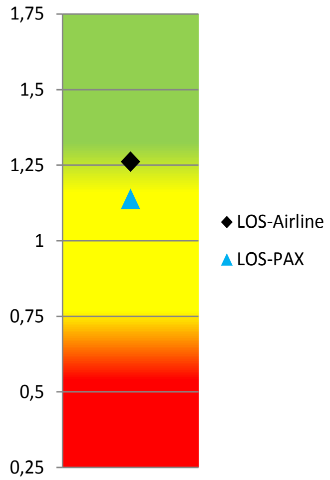
Follow the Tool-Recommendation
"TO NOT WAIT"

OR

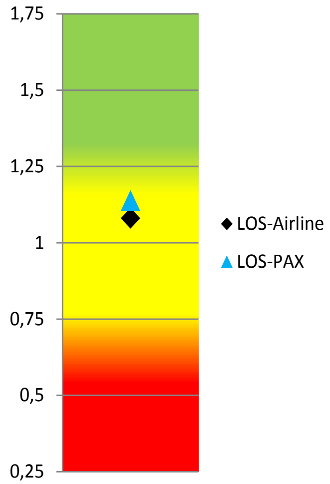
Take the Opposite Decision
"TO WAIT"

Pax-Recovery possible

Air1:

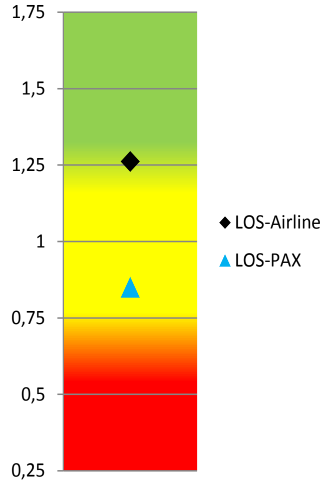


Air2:

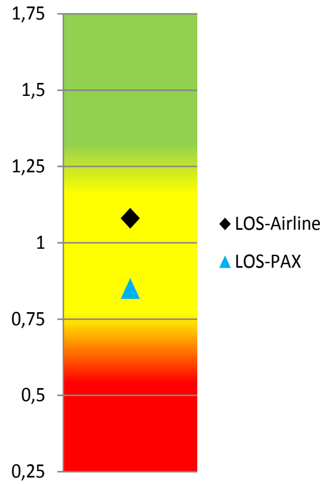


Pax-Recovery not possible

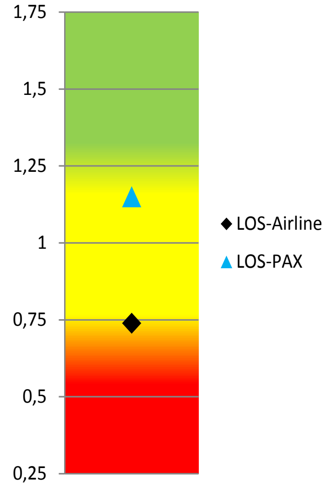
Air1:



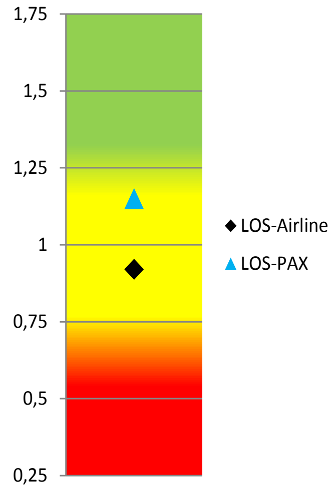
Air2:



Air1:



Air2:



SCENARIO 2

ARRIVING FLIGHT			
Pax-Group I	**Pax-Number**	**Ticket Price**	**Ticket-Revenue**
VIPs	2	4.873 €	9.746,00 €
1. C	1	3.625 €	3.625,00 €
BUS+FFPs	16	2.500 €	40.000,00 €
Summe	**19**		**53.371,00 €**
DEPARTING FLIGHT			
Pax-Group II	**Pax-Number**	**Ticket Price**	**Ticket-Revenue**
VIPs	1	6.500 €	6.500,00 €
1. C	2	5.200 €	10.400,00 €
BUS+FFPs	63	3.590 €	226.170,00 €
Summe	**66**		**243.070,00 €**
m1 (Pax-Group II-1)			60
m2 (Pax-Group II-2)			6
m + n			**85**
ARRIVING + DEPARTING			
TP (all high-fare Paxs)			**296.441,00 €**
Value "y"			0,18
Value "z"			0,82
Eq.(14):			**-0,6399**

The *value of the passenger* **α**		
VIP-Pax	**α1**	0,448
1.C-Pax	**α2**	0,352
BUS/FFPs-Pax	**α3**	0,2
	α1+α2+α3=1	1

Eq.(9): **a =** **-0,1095** < 0

Air1: β1*a + β2*(y-z) = **-0,5869** < 0 --> DEVOTED DSS Tool recommends: **to not wait**

Air2: β1*a + β2*(y-z) = **-0,2156** < 0 --> DEVOTED DSS Tool recommends: **to not wait**

Decision Threshold-Value		Not Available
For the value of APP1	**β1**	1,21
For the value of APP2	**β2**	-0,21

β1 = -(y-z)/(a-(y-z))

β2 = 1 - β1

SCENARIO 2
DEVOTED DSS Tool Recommendation

Follow the Tool-Recommendation "TO NOT WAIT"

OR

Take the Opposite Decision "TO WAIT"

Pax-Group I go the Recovery-Plan
Follow the Algorithm-Comp. 2

LOS Pax		
Pax-Group I	dissatisf.	14,25
Pax-Group II-1	satisf.	75
Pax-Group II-2	satisf.	7,5
Eq.(32) =		**1,1382**

LOS Airline	
ω (|Air1|)=	**1,4402**
ω (|Air2|)=	**1,1617**

Cost	
Cost(Air1)=	17.000,00 €
Cost(Air2)=	0,00 €

"Refused Pax"
Follow the Algorithm-Comp. 1

LOS Pax		
Pax-Group I	very dissatisf.	4,75
Pax-Group II-1	satisf.	60
Pax-Group II-2	satisf.	7,5
Eq.(32) =		**0,8500**

LOS Airline	
ω (|Air1|)=	**1,4402**
ω (|Air2|)=	**1,1617**

Cost	
Cost(Air1)=	89.556,50 €
Cost(Air2)=	89.556,50 €
Opport.Cost=	62.871,00 €
(TicketRevenue)ARR	53.371,00 €
(1/2 TR)ARR	26.685,50 €
TP (all high-fare Paxs)	296.441,00 €

Follow the Algorithm-Comp. 4

LOS Pax		
Pax-Group I	very stisf.	33,25
Pax-Group II-1	neutral	60
Pax-Group II-2	dissatisf.	4,5
Eq.(32) =		**1,1500**

LOS Airline	
ω (-|Air1|)=	**0,5598**
ω (-|Air2|)=	**0,8383**

Cost	
Cost(Air1)=	0,00 €
Cost(Air2)=	0,00 €

SCENARIO 2
The Tool-Output

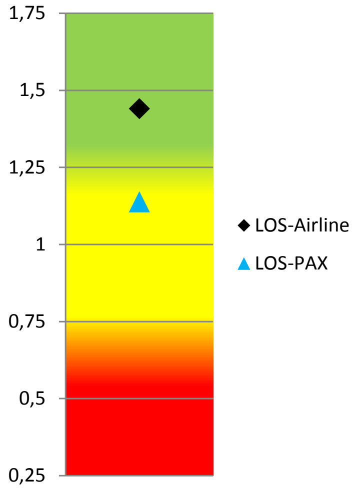
Follow the Tool-Recommendation
"TO NOT WAIT"

OR

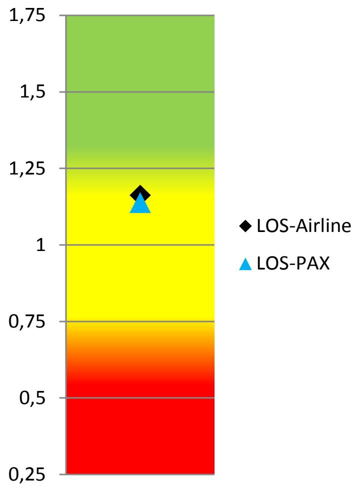
Take the Opposite Decision
"TO WAIT"

Pax Recovery possible

Air1:

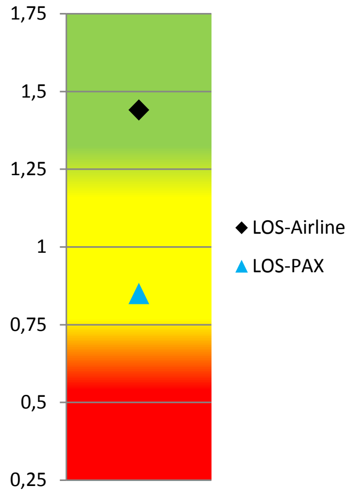


Air2:

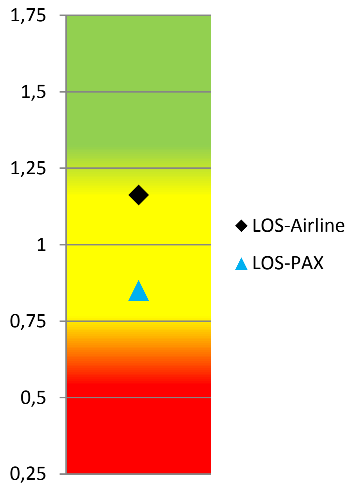


Pax-Recovery not possible

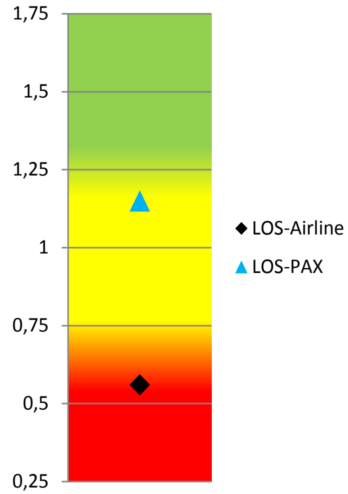
Air1:



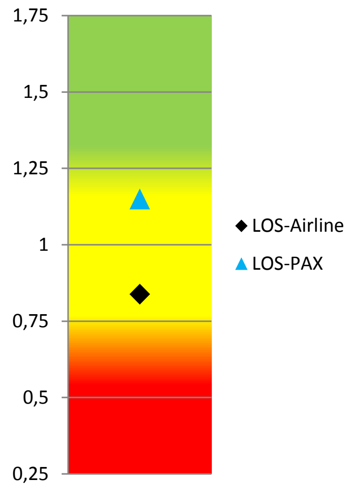
Air2:



Air1:



Air2:



SCENARIO 2a

ARRIVING FLIGHT			
Pax-Group I	**Pax-Number**	**Ticket Price**	**Ticket-Revenue**
VIPs	2	6.500 €	13.000,00 €
1. C	1	5.200 €	5.200,00 €
BUS+FFPs	16	3.590 €	57.440,00 €
Summe	**19**		**75.640,00 €**
DEPARTING FLIGHT			
Pax-Group II	**Pax-Number**	**Ticket Price**	**Ticket-Revenue**
VIPs	1	4.873 €	4.873,00 €
1. C	2	3.625 €	7.250,00 €
BUS+FFPs	63	2.500 €	157.500,00 €
Summe	**66**		**169.623,00 €**
m1 (Pax-Group II-1)			60
m2 (Pax-Group II-2)			6
m + n			**85**
ARRIVING + DEPARTING			
TP (all high-fare Paxs)			**245.263,00 €**
Value "y"			0,31
Value "z"			0,69
Eq.(14):			**-0,3832**

The *value of the passenger* **α**		
VIP-Pax	**α1**	0,448
1.C-Pax	**α2**	0,352
BUS/FFPs-Pax	**α3**	0,2
	α1+α2+α3=1	1

Eq.(9): **a =** **-0,1095** < 0

Air1: β1*a + β2*(y-z) = **-0,3558** < 0 --> DEVOTED DSS Tool recommends: **to not wait**

Air2: β1*a + β2*(y-z) = **-0,1642** < 0 --> DEVOTED DSS Tool recommends: **to not wait**

Decision Threshold-Value		Not Available
For the value of APP1	**β1**	1,40
For the value of APP2	**β2**	-0,40

β1 = -(y-z)/(a-(y-z))

β2 = 1 - β1

SCENARIO 2a

DEVOTED DSS Tool Recommendation

Follow the Tool-Recommendation — **"TO NOT WAIT"**

OR

Take the Opposite Decision — **"TO WAIT"**

Follow the Tool-Recommendation "TO NOT WAIT"

Pax-Group I go the Recovery-Plan
Follow the Algorithm-Comp. 2

LOS Pax		
Pax-Group I	dissatisf.	14,25
Pax-Group II-1	satisf.	75
Pax-Group II-2	satisf.	7,5
Eq.(32) =		**1,1382**

LOS Airline	
ω (|Air1|)=	**1,2669**
ω (|Air2|)=	**1,1232**

Cost	
Cost(Air1)=	17.000,00 €
Cost(Air2)=	0,00 €

"Refused Pax"
Follow the Algorithm-Comp. 1

LOS Pax		
Pax-Group I	very dissatisf.	4,75
Pax-Group II-1	satisf.	60
Pax-Group II-2	satisf.	7,5
Eq.(32) =		**0,8500**

LOS Airline	
ω (|Air1|)=	**1,2669**
ω (|Air2|)=	**1,1232**

Cost	
Cost(Air1)=	122.960,00 €
Cost(Air2)=	122.960,00 €
Opport. Cost=	85.140,00 €
(TicketRevenue)ARR	75.640,00 €
(1/2 TR)ARR	37.820,00 €
TR (all high-fare Paxs)	245.263,00 €

Take the Opposite Decision "TO WAIT"

Follow the Algorithm-Comp. 4

LOS Pax		
Pax-Group I	very stisf.	33,25
Pax-Group II-1	neutral	60
Pax-Group II-2	dissatisf.	4,5
Eq.(32) =		**1,1500**

LOS Airline	
ω (-|Air1|)=	**0,7332**
ω (-|Air2|)=	**0,8769**

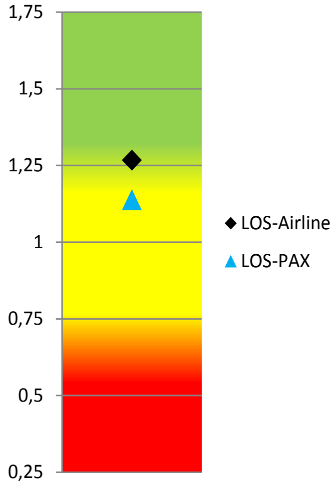
Cost	
Cost(Air1)=	0,00 €
Cost(Air2)=	0,00 €

SCENARIO 2a
The Tool-Output

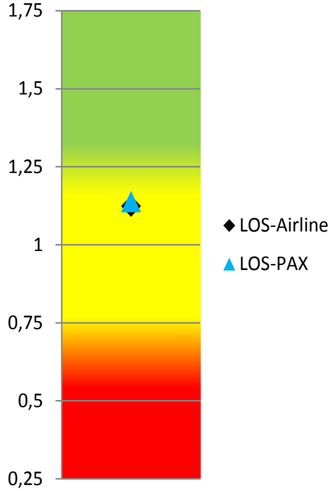
Follow the Tool-Recommendation "TO NOT WAIT" | **OR** | **Take the Opposite Decision "TO WAIT"**

Pax Recovery possible

Air1:

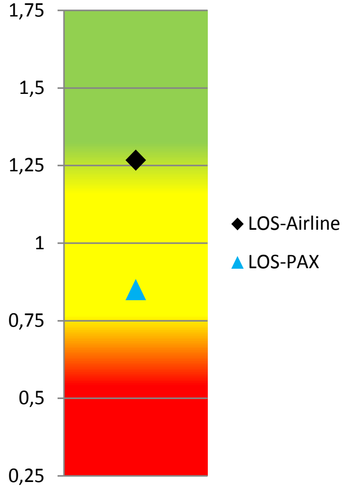


Air2:

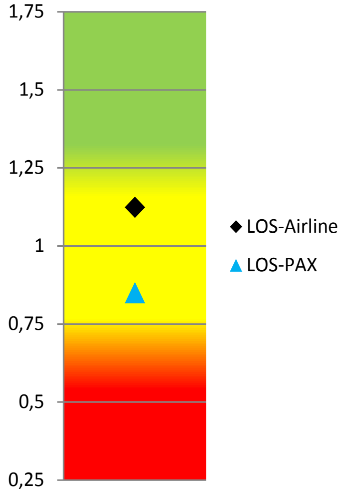


Pax-Recovery not possible

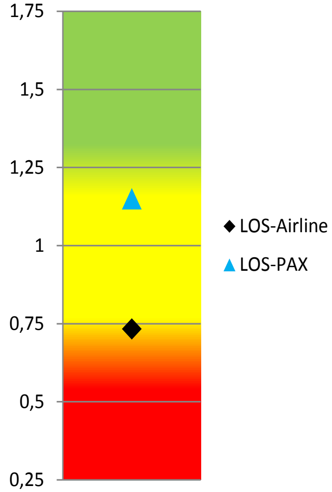
Air1:



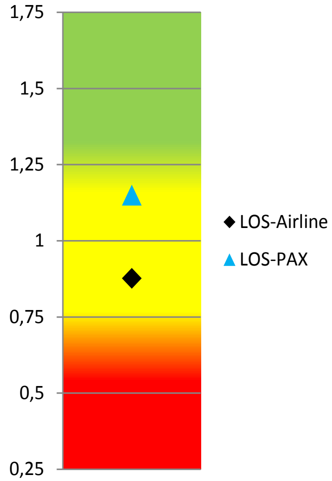
Air2:



Air1:



Air2:



SCENARIO 3

ARRIVING FLIGHT			
Pax-Group I	**Pax-Number**	**Ticket Price**	**Ticket-Revenue**
VIPs	1	4.873 €	4.873,00 €
1. C	4	3.625 €	14.500,00 €
BUS+FFPs	65	2.500 €	162.500,00 €
Summe	**70**		**181.873,00 €**
DEPARTING FLIGHT			
Pax-Group II	**Pax-Number**	**Ticket Price**	**Ticket-Revenue**
VIPs	1	6.500 €	6.500,00 €
1. C	7	5.200 €	36.400,00 €
BUS+FFPs	55	3.590 €	197.450,00 €
Summe	**63**		**240.350,00 €**
m1 (Pax-Group II-1)			53
m2 (Pax-Group II-2)			10
m + n			**133**
ARRIVING + DEPARTING			
TP (all high-fare Paxs)			**422.223,00 €**
Value "y"			0,43
Value "z"			0,57
Eq.(14):			**-0,1385**

The *value of the passenger* **α**		
VIP-Pax	**α1**	0,8
1.C-Pax	**α2**	0,1184
BUS/FFPs-Pax	**α3**	0,0816
	α1+α2+α3=1	1

Eq.(9): **a =** **0,0035**

Air1: β1*a + β2*(y-z) = **-0,1243** < 0 --> DEVOTED DSS Tool recommends: **to not wait**

Air2: β1*a + β2*(y-z) = **-0,0249** < 0 --> DEVOTED DSS Tool recommends: **to not wait**

Decision Threshold-Value		Not available
For the value of APP1	**β1**	1,01
For the value of APP2	**β2**	-0,01

$\beta 1 = -(y-z)/(a-(y-z))$

$\beta 2 = 1 - \beta 1$

SCENARIO 3
DEVOTED DSS Tool Recommendation

Follow the Tool-Recommendation **"TO NOT WAIT"** OR **Take the Opposite Decision** **"TO WAIT"**

Follow the Tool-Recommendation — "TO NOT WAIT"

Pax-Group I go the Recovery-Plan
Follow the Algorithm-Comp. 2

LOS Pax		
Pax-Group I	dissatisf.	52,5
Pax-Group II-1	satisf.	66,25
Pax-Group II-2	satisf.	12,5
Eq.(32) =		**0,9868**

LOS Airline	
ω (|Air1|)=	**1,0932**
ω (|Air2|)=	**1,0187**

Cost	
Cost(Air1)=	17.000,00 €
Cost(Air2)=	0,00 €

"Refused Pax"
Follow the Algorithm-Comp. 1

LOS Pax		
Pax-Group I	very dissatisf.	17,5
Pax-Group II-1	satisf.	66,25
Pax-Group II-2	satisf.	12,5
Eq.(32) =		**0,7237**

LOS Airline	
ω (|Air1|)=	**1,0932**
ω (|Air2|)=	**1,0187**

Cost	
Cost(Air1)=	307.809,50 €
Cost(Air2)=	307.809,50 €
Opport.Cost=	216.873,00 €
(TicketRevenue)ARR	181.873,00 €
(1/2 TR)ARR	90.936,50 €
TR (all high-fare Paxs)	422.223,00 €

Take the Opposite Decision — "TO WAIT"

Follow the Algorithm-Comp. 4

LOS Pax		
Pax-Group I	very stisf.	122,5
Pax-Group II-1	neutral	53
Pax-Group II-2	dissatisf.	7,5
Eq.(32) =		**1,3759**

LOS Airline	
ω (-|Air1|)=	**0,9068**
ω (-|Air2|)=	**0,9813**

Cost	
Cost(Air1)=	0,00 €
Cost(Air2)=	0,00 €

SCENARIO 3
The Tool-Output

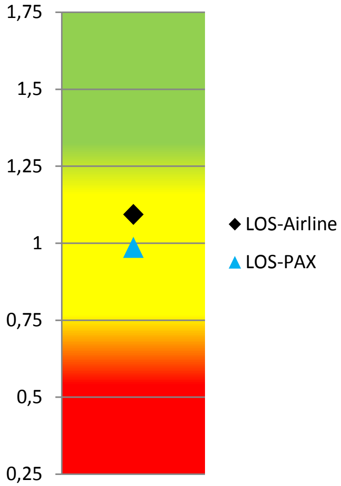
Follow the Tool-Recommendation
"TO NOT WAIT"

OR

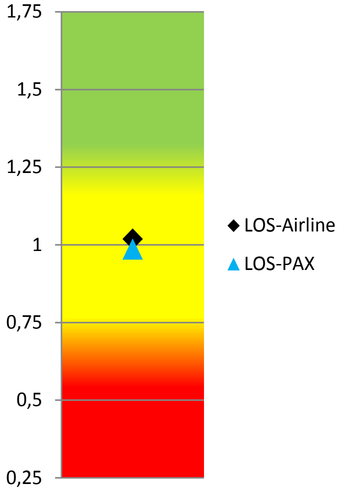
Take the Opposite Decision
"TO WAIT"

Pax-Recovery possible

Air1:

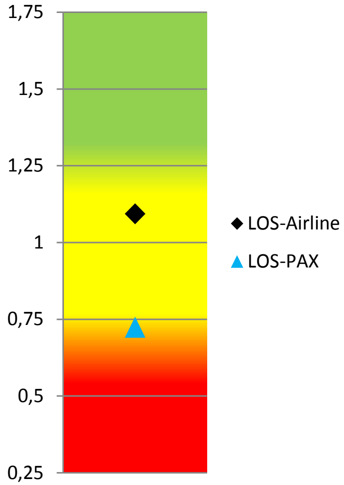


Air2:

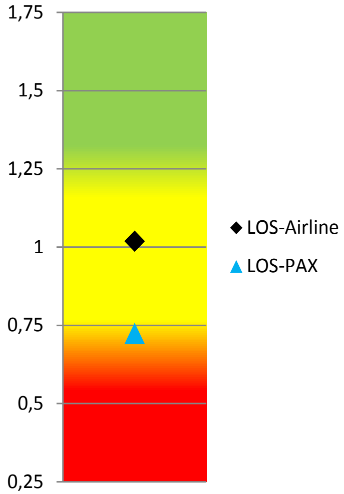


Pax-Recovery not possible

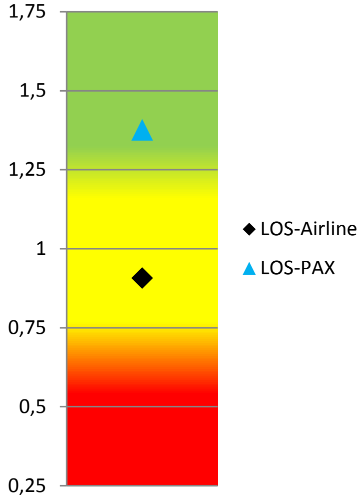
Air1:



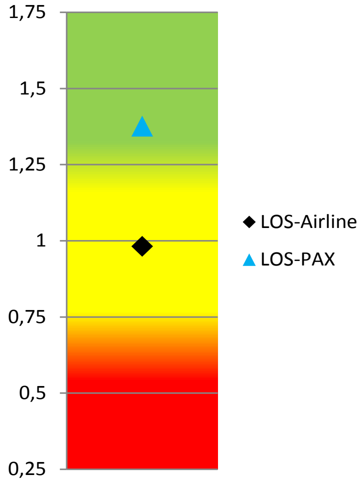
Air2:



Air1:



Air2:



SCENARIO 3a

ARRIVING FLIGHT			
Pax-Group I	**Pax-Number**	**Ticket Price**	**Ticket-Revenue**
VIPs	1	6.500 €	6.500,00 €
1. C	4	5.200 €	20.800,00 €
BUS+FFPs	65	3.590 €	233.350,00 €
Summe	**70**		**260.650,00 €**
DEPARTING FLIGHT			
Pax-Group II	**Pax-Number**	**Ticket Price**	**Ticket-Revenue**
VIPs	1	4.873 €	4.873,00 €
1. C	7	3.625 €	25.375,00 €
BUS+FFPs	55	2.500 €	137.500,00 €
Summe	**63**		**167.748,00 €**
m1 (Pax-Group II-1)			53
m2 (Pax-Group II-2)			10
m + n			**133**
ARRIVING + DEPARTING			
TP (all high-fare Paxs)			**428.398,00 €**
Value "y"			0,61
Value "z"			0,39
Eq.(14):			**0,2169**

The *value of the passenger* **α**		
VIP-Pax	**α1**	0,8
1.C-Pax	**α2**	0,1184
BUS/FFPs-Pax	**α3**	0,0816
	α1+**α2**+**α3**=1	1

Eq.(9): **a =** **0,0035**

Air1: β1*a + β2*(y-z) = **0,1955** > 0 --> DEVOTED DSS Tool recommends: **to wait**

Air2: β1*a + β2*(y-z) = **0,0461** > 0 --> DEVOTED DSS Tool recommends: **to wait**

Decision Threshold-Value		Not available
For the value of APP1	**β1**	1,02
For the value of APP2	**β2**	-0,02

β1 = -(y-z)/(a-(y-z))

β2 = 1 - β1

SCENARIO 3a
DEVOTED DSS Tool Recommendation

: Tool-Recommendation **"TO WAIT"** — **OR** — **Take the Opposite Decision** **"TO NOT WAIT"**

Tool-Recommendation "TO WAIT"

Follow the Algorithm-Comp. 3

LOS Pax		
Pax-Group I	very satisf.	122,5
Pax-Group II-1	neutr.	53
Pax-Group II-2	dissatisf.	7,5
Eq.(32) =		**1,3759**

LOS Airline	
ω (|Air1|)=	**1,1496**
ω (|Air2|)=	**1,0346**

Cost	
Cost(Air1)=	0,00 €
Cost(Air2)=	0,00 €

Take the Opposite Decision "TO NOT WAIT"

Pax-Group I go the Recovery-Plan
Follow the Algorithm-Comp. 2

LOS Pax		
Pax-Group I	dissatisf.	52,5
Pax-Group II-1	satisf.	66,25
Pax-Group II-2	satisf.	12,5
Eq.(32) =		**0,9868**

LOS Airline	
ω (-|Air1|)=	**0,8504**
ω (-|Air2|)=	**0,9654**

Cost	
Cost(Air1)=	17.000,00 €
Cost(Air2)=	0,00 €

"Refused Pax"
Follow the Algorithm-Comp. 1

LOS Pax		
Pax-Group I	very dissatisf.	17,5
Pax-Group II-1	satisf.	66,25
Pax-Group II-2	satisf.	12,5
Eq.(32) =		**0,7237**

LOS Airline	
ω (-|Air1|)=	**0,8504**
ω (-|Air2|)=	**0,9654**

Cost	
Cost(Air1)=	425.975,00 €
Cost(Air2)=	425.975,00 €
Opport.Cost=	295.650,00 €
$(\text{TicketRevenue})_{ARR}$	260.650,00 €
$(1/2\ \text{TR})_{ARR}$	130.325,00 €
TR (all high-fare Paxs)	428.398,00 €

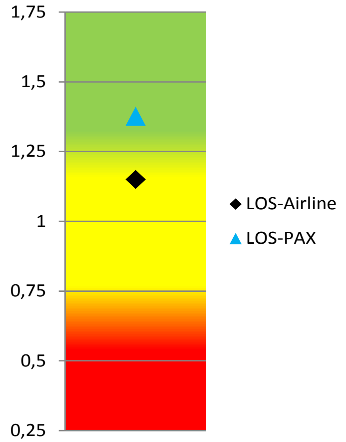
SCENARIO 3a
The Tool-Output

Follow the Tool-Recommendation
"TO WAIT"

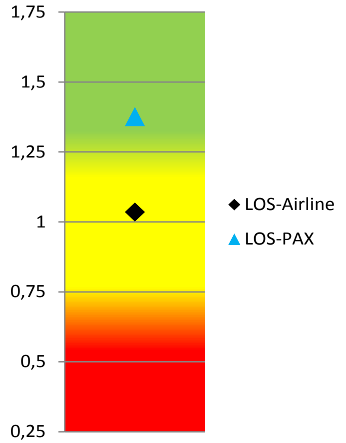
OR

Take the Opposite Decision
"TO NOT WAIT"

Air1:

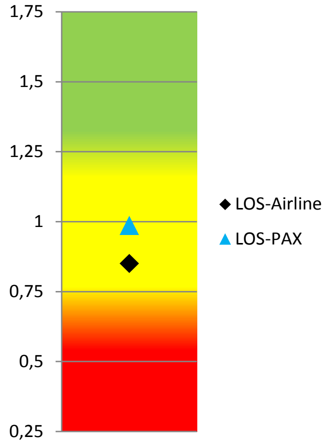


Air2:

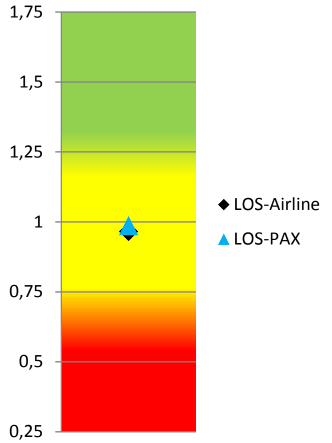


Pax-Recovery possible

Air1:

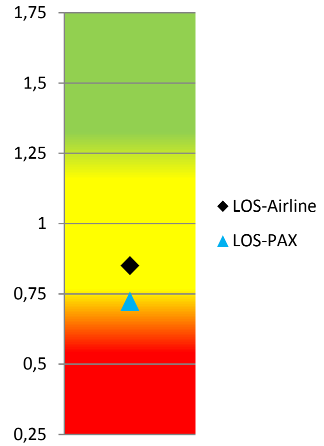


Air2:

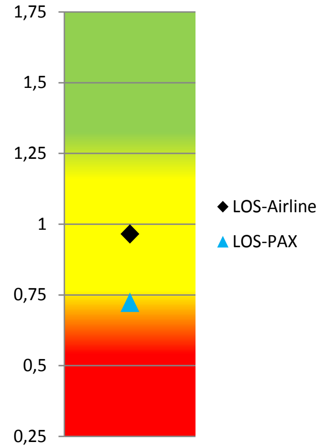


Pax-Recovery not possible

Air1:



Air2:



SCENARIO 4

ARRIVING FLIGHT			
Pax-Group I	**Pax-Number**	**Ticket Price**	**Ticket-Revenue**
VIPs	1	4.873 €	4.873,00 €
1. C	4	3.625 €	14.500,00 €
BUS+FFPs	65	2.500 €	162.500,00 €
Summe	**70**		**181.873,00 €**
DEPARTING FLIGHT			
Pax-Group II	**Pax-Number**	**Ticket Price**	**Ticket-Revenue**
VIPs	1	6.500 €	6.500,00 €
1. C	7	5.200 €	36.400,00 €
BUS+FFPs	55	3.590 €	197.450,00 €
Summe	**63**		**240.350,00 €**
m1 (Pax-Group II-1)			53
m2 (Pax-Group II-2)			10
m + n			**133**
ARRIVING + DEPARTING			
TP (all high-fare Paxs)			**422.223,00 €**
Value "y"			0,43
Value "z"			0,57
Eq.(14):			**-0,1385**

The *value of the passenger* **α**		
VIP-Pax	**α1**	0,448
1.C-Pax	**α2**	0,352
BUS/FFPs-Pax	**α3**	0,2
	α1+α2+α3=1	1

Eq.(9): **a =** **0,0071** > 0

Air1: β1*a + β2*(y-z) = **-0,1239** < 0 --> DEVOTED DSS Tool recommends: **to not wait**

Air2: β1*a + β2*(y-z) = **-0,0220** < 0 --> DEVOTED DSS Tool recommends: **to not wait**

Decision Threshold-Value		Available
For the value of APP1	**β1**	0,95
For the value of APP2	**β2**	0,05

β1 = -(y-z)/(a-(y-z))

β2 = 1 - β1

SCENARIO 4
DEVOTED DSS Tool Recommendation

Follow the Tool-Recommendation
"TO NOT WAIT"

OR

Take the Opposite Decision
"TO WAIT"

Pax-Group I go the Recovery-Plan
Follow the Algorithm-Comp. 2

LOS Pax		
Pax-Group I	dissatisf.	52,5
Pax-Group II-1	satisf.	66,25
Pax-Group II-2	satisf.	12,5
Eq.(32) =		**0,99**

LOS Airline	
ω (|Air1|)=	**1,09**
ω (|Air2|)=	**1,02**

Cost	
Cost(Air1)=	17.000,00 €
Cost(Air2)=	0,00 €

"Refused Pax"
Follow the Algorithm-Comp. 1

LOS Pax		
Pax-Group I	very dissatisf.	17,5
Pax-Group II-1	satisf.	66,25
Pax-Group II-2	satisf.	12,5
Eq.(32) =		**0,72**

LOS Airline	
ω (|Air1|)=	**1,09**
ω (|Air2|)=	**1,02**

Cost	
Cost(Air1)=	307.809,50
Cost(Air2)=	307.809,50
Opport.Cost=	216.873,00
(TicketRevenue)ARR	181.873,00 €
(1/2 TR)ARR	90.936,50 €
TP (all high-fare Paxs)	422.223,00 €

Follow the Algorithm-Comp. 4

LOS Pax		
Pax-Group I	very stisf.	122,5
Pax-Group II-1	neutral	53
Pax-Group II-2	dissatisf.	7,5
Eq.(32) =		**1,38**

LOS Airline	
ω (-|Air1|)=	**0,91**
ω (-|Air2|)=	**0,99**

Cost	
Cost(Air1)=	0,00 €
Cost(Air2)=	0,00 €

SCENARIO 4
The Tool-Output

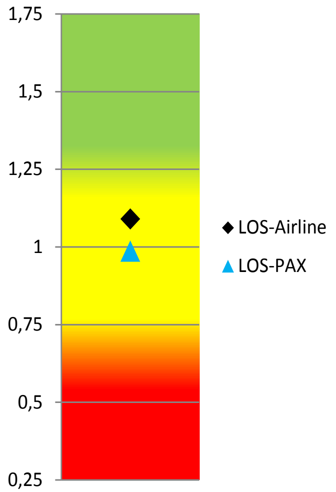
Follow the Tool-Recommendation
"TO NOT WAIT"

OR

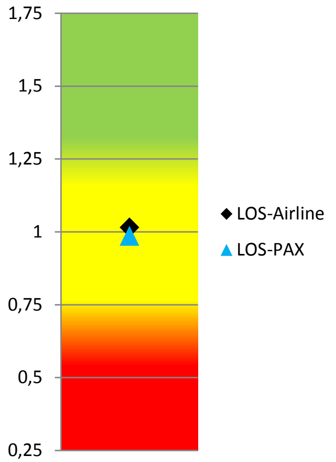
Take the Opposite Decision
"TO WAIT"

Pax-Recovery possible

Air1:

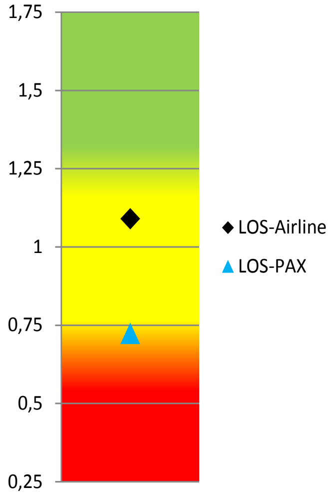


Air2:

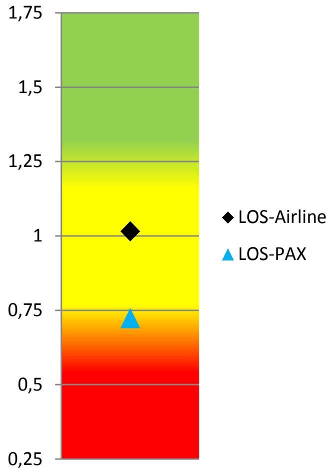


Pax-Recovery not possible

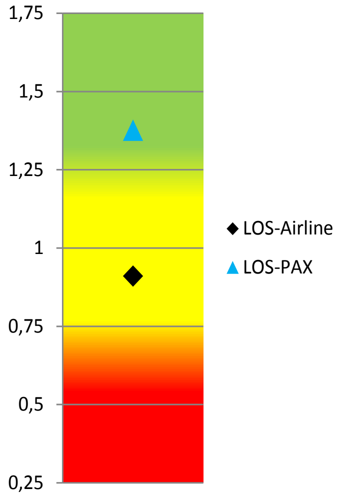
Air1:



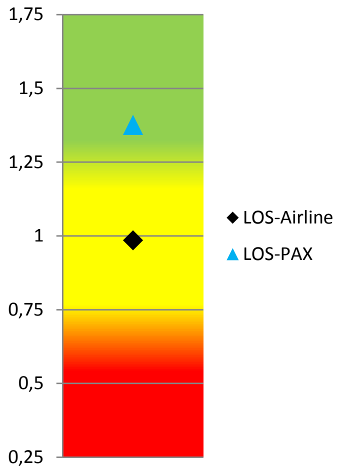
Air2:



Air1:



Air2:



SCENARIO 4a

ARRIVING FLIGHT			
Pax-Group I	**Pax-Number**	**Ticket Price**	**Ticket-Revenue**
VIPs	1	6.500 €	6.500,00 €
1. C	4	5.200 €	20.800,00 €
BUS+FFPs	65	3.590 €	233.350,00 €
Summe	**70**		**260.650,00 €**
DEPARTING FLIGHT			
Pax-Group II	**Pax-Number**	**Ticket Price**	**Ticket-Revenue**
VIPs	1	4.873 €	4.873,00 €
1. C	7	3.625 €	25.375,00 €
BUS+FFPs	55	2.500 €	137.500,00 €
Summe	**63**		**167.748,00 €**
m1 (Pax-Group II-1)			53
m2 (Pax-Group II-2)			10
m + n			**133**
ARRIVING + DEPARTING			
TP (all high-fare Paxs)			**428.398,00 €**
Value "y"			0,61
Value "z"			0,39
Eq.(14):			**0,2169**

The *value of the passenger* **α**		
VIP-Pax	**α1**	0,448
1.C-Pax	**α2**	0,352
BUS/FFPs-Pax	**α3**	0,2
	α1+**α2**+**α3**=1	1

Eq.(9): **a =** **0,0071** > 0

Air1: β1*a + β2*(y-z) = **0,1959** < 0 --> DEVOTED DSS Tool recommends: **to wait**

Air2: β1*a + β2*(y-z) = **0,0491** < 0 --> DEVOTED DSS Tool recommends: **to wait**

Decision Threshold-Value		Not available
For the value of APP1	**β1**	1,02
For the value of APP2	**β2**	-0,02

β1 = -(y-z)/(a-(y-z))

β2 = 1 - β1

SCENARIO 4a
DEVOTED DSS Tool Recommendation

Follow the Tool-Recommendation
"TO WAIT"

OR

Take the Opposite Decision
"TO NOT WAIT"

Follow the Tool-Recommendation "TO WAIT"

Follow the Algorithm-Comp. 3

LOS Pax		
Pax-Group I	very satisf.	122,5
Pax-Group II-1	neutr.	53
Pax-Group II-2	dissatisf.	7,5
Eq.(32) =		**1,38**

LOS Airline	
ω (|Air1|)=	**1,15**
ω (|Air2|)=	**1,04**

Cost	
Cost(Air1)=	0,00 €
Cost(Air2)=	0,00 €

Take the Opposite Decision "TO NOT WAIT"

Pax-Group I go the Recovery-Plan
Follow the Algorithm-Comp. 2

LOS Pax		
Pax-Group I	dissatisf.	52,5
Pax-Group II-1	satisf.	66,25
Pax-Group II-2	satisf.	12,5
Eq.(32) =		**0,99**

LOS Airline	
ω (-|Air1|)=	**0,85**
ω (-|Air2|)=	**0,96**

Cost	
Cost(Air1)=	17.000,00 €
Cost(Air2)=	0,00 €

"Refused Pax"
Follow the Algorithm-Comp. 1

LOS Pax		
Pax-Group I	very dissatisf.	17,5
Pax-Group II-1	satisf.	66,25
Pax-Group II-2	satisf.	12,5
Eq.(32) =		**0,72**

LOS Airline	
ω (-|Air1|)=	**0,85**
ω (-|Air2|)=	**0,96**

Cost	
Cost(Air1)=	425.975,00 €
Cost(Air2)=	425.975,00 €
Opport.Cost=	295.650,00 €
(TicketRevenue)ARR	260.650,00 €
(1/2 TR)ARR	130.325,00 €
TP (all high-fare Paxs)	428.398,00 €

SCENARIO 4a
The Tool-Output

Follow the Tool-Recommendation
"TO WAIT"

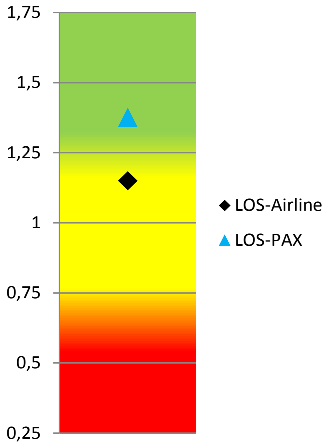
OR

Take the Opposite Decision
"TO NOT WAIT"

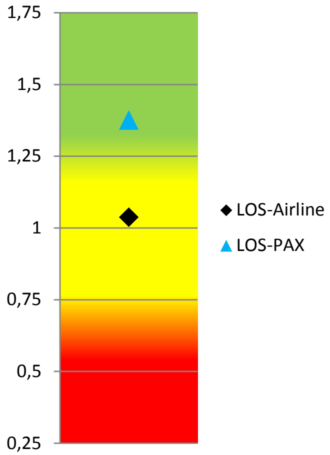
Pax-Recovery possible | **Pax-Recovery not possible**

Follow the Tool-Recommendation "TO WAIT"

Air1:

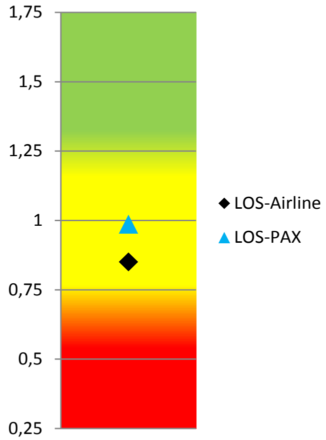


Air2:

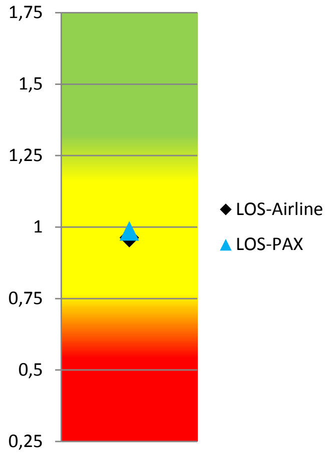


Take the Opposite Decision "TO NOT WAIT" – Pax-Recovery possible

Air1:

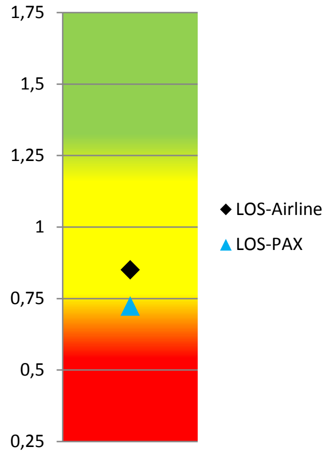


Air2:

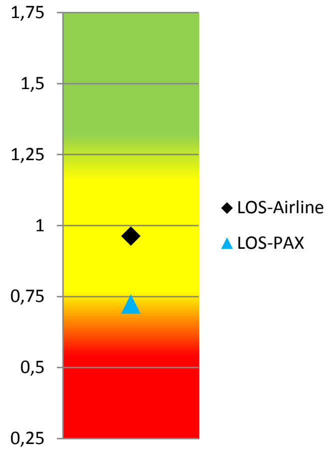


Take the Opposite Decision "TO NOT WAIT" – Pax-Recovery not possible

Air1:



Air2:



SCENARIO 4b

ARRIVING FLIGHT			
Pax-Group I	**Pax-Number**	**Ticket Price**	**Ticket-Revenue**
VIPs	1	4.873 €	4.873,00 €
1. C	4	3.625 €	14.500,00 €
BUS+FFPs	65	2.500 €	162.500,00 €
Summe	**70**		**181.873,00 €**
DEPARTING FLIGHT			
Pax-Group II	**Pax-Number**	**Ticket Price**	**Ticket-Revenue**
VIPs	1	6.500 €	6.500,00 €
1. C	7	5.200 €	36.400,00 €
BUS+FFPs	55	3.590 €	197.450,00 €
Summe	**63**		**240.350,00 €**
m1 (Pax-Group II-1)			**10**
m2 (Pax-Group II-2)			**53**
m + n			**133**
ARRIVING + DEPARTING			
TP (all high-fare Paxs)			**422.223,00 €**
Value "y"			0,43
Value "z"			0,57
Eq.(14):			**-0,1385**

The *value of the passenger* **α**		
VIP-Pax	α1	0,448
1.C-Pax	α2	0,352
BUS/FFPs-Pax	α3	0,2
	α1+α2+α3=1	1

Eq.(9): **a =** **0,0071** > 0

Air1: β1*a + β2*(y-z) = **-0,1239** < 0 --> DEVOTED DSS Tool recommends: **to not wait**

Air2: β1*a + β2*(y-z) = **-0,0220** < 0 --> DEVOTED DSS Tool recommends: **to not wait**

Decision Threshold-Value		Available
For the value of APP1	**β1**	0,95
For the value of APP2	**β2**	0,05

β1 = -(y-z)/(a-(y-z))

β2 = 1 - β1

SCENARIO 4b
DEVOTED DSS Tool Recommendation

Follow the Tool-Recommendation
"TO NOT WAIT"

OR

Take the Opposite Decision
"TO WAIT"

Follow the Tool-Recommendation "TO NOT WAIT"

Pax-Group I go the Recovery-Plan
Follow the Algorithm-Comp. 2

LOS Pax		
Pax-Group I	dissatisf.	52,5
Pax-Group II-1	satisf.	12,5
Pax-Group II-2	satisf.	66,25
Eq.(32) =		**0,9868**

LOS Airline	
ω (|Air1|)=	**1,0900**
ω (|Air2|)=	**1,0150**

Cost	
Cost(Air1)=	17.000,00 €
Cost(Air2)=	0,00 €

"Refused Pax"
Follow the Algorithm-Comp. 1

LOS Pax		
Pax-Group I	very dissatisf.	17,5
Pax-Group II-1	satisf.	12,5
Pax-Group II-2	satisf.	66,25
Eq.(32) =		**0,7237**

LOS Airline	
ω (-|Air1|)=	**1,0900**
ω (-|Air2|)=	**1,0150**

Cost	
Cost(Air1)=	307.809,50
Cost(Air2)=	307.809,50
Opport.Cost=	216.873,00
(TicketRevenue)ARR	181.873,00 €
(1/2 TR)ARR	90.936,50 €
TP (all high-fare Paxs)	422.223,00 €

Take the Opposite Decision "TO WAIT"

Follow the Algorithm-Comp. 3

LOS Pax		
Pax-Group I	very satisf.	122,5
Pax-Group II-1	neutr.	10
Pax-Group II-2	dissatisf.	39,75
Eq.(32) =		**1,2951**

LOS Airline	
ω (-|Air1|)=	**0,9100**
ω (-|Air2|)=	**0,9850**

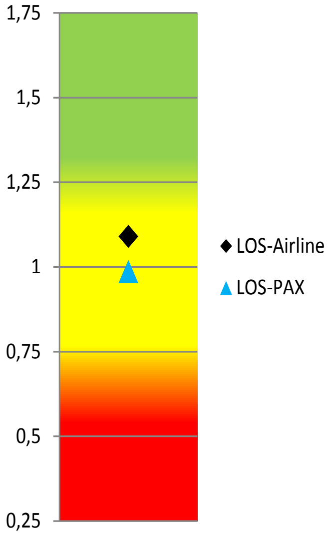
Cost	
Cost(Air1)=	0,00 €
Cost(Air2)=	0,00 €

SCENARIO 4b
The Tool-Output

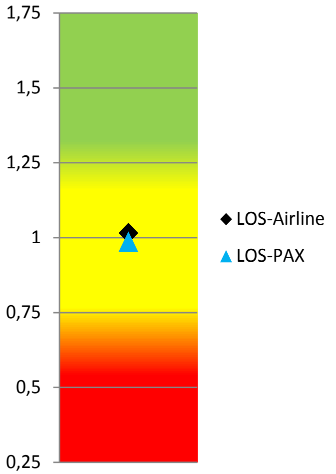
Follow the Tool-Recommendation
"TO NOT WAIT"

Pax-Recovery possible

Air1:

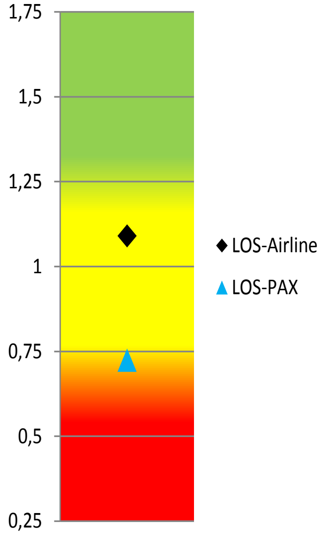


Air2:

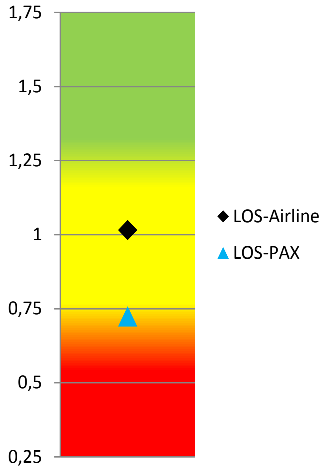


Pax-Recovery not possible

Air1:



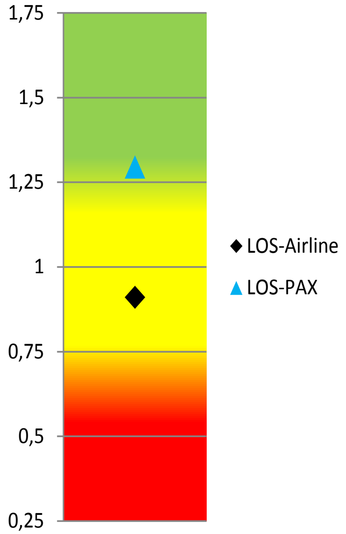
Air2:



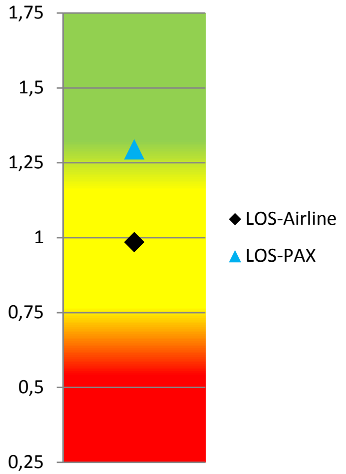
OR

Take the Opposite Decision
"TO WAIT"

Air1:



Air2:



SCENARIO 4c

ARRIVING FLIGHT			
Pax-Group I	**Pax-Number**	**Ticket Price**	**Ticket-Revenue**
VIPs	1	6.500 €	6.500,00 €
1. C	4	5.200 €	20.800,00 €
BUS+FFPs	65	3.590 €	233.350,00 €
Summe	**70**		**260.650,00 €**
DEPARTING FLIGHT			
Pax-Group II	**Pax-Number**	**Ticket Price**	**Ticket-Revenue**
VIPs	1	4.873 €	4.873,00 €
1. C	7	3.625 €	25.375,00 €
BUS+FFPs	55	2.500 €	137.500,00 €
Summe	**63**		**167.748,00 €**
m1 (Pax-Group II-1)			**10**
m2 (Pax-Group II-2)			**53**
m + n			**133**
ARRIVING + DEPARTING			
TP (all high-fare Paxs)			**428.398,00 €**
Value "y"			0,61
Value "z"			0,39
Eq.(14):			**0,2169**

The *value of the passenger* **α**		
VIP-Pax	α1	0,448
1.C-Pax	α2	0,352
BUS/FFPs-Pax	α3	0,2
	α1+α2+α3=1	1

Eq.(9): **a =** **0,0071** > 0

Air1: β1*a + β2*(y-z) = **0,1959** > 0 --> DEVOTED DSS Tool recommends: **to wait**

Air2: β1*a + β2*(y-z) = **0,0491** > 0 --> DEVOTED DSS Tool recommends: **to wait**

Decision Threshold-Value		Not available
For the value of APP1	**β1**	1,03
For the value of APP2	**β2**	-0,03

β1 = -(y-z)/(a-(y-z))

β2 = 1 - β1

SCENARIO 4c

DEVOTED DSS Tool Recommendation

Follow the Tool-Recommendation "TO WAIT"	**OR**	**Take the Opposite Decision "TO NOT WAIT"**

Follow the Algorithm-Comp. 3

LOS Pax		
Pax-Group I	very satisf.	122,5
Pax-Group II-1	neutr.	10
Pax-Group II-2	dissatisf.	39,75
Eq.(32) =		**1,2951**

LOS Airline	
ω (|Air1|)=	**1,1469**
ω (|Air2|)=	**1,0368**

Cost	
Cost(Air1)=	0,00 €
Cost(Air2)=	0,00 €

Pax-Group I go the Recovery-Plan
Follow the Algorithm-Comp. 2

LOS Pax		
Pax-Group I	dissatisf.	52,5
Pax-Group II-1	satisf.	12,5
Pax-Group II-2	satisf.	66,25
Eq.(32) =		**0,9868**

LOS Airline	
ω (-|Air1|)=	**0,8531**
ω (-|Air2|)=	**0,9632**

Cost	
Cost(Air1)=	17.000,00 €
Cost(Air2)=	0,00 €

"Refused Pax"
Follow the Algorithm-Comp. 1

LOS Pax		
Pax-Group I	very dissatisf.	17,5
Pax-Group II-1	satisf.	12,5
Pax-Group II-2	satisf.	66,25
Eq.(32) =		**0,7237**

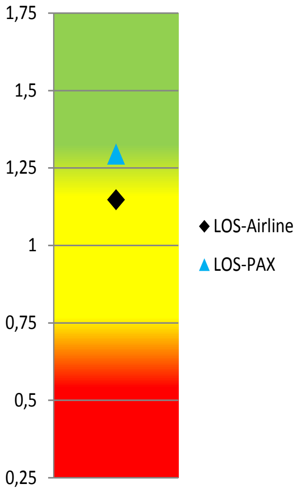
LOS Airline	
ω (-|Air1|)=	**0,8531**
ω (-|Air2|)=	**0,9632**

Cost	
Cost(Air1)=	425.975,00 €
Cost(Air2)=	425.975,00 €
Opport.Cost=	295.650,00 €
(TicketRevenue)ARR	260.650,00 €
(1/2 TR)ARR	130.325,00 €
TP (all high-fare Paxs)	428.398,00 €

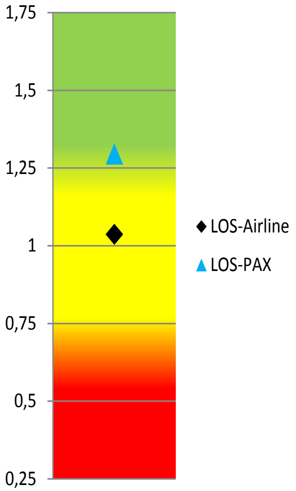
SCENARIO 4c
The Tool-Output

Follow the Tool-Recommendation
"TO WAIT"

Air1:



Air2:

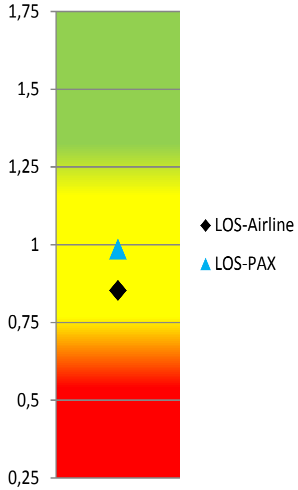


OR

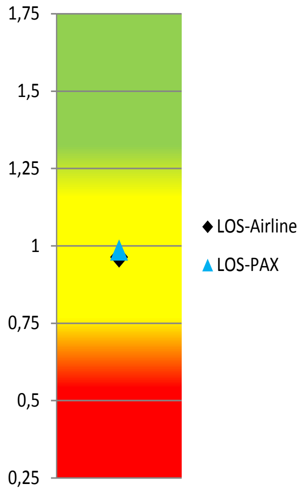
Take the Opposite Decision
"TO NOT WAIT"

Pax-Recovery possible

Air1:

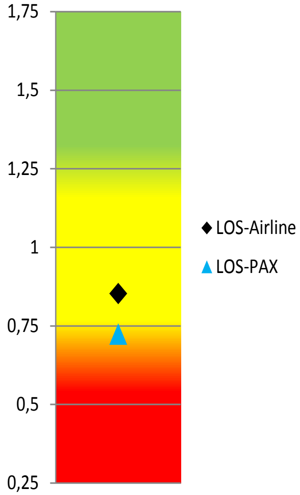


Air2:

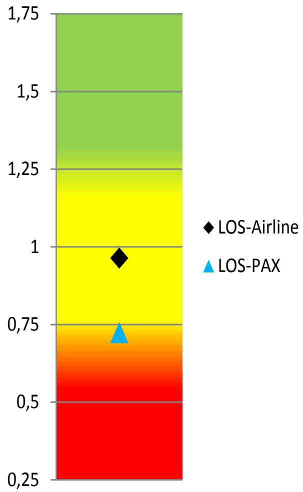


Pax-Recovery not possible

Air1:



Air2:



SCENARIO 5

ARRIVING FLIGHT			
Pax-Group I	**Pax-Number**	**Ticket Price**	**Ticket-Revenue**
VIPs	1	6.500 €	6.500,00 €
1. C	1	5.200 €	5.200,00 €
BUS+FFPs	44	3.590 €	157.960,00 €
Summe	**46**		**169.660,00 €**
DEPARTING FLIGHT			
Pax-Group II	**Pax-Number**	**Ticket Price**	**Ticket-Revenue**
VIPs	8	4.873 €	38.984,00 €
1. C	7	3.625 €	25.375,00 €
BUS+FFPs	41	2.500 €	102.500,00 €
Summe	**56**		**166.859,00 €**
m1 (Pax-Group II-1)			40
m2 (Pax-Group II-2)			16
m + n			**102**
ARRIVING + DEPARTING			
TP (all high-fare Paxs)			**336.519,00 €**
Value "y"			0,5042
Value "z"			0,4958
Eq.(14):			**0,0083**

The *value of the passenger* **α**		
VIP-Pax	α1	**0,8**
1.C-Pax	α2	**0,1184**
BUS/FFPs-Pax	α3	**0,0816**
	α1+α2+α3=1	1

Eq.(9): **a =** **-0,0595**

Air1: β1*a + β2*(y-z) = **0,0015** > 0 --> DEVOTED DSS Tool recommends: **to wait**

Air2: β1*a + β2*(y-z) = **-0,0459** < 0 --> DEVOTED DSS Tool recommends: **to not wait**

Decision Threshold-Value		Available
For the value of APP1	β1	**0,12**
For the value of APP2	β2	**0,88**

β1 = -(y-z)/(a-(y-z))

β2 = 1 - β1

SCENARIO 5

DEVOTED DSS Tool Recommendation to the airline Air1

Follow the Tool-Recommendation "TO WAIT" OR **Take the Opposite Decision "TO NOT WAIT"**

Follow the Algorithm-Comp. 3

LOS Pax		
Pax-Group I	very satisf.	80,5
Pax-Group II-1	neutr.	40
Pax-Group II-2	dissatisf.	12
Eq.(32) =		**0,9962**

LOS Airline	
ω (|Air1|)=	**1,0011**

Cost	
Cost(Air1)=	0,00 €

Pax-Group I go the Recovery-Plan
Follow the Algorithm-Comp. 2

LOS Pax		
Pax-Group I	dissatisf.	34,5
Pax-Group II-1	satisf.	50
Pax-Group II-2	satisf.	20
Eq.(32) =		**0,7857**

LOS Airline	
ω (-|Air1|)=	**0,9989**

Cost	
Cost(Air1)	17.000,00 €

"Refused Pax"
Follow the Algorithm-Comp. 1

LOS Pax		
Pax-Group I	very dissatisf.	11,5
Pax-Group II-1	satisf.	50
Pax-Group II-2	satisf.	20
Eq.(32) =		**0,6128**

LOS Airline	
ω (-|Air1|)=	**0,9989**

Cost	
Cost(Air1)=	277.490,00 €
Opport.Cost=	192.660,00 €
$(\text{TicketRevenue})_{ARR}$	169.660,00 €
$(1/2\ TR)_{ARR}$	84.830,00 €
TP (all high-fare Paxs)	336.519,00 €

SCENARIO 5

DEVOTED DSS Tool Recommendation to the airline Air2

Follow the Tool-Recommendation **"TO NOT WAIT"** **OR** **Take the Opposite Decision** **"TO WAIT"**

Follow the Tool-Recommendation "TO NOT WAIT"

Pax-Group I go the Recovery-Plan
Follow the Algorithm-Comp. 2

LOS Pax		
Pax-Group I	dissatisf.	34,5
Pax-Group II-1	satisf.	50
Pax-Group II-2	satisf.	20
Eq.(32) =		**0,7857**

LOS Airline	
ω (|Air2|)=	**1,0344**

Cost	
Cost(Air2)=	0,00 €

"Refused Pax"
Follow the Algorithm-Comp. 1

LOS Pax		
Pax-Group I	very dissatisf.	11,5
Pax-Group II-1	satisf.	50
Pax-Group II-2	satisf.	20
Eq.(32) =		**0,6128**

LOS Airline	
ω (|Air2|)=	**1,0344**

Cost	
Cost(Air2)=	277.490,00 €
Opport.Cost=	192.660,00 €
(TicketRevenue)ARR	169.660,00 €
(1/2 TR)ARR	84.830,00 €
TP (all high-fare Paxs)	336.519,00 €

Take the Opposite Decision "TO WAIT"

Follow the Algorithm-Comp. 4

LOS Pax		
Pax-Group I	very stisf.	80,5
Pax-Group II-1	neutral	40
Pax-Group II-2	dissatisf.	12
Eq.(32) =		**0,9962**

LOS Airline	
ω (-|Air2|)=	**0,9656**

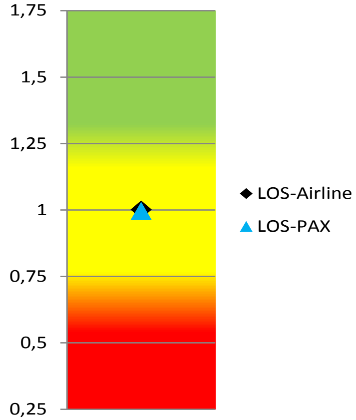
Cost	
Cost(Air2)=	0,00 €

SCENARIO 5
The Tool-Output

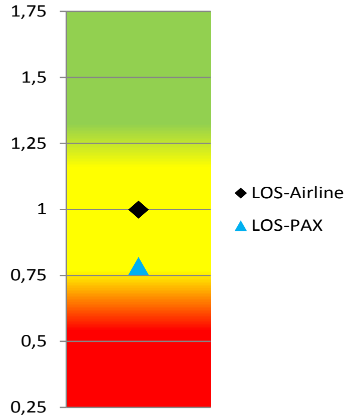
Air1

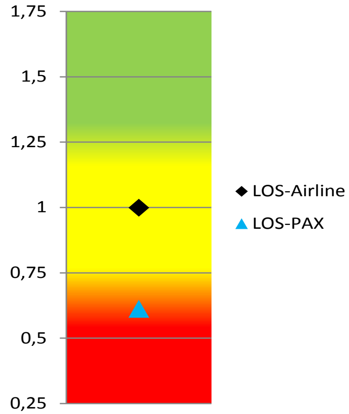
Follow the Tool-Recommendation OR **Take the Opposite Decision**

"TO WAIT"



Pax-recovery possible **"TO NOT WAIT"** **Pax-Recovery not possible**

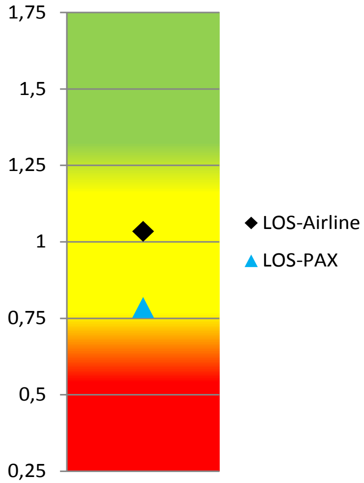


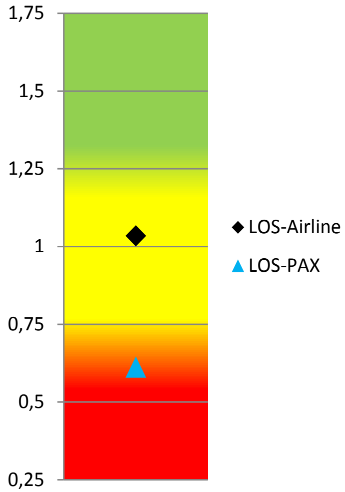


Air2

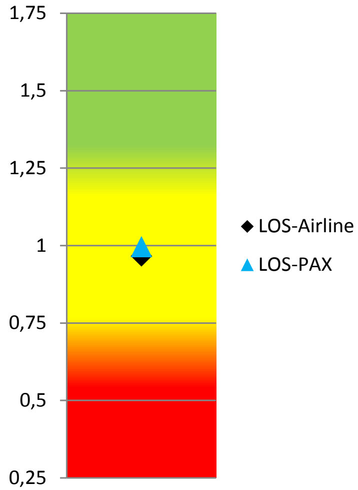
Follow the Tool-Recommendation OR **Take the Opposite Decision**

Pax-Recovery possible **"TO NOT WAIT"** **Pax-Recovery not possible**





"TO WAIT"



SCENARIO 5a

ARRIVING FLIGHT			
Pax-Group I	**Pax-Number**	**Ticket Price**	**Ticket-Revenue**
VIPs	1	6.500 €	6.500,00 €
1. C	1	5.200 €	5.200,00 €
BUS+FFPs	44	3.590 €	157.960,00 €
Summe	**46**		**169.660,00 €**
DEPARTING FLIGHT			
Pax-Group II	**Pax-Number**	**Ticket Price**	**Ticket-Revenue**
VIPs	8	4.873 €	38.984,00 €
1. C	7	3.625 €	25.375,00 €
BUS+FFPs	41	2.500 €	102.500,00 €
Summe	**56**		**166.859,00 €**
m1 (Pax-Group II-1)			40
m2 (Pax-Group II-2)			16
m + n			**102**
ARRIVING + DEPARTING			
TP (all high-fare Paxs)			**336.519,00 €**
Value "y"			0,5042
Value "z"			0,4958
Eq.(14):			**0,0083**

The *value of the passenger* **α**		
VIP-Pax	α1	**0,448**
1.C-Pax	α2	**0,352**
BUS/FFPs-Pax	α3	**0,2**
	α1+α2+α3=1	1

Eq.(9): **a =** **-0,0456**

Air1: β1*a + β2*(y-z) = **0,0029** > 0 --> DEVOTED DSS Tool recommends: **to wait**

Air2: β1*a + β2*(y-z) = **-0,0348** < 0 --> DEVOTED DSS Tool recommends: **to not wait**

Decision Threshold-Value		Available
For the value of APP1	β1	**0,15**
For the value of APP2	β2	**0,85**

β1 = -(y-z)/(a-(y-z))

β2 = 1 - β1

SCENARIO 5a
DEVOTED DSS Tool Recommendation to the airline Air1

Follow the Tool-Recommendation "TO WAIT" OR **Take the Opposite Decision "TO NOT WAIT"**

Follow the Tool-Recommendation "TO WAIT"

Follow the Algorithm-Comp. 3

LOS Pax		
Pax-Group I	very satisf.	80,5
Pax-Group II-1	neutr.	40
Pax-Group II-2	dissatisf.	12
Eq.(32) =		**0,9962**

LOS Airline	
ω (|Air1|)=	**1,0022**

Cost	
Cost(Air1)=	0,00 €

Take the Opposite Decision "TO NOT WAIT"

Pax-Group I go the Recovery-Plan
Follow the Algorithm-Comp. 2

LOS Pax		
Pax-Group I	dissatisf.	34,5
Pax-Group II-1	satisf.	50
Pax-Group II-2	satisf.	20
Eq.(32) =		**0,7857**

LOS Airline	
ω (-|Air1|)=	**0,9978**

Cost	
Cost(Air1)	17.000,00 €

"Refused Pax"
Follow the Algorithm-Comp. 1

LOS Pax		
Pax-Group I	very dissatisf.	11,5
Pax-Group II-1	satisf.	50
Pax-Group II-2	satisf.	20
Eq.(32) =		**0,6128**

LOS Airline	
ω (-|Air1|)=	**0,9978**

Cost	
Cost(Air1)=	277.490,00 €
Opport.Cost=	192.660,00 €
(TicketRevenue)ARR	169.660,00 €
(1/2 TR)ARR	84.830,00 €
TP (all high-fare Paxs)	336.519,00 €

SCENARIO 5a

DEVOTED DSS Tool Recommendation to the airline Air2

Follow the Tool-Recommendation "TO NOT WAIT" OR **Take the Opposite Decision "TO WAIT"**

Pax-Group I go the Recovery-Plan
Follow the Algorithm-Comp. 2

LOS Pax		
Pax-Group I	dissatisf.	34,5
Pax-Group II-1	satisf.	50
Pax-Group II-2	satisf.	20
Eq.(32) =		**0,7857**

LOS Airline	
ω (|Air2|)=	**1,0261**

Cost	
Cost(Air2)=	0,00 €

"Refused Pax"
Follow the Algorithm-Comp. 1

LOS Pax		
Pax-Group I	very dissatisf.	11,5
Pax-Group II-1	satisf.	50
Pax-Group II-2	satisf.	20
Eq.(32) =		**0,6128**

LOS Airline	
ω (|Air2|)=	**1,0261**

Cost	
Cost(Air2)=	277.490,00 €
Opport.Cost=	192.660,00 €
$(\text{TicketRevenue})_{\text{ARR}}$	169.660,00 €
$(1/2\ \text{TR})_{\text{ARR}}$	84.830,00 €
TP (all high-fare Paxs)	336.519,00 €

Follow the Algorithm-Comp. 4

LOS Pax		
Pax-Group I	very stisf.	80,5
Pax-Group II-1	neutral	40
Pax-Group II-2	dissatisf.	12
Eq.(32) =		**0,9962**

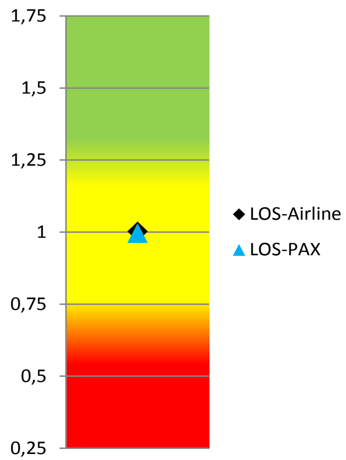
LOS Airline	
ω (-|Air2|)=	**0,9739**

Cost	
Cost(Air2)=	0,00 €

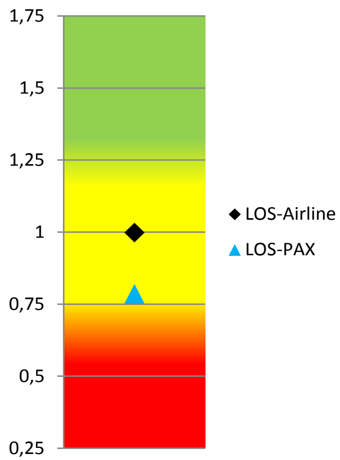
SCENARIO 5a
The Tool-Output

Air1

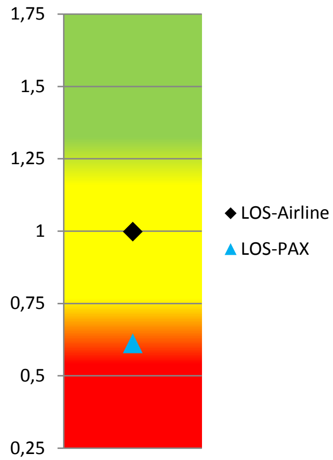
Follow the Tool-Recommendation "TO WAIT" **OR** Take the Opposite Decision "TO NOT WAIT"



Pax-Recovery possible



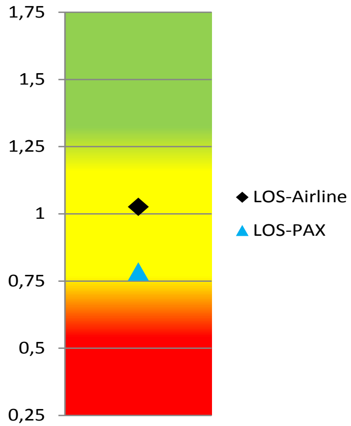
Pax-Recovery not possible



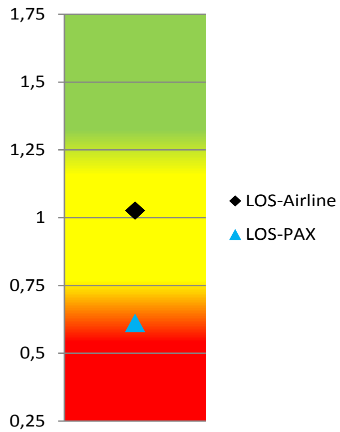
Air2

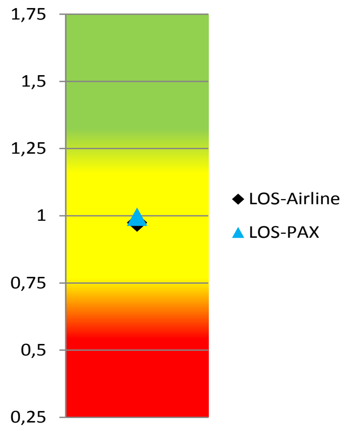
Follow the Tool-Recommendation "TO NOT WAIT" **OR** Take the Opposite Decision "TO WAIT"

Pax-Recovery possible

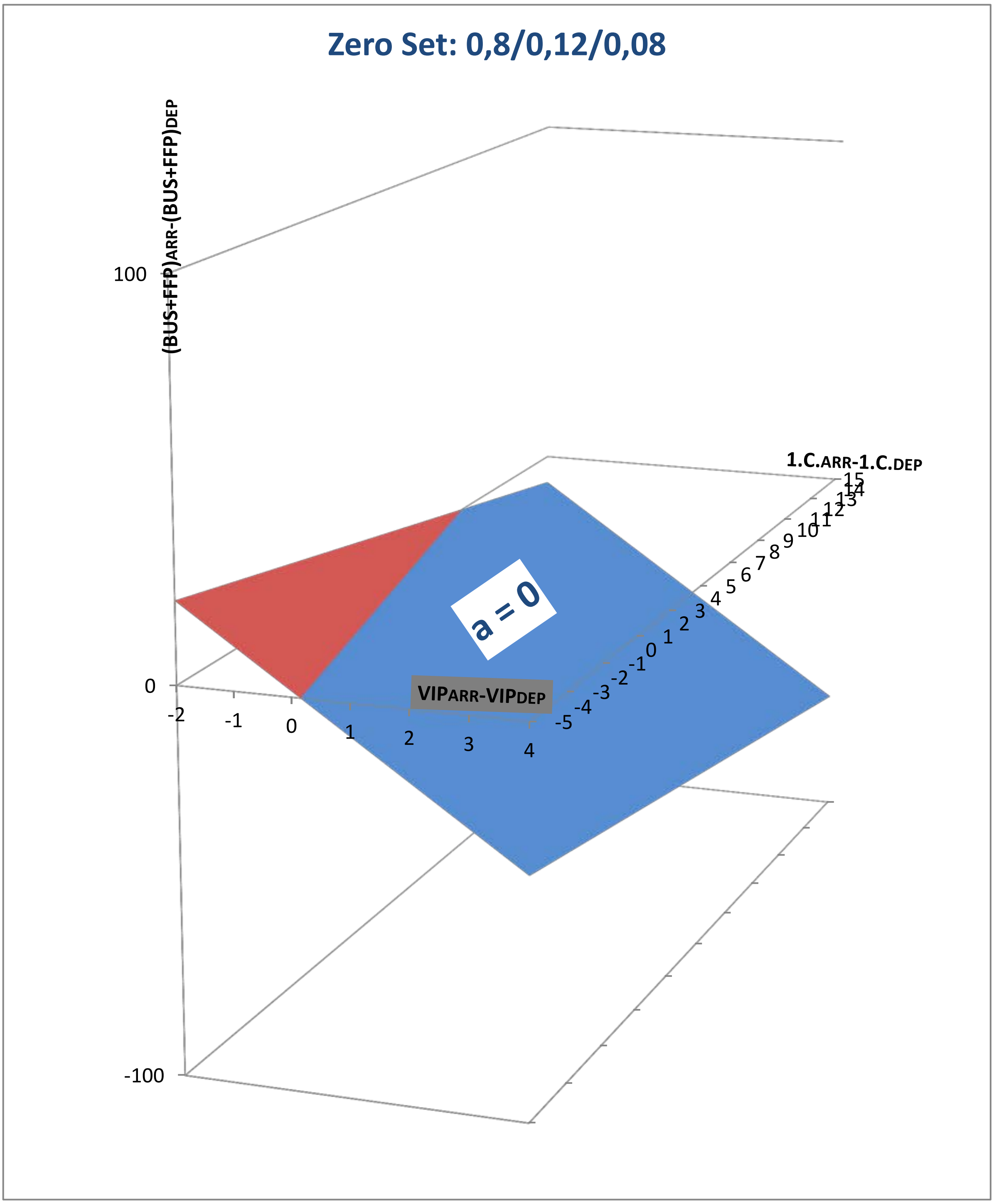


Pax-Recovery not possible





a- Zero (0,8)



Zero Set: 0,8/0,12/0,08
(BUS+FFP)ARR-(BUS+FFP)DEP
100
0
-100
a = 0
VIPARR-VIPDEP
-2
-1
0
1
2
3
4
1.C.ARR-1.C.DEP
-5 -4 -3 -2 -1 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Results: All Scenarios

	DEVOTED DSS Tool: Testing Evaluation						
	Key Characteristics of the Testing Scenarios					**The Tool Decision-Recommendation**	
SCENARIOS	***Pax-Value Coeff.***	***Passenger-Groups***	***Relation of Ticket Prices: ARR/DEP***	***Value of the Eq. (8)***	***Value of the Eq. (13)***	***Air1***	***Air2***
Scenario 1	α1=0,8 α2=0,118 α3=0,082	Pax-Group I =19 Pax-Group II-1 =60 Pax-Group II-2 =6	TicketPrices(ARR) **<** TicketPrices(DEP)	-0,0371	-0,6399	to not wait	to not wait
Scenario 1a			TicketPrices(ARR) **>** TicketPrices(DEP)	-0,0371	-0,3832	to not wait	to not wait
Scenario 2	α1=0,45 α2=0,35 α3=0,2	Pax-Group I =19 Pax-Group II-1 =60 Pax-Group II-2 =6	TicketPrices(ARR) **<** TicketPrices(DEP)	-0,1095	-0,6399	to not wait	to not wait
Scenario 2a			TicketPrices(ARR) **>** TicketPrices(DEP)	-0,1095	-0,3832	to not wait	to not wait
Scenario 3	α1=0,8 α2=0,118 α3=0,082	Pax-Group I =70 Pax-Group II-1 =53 Pax-Group II-2 =10	TicketPrices(ARR) **<** TicketPrices(DEP)	0,0035	-0,1385	to not wait	to not wait
Scenario 3a			TicketPrices(ARR) **>** TicketPrices(DEP)	0,0035	0,2169	to wait	to wait
Scenario 4	α1=0,45 α2=0,35 α3=0,2	Pax-Group I =70 Pax-Group II-1 =**53** Pax-Group II-2 =**10**	TicketPrices(ARR) **<** TicketPrices(DEP)	0,0071	-0,1385	to not wait	to not wait
Scenario 4a			TicketPrices(ARR) **>** TicketPrices(DEP)	0,0071	0,2169	to wait	to wait
Scenario 4b	α1=0,45 α2=0,35 α3=0,2	Pax-Group I =70 Pax-Group II-1 =**10** Pax-Group II-2 =**53**	TicketPrices(ARR) < TicketPrices(DEP)	0,0071	-0,1385	to not wait	to not wait
Scenario 4c			TicketPrices(ARR) **>** TicketPrices(DEP)	0,0071	0,2169	to wait	to wait
Scenario 5	α1=0,8 α2=0,118 α3=0,082	Pax-Group I =46 Pax-Group II-1 =4**0** Pax-Group II-2 =16	TicketPrices(ARR) **>** TicketPrices(DEP)	-0,0595	0,0083	to wait	to not wait
Scenario 5a	α1=0,45 α2=0,35 α3=0,2		TicketPrices(ARR) **>** TicketPrices(DEP)	-0,0456	0,0083	to wait	to not wait

Tool Algorithm-Paths for Air1

Air1	DECISION MAKING ALGORITHM-PATHS TAKEN							
	If Taking the Tool-Recommendation				**If Taking the Opposite Decision**			
SCENARIOS	*Alg.-Comp.1*	*Alg.-Comp.2*	*Alg.-Comp.3*	*Alg.-Comp.4*	*Alg.-Comp.1*	*Alg.-Comp.2*	*Alg.-Comp.3*	*Alg.-Comp.4*
Scenario 1	x	x						x
Scenario 1a	x	x						x
Scenario 2	x	x						x
Scenario 2a	x	x						x
Scenario 3	x	x						x
Scenario 3a			x		x	x		
Scenario 4	x	x						x
Scenario 4a			x		x	x		
Scenario 4b	x	x					x	
Scenario 4c			x		x	x		
Scenario 5			x		x	x		
Scenario 5a			x		x	x		

Tool Algorithm-Paths for Air2

Air2	DECISION MAKING ALGORITHM-PATHS TAKEN							
	If Taking the Tool-Recommendation				**If Taking the Opposite Decision**			
SCENARIOS	*Alg.-Comp.1*	*Alg.-Comp.2*	*Alg.-Comp.3*	*Alg.-Comp.4*	*Alg.-Comp.1*	*Alg.-Comp.2*	*Alg.-Comp.3*	*Alg.-Comp.4*
Scenario 1	x	x						x
Scenario 1a	x	x						x
Scenario 2	x	x						x
Scenario 2a	x	x						x
Scenario 3	x	x						x
Scenario 3a			x		x	x		
Scenario 4	x	x						x
Scenario 4a			x		x	x		
Scenario 4b	x	x					x	
Scenario 4c			x		x	x		
Scenario 5	x	x						x
Scenario 5a	x	x						x

Test Results for Air1

Air1	The DEVOTED DSS Tool OUTPUT							
	Follow the Tool-Recommendation				Take the Opposite Decision			
	Pax-Recovery possible		Pax-Recovery not possible		Pax-Recovery possible		Pax-Recovery not possible	
SCENARIOS	***LOS Pax***	***LOS Airline***	***LOS Pax***	***LOS Airline***	***LOS Pax***	***LOS Airline***	***LOS Pax***	***LOS Airline***
Scenario 1	1,14	1,44	0,85	1,44	1,15	0,57		
Scenario 1a	1,14	1,26	0,85	1,26	1,15	0,74		
Scenario 2	1,14	1,44	0,85	1,44	1,15	0,56		
Scenario 2a	1,14	1,27	0,85	1,27	1,15	0,73		
Scenario 3	0,99	1,09	0,72	1,09	1,38	0,91		
Scenario 3a	1,38	1,15			0,99	0,85	0,72	0,85
Scenario 4	0,99	1,09	0,72	1,09	1,38	0,91		
Scenario 4a	1,38	1,15	0,99	0,85	0,72	0,85		
Scenario 4b	0,9868	1,09	0,7237	1,09	1,2951	0,91		
Scenario 4c	1,2951	1,1469			0,9868	0,8537	0,7237	0,8537
Scenario 5	0,9962	1,0011			0,7857	0,9989	0,6128	0,9989
Scenario 5a	0,9962	1,0022			0,7857	0,9978	0,6128	0,9978

Test Results for Air2

Air2	The DEVOTED DSS Tool OUTPUT							
	Follow the Tool-Recommendation				Take the Opposite Decision			
	Pax-Recovery possible		Pax-Recovery not possible		Pax-Recovery possible		Pax-Recovery not possible	
SCENARIOS	***LOS Pax***	***LOS Airline***	***LOS Pax***	***LOS Airline***	***LOS Pax***	***LOS Airline***	***LOS Pax***	***LOS Airline***
Scenario 1	1,14	1,44	0,85	1,44	1,15	0,57		
Scenario 1a	1,14	1,26	0,85	1,26	1,15	0,74		
Scenario 2	1,14	1,44	0,85	1,44	1,15	0,56		
Scenario 2a	1,14	1,27	0,85	1,27	1,15	0,73		
Scenario 3	0,99	1,09	0,72	1,09	1,38	0,91		
Scenario 3a	1,38	1,15			0,99	0,85	0,72	0,85
Scenario 4	0,99	1,09	0,72	1,09	1,38	0,91		
Scenario 4a	1,38	1,15	0,99	0,85	0,72	0,85		
Scenario 4b	0,9868	1,09	0,7237	1,09	1,2951	0,91		
Scenario 4c	1,2951	1,1469			0,9868	0,8537	0,7237	0,8537
Scenario 5	0,7857	1,0344	0,6128	1,0344	0,9962	0,9656		
Scenario 5a	0,7857	1,0261	0,6128	1,0261	0,9962	0,9739		

Costs for Air1

Air1	The DEVOTED DSS Tool OUTPUT: COST						
	Follow the Tool-Recommendation			Take the Opposite Decision			
	Pax-Recovery possible	Pax-Recovery not possible		Pax-Recovery possible	Pax-Recovery not possible		Ticket-Revenue (ARR+DEP)
SCENARIOS	Cost	Cost	Opportunity Cost	Cost	Cost	Opportunity Cost	
Scenario 1	17.000,00 €	81.956,50 €	55.271,00 €	0,00 €			296.441,00 €
Scenario 1a	17.000,00 €	122.960,00	85.140,00	0,00			245.263,00 €
Scenario 2	17.000,00 €	89.556,50	62.871,00	0,00			296.441,00 €
Scenario 2a	17.000,00 €	122.960,00	85.140,00	0,00			245.263,00 €
Scenario 3	17.000,00 €	307.809,50	216.873,00	0,00			422.223,00 €
Scenario 3a	0,00 €			17.000,00	425.975,00	295.650,00	428.398,00 €
Scenario 4	17.000,00 €	307.809,50	216.873,00	0,00			422.223,00 €
Scenario 4a	0,00 €			17.000,00	425.975,00	295.975,00	428.398,00 €
Scenario 4b	17.000,00 €	307.809,50	216.873,00	0,00			422.223,00 €
Scenario 4c	0,00 €			17.000,00	425.975,00	295.650,00	428.398,00 €
Scenario 5	0,00 €			17.000,00	277.490,00	19.266,00	336.519,00 €
Scenario 5a	0,00 €			17.000,00	277.490,00	19.266,00	336.519,00 €

Costs for Air2

<table>
<tr><th rowspan="3">Air2
SCENARIOS</th><th colspan="6">The DEVOTED DSS Tool OUTPUT: COST</th><th rowspan="3">Ticket-Revenue (ARR+DEP)</th></tr>
<tr><th colspan="3">Follow the Tool-Recommendation</th><th colspan="3">Take the Opposite Decision</th></tr>
<tr><th>Pax-Recovery possible
Cost</th><th>Pax-Recovery not possible
Cost</th><th>Pax-Recovery not possible
Opportunity Cost</th><th>Pax-Recovery possible
Cost</th><th>Pax-Recovery not possible
Cost</th><th>Pax-Recovery not possible
Opportunity Cost</th></tr>
<tr><td>Scenario 1</td><td>0,00 €</td><td>81.956,50 €</td><td>55.271,00 €</td><td>0,00 €</td><td></td><td></td><td>296.441,00 €</td></tr>
<tr><td>Scenario 1a</td><td>0,00 €</td><td>122.960,00 €</td><td>85.140,00 €</td><td>0,00 €</td><td></td><td></td><td>245.263,00 €</td></tr>
<tr><td>Scenario 2</td><td>0,00 €</td><td>89.556,50 €</td><td>62.871,00 €</td><td>0,00 €</td><td></td><td></td><td>296.441,00 €</td></tr>
<tr><td>Scenario 2a</td><td>0,00 €</td><td>122.960,00 €</td><td>85.140,00 €</td><td>0,00 €</td><td></td><td></td><td>245.263,00 €</td></tr>
<tr><td>Scenario 3</td><td>0,00 €</td><td>307.809,50 €</td><td>216.873,00 €</td><td>0,00 €</td><td></td><td></td><td>422.223,00 €</td></tr>
<tr><td>Scenario 3a</td><td>0,00 €</td><td></td><td></td><td>0,00 €</td><td>425.975,00 €</td><td>295.650,00 €</td><td>428.398,00 €</td></tr>
<tr><td>Scenario 4</td><td>0,00 €</td><td>307.809,50 €</td><td>216.873,00 €</td><td>0,00 €</td><td></td><td></td><td>422.223,00 €</td></tr>
<tr><td>Scenario 4a</td><td>0,00 €</td><td></td><td></td><td>0,00 €</td><td>425.975,00 €</td><td>295.650,00 €</td><td>428.398,00 €</td></tr>
<tr><td>Scenario 4b</td><td>0,00 €</td><td>307.809,50 €</td><td>216.873,00 €</td><td>0,00 €</td><td></td><td></td><td>422.223,00 €</td></tr>
<tr><td>Scenario 4c</td><td>0,00 €</td><td></td><td></td><td></td><td>425.975,00 €</td><td>295.650,00 €</td><td>428.398,00 €</td></tr>
<tr><td>Scenario 5</td><td>0,00 €</td><td>277.490,00 €</td><td>192.660,00 €</td><td>0,00 €</td><td></td><td></td><td>336.519,00 €</td></tr>
<tr><td>Scenario 5a</td><td>0,00 €</td><td>277.490,00 €</td><td>192.660,00 €</td><td>0,00 €</td><td></td><td></td><td>336.519,00 €</td></tr>
</table>

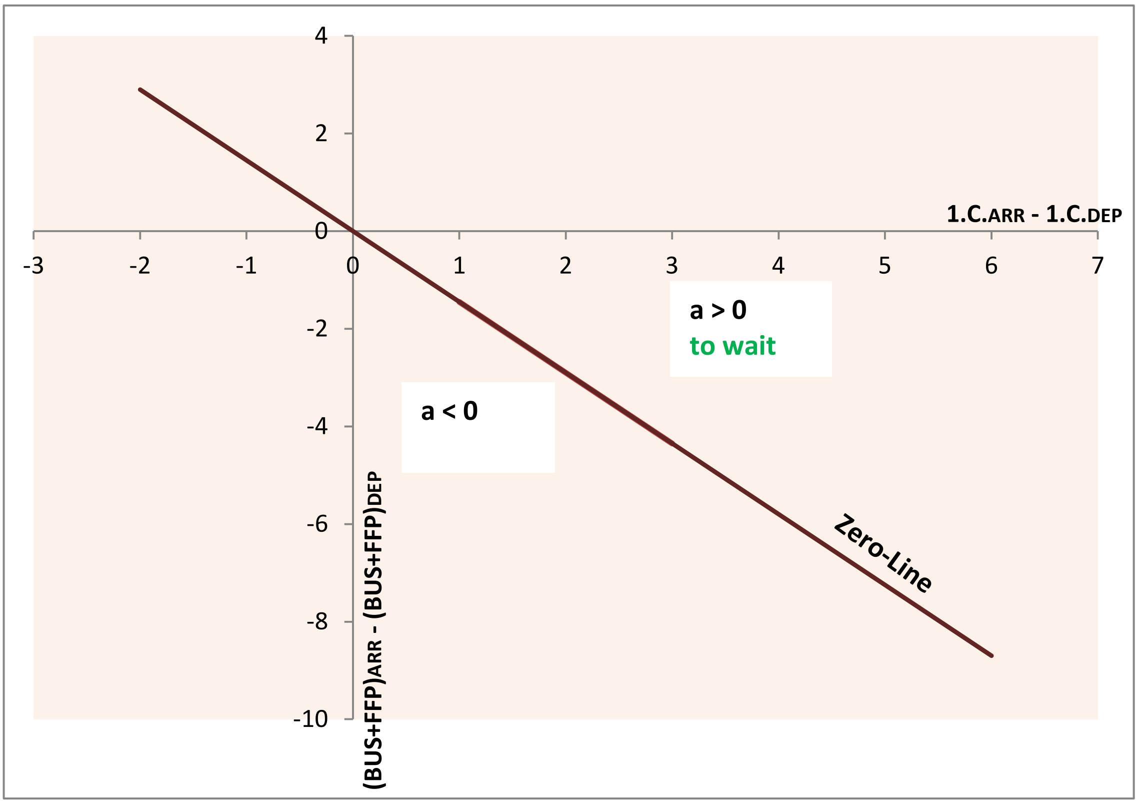
"Zero-Line" dividing *to wait* and *to not wait*
1.C.ARR-1.C.DEP/(BUS+FFP)ARR-(BUS+FFP)DEP

The *value of the passenger* **α**		
VIP-Pax	α1	**0,8**
1.C-Pax	α2	**0,1184**
BUS/FFPs-Pax	α3	**0,0816**
	α1+α2+α3=1	1

Calcultion of the "zero-line" laying between the decision possibilities "to wait" and "not to wait"

VIPARR - VIPDEP	**1.C.ARR - 1.C.DEP**	**(BUS+FFP)ARR - (BUS+FFP)DEP**
0	1	-1,4510
0	2	-2,9020
0	3	-4,3529

1.C.ARR - 1.C.DEP	**(BUS+FFP)ARR - (BUS+FFP)DEP**
1	-1,45
2	-2,90
3	-4,35



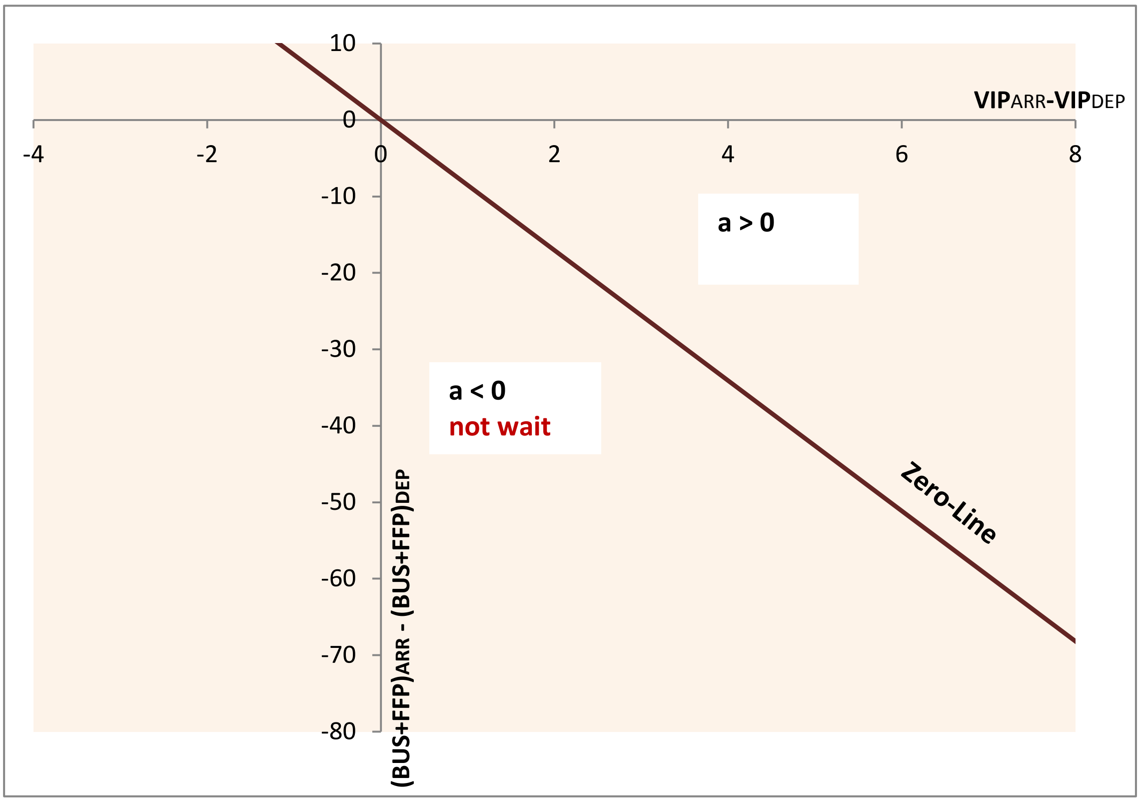
"Zero-Line" dividing *to wait* and *to not wait*
$(VIP_{ARR}-VIP_{DEP})/(BUS+FFP)_{ARR}-(BUS+FFP)_{DEP}$

The *value of the passenger* **α**		
VIP-Pax	α1	**0,8**
1.C-Pax	α2	**0,1184**
BUS/FFPs-Pax	α3	**0,0816**
	α1+α2+α3=1	1

Calcultion of the "zero-line" laying between the decision possibilities "to wait" and "not to wait"

$1.C._{ARR}$ - $1.C._{DEP}$	**VIP_{ARR} - VIP_{DEP}**	**$(BUS+FFP)_{ARR}$ - $(BUS+FFP)_{DEP}$**
0	1	-9,8039
0	2	-19,6078
0	3	-29,4118

VIP_{ARR} - VIP_{DEP}	**$(BUS+FFP)_{ARR}$ - $(BUS+FFP)_{DEP}$**
1	-9,80
2	-19,61
3	-29,41



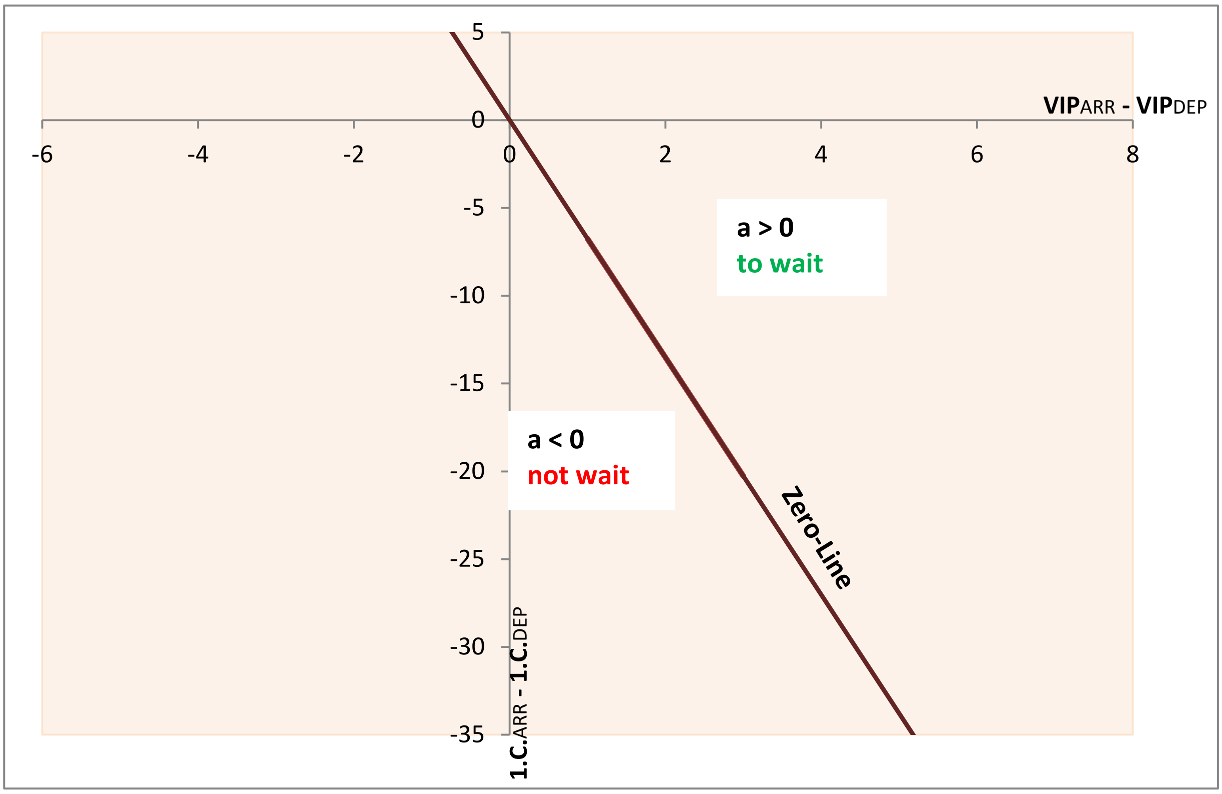
"Zero-Line" dividing to wait and to not wait
(VIPARR-VIPDEP)/(1.C.ARR-1.C.DEP)

The *value of the passenger* **α**		
VIP-Pax	α1	**0,8**
1.C-Pax	α2	**0,1184**
BUS/FFPs-Pax	α3	**0,0816**
	α1+α2+α3=1	1

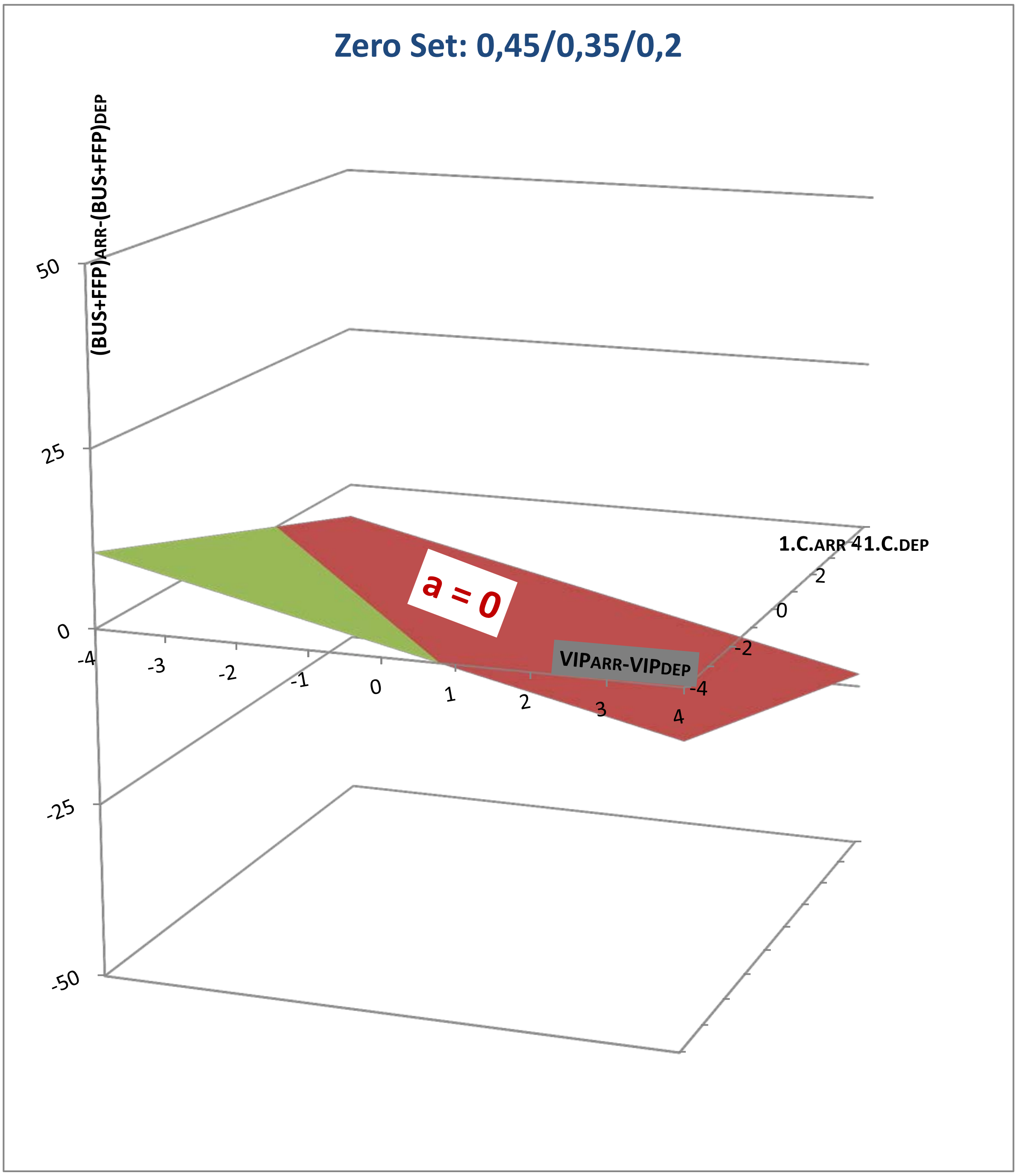
Calcultion of the "zero-line" laying between the decision possibilities "to wait" and "not to wait"

(BUS+FFP)ARR - (BUS+FFP)DEP	VIPARR - VIPDEP	1.C.ARR - 1.C.DEP
0	1	-6,7568
0	2	-13,5135
0	3	-20,2703

VIPARR - VIPDEP	1.C.ARR - 1.C.DEP
1	-6,76
2	-13,51
3	-20,27



a - Zero (0,45)


Zero Set: 0,45/0,35/0,2
(BUS+FFP)ARR-(BUS+FFP)DEP
50
25
0
-25
-50
-4
-3
-2
-1
0
1
2
3
4
VIPARR-VIPDEP
1.C.ARR-1.C.DEP
2
0
-2
-4
a = 0

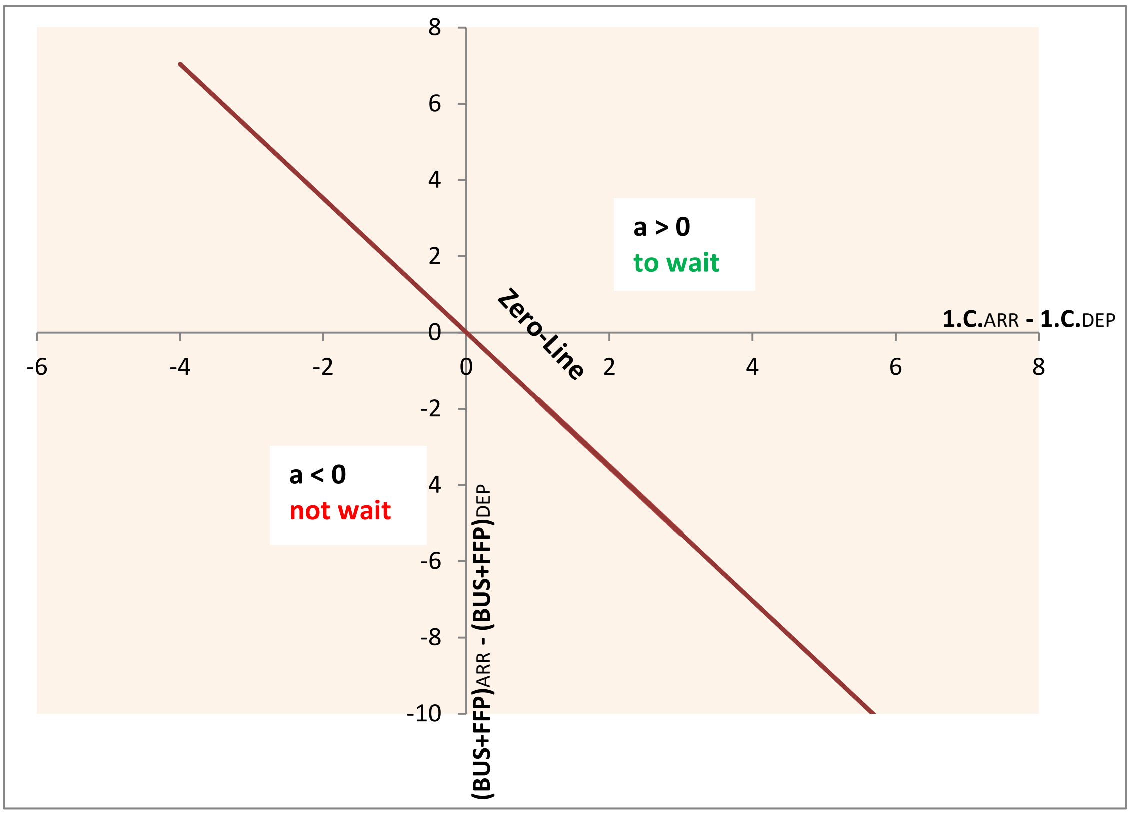
"Zero-Line" dividing *to wait* and *to not wait*
1.C.ARR-1.C.DEP/(BUS+FFP)ARR-(BUS+FFP)DEP

The *value of the passenger* **α**		
VIP-Pax	α1	**0,448**
1.C-Pax	α2	**0,352**
BUS/FFPs-Pax	α3	**0,2**
	α1+α2+α3=1	1

Calcultion of the "zero-line" laying between the decision possibilities "to wait" and "not to wait"

VIPARR - VIPDEP	**1.C.ARR - 1.C.DEP**	**(BUS+FFP)ARR - (BUS+FFP)DEP**
0	1	-1,7600
0	2	-3,5200
0	3	-5,2800

1.C.ARR - 1.C.DEP	**(BUS+FFP)ARR - (BUS+FFP)DEP**
1	-1,76
2	-3,52
3	-5,28



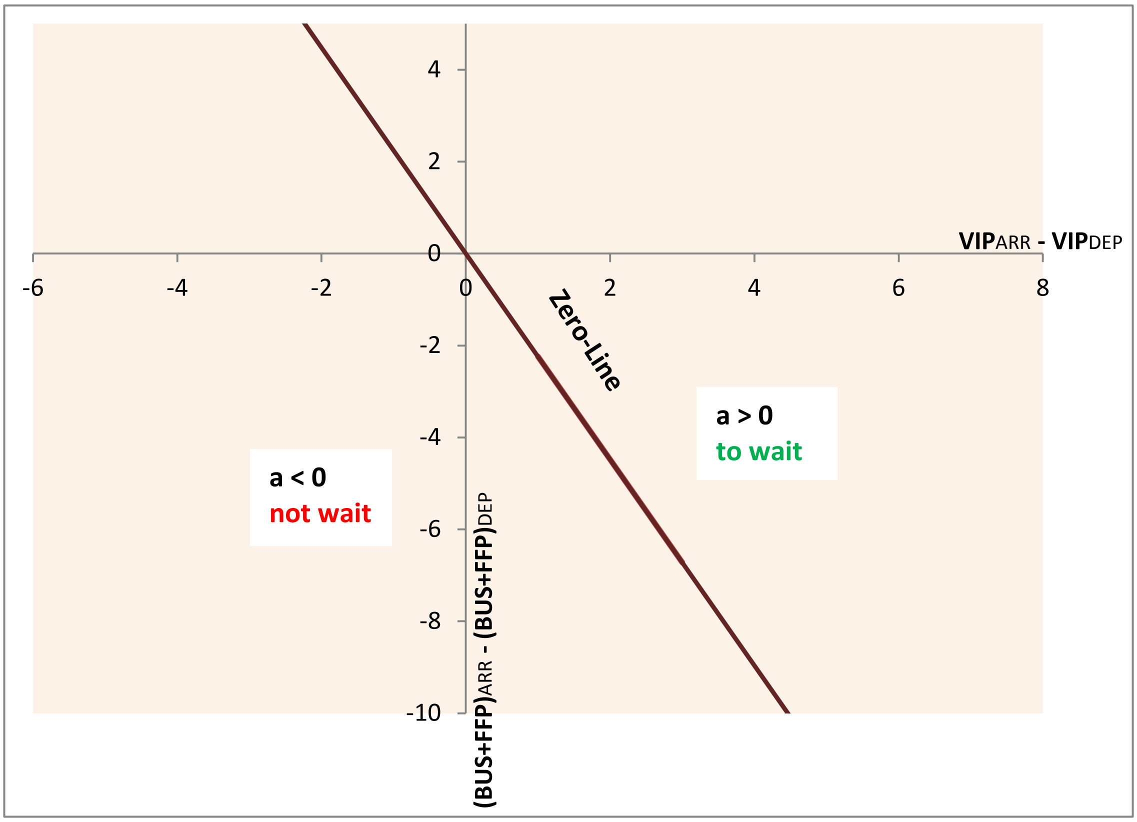
"Zero-Line" dividing *to wait* and *to not wait*
VIPARR-VIPDEP/(BUS+FFP)ARR-(BUS+FFP)DEP

The *value of the passenger* **α**		
VIP-Pax	α1	**0,448**
1.C-Pax	α2	**0,352**
BUS/FFPs-Pax	α3	**0,2**
	α1+α2+α3=1	1

Calcultion of the "zero-line" laying between the decision possibilities "to wait" and "not to wait"

1.C.ARR - 1.C.DEP	**VIPARR - VIPDEP**	**(BUS+FFP)ARR - (BUS+FFP)DEP**
0	1	-2,2400
0	2	-4,4800
0	3	-6,7200

VIPARR - VIPDEP	**(BUS+FFP)ARR - (BUS+FFP)DEP**
1	-2,24
2	-4,48
3	-6,72



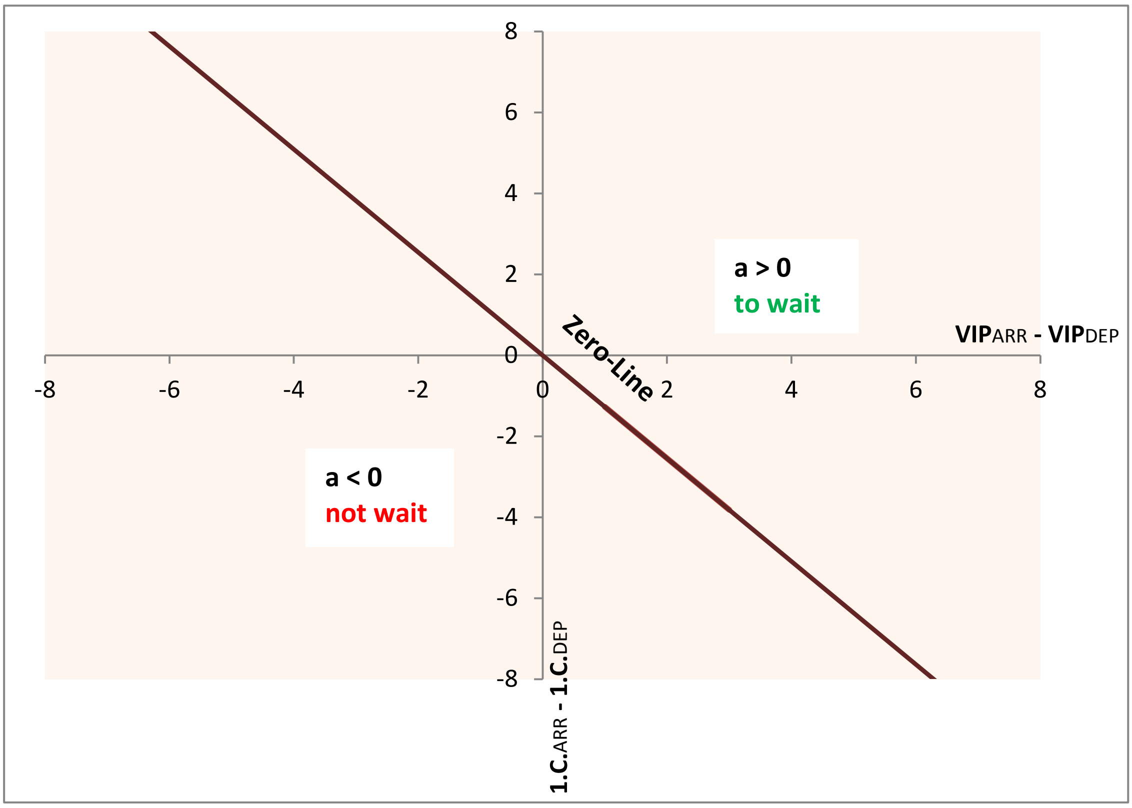
"Zero-Line" dividing *to wait* and *to not wait*
(VIPARR-VIPDEP) / (1.C.ARR-1.C.DEP)

The *value of the passenger* **α**		
VIP-Pax	**α1**	**0,448**
1.C-Pax	**α2**	**0,352**
BUS/FFPs-Pax	**α3**	**0,2**
	α1+**α2**+**α3**=1	1

Calcultion of the "zero-line" laying between the decision possibilities "to wait" and "not to wait"

(BUS+FFP)ARR - (BUS+FFP)DEP	VIPARR - VIPDEP	1.C.ARR - 1.C.DEP
0	1	-1,2727
0	2	-2,5455
0	3	-3,8182

VIPARR - VIPDEP	1.C.ARR - 1.C.DEP
1	-1,27
2	-2,55
3	-3,82



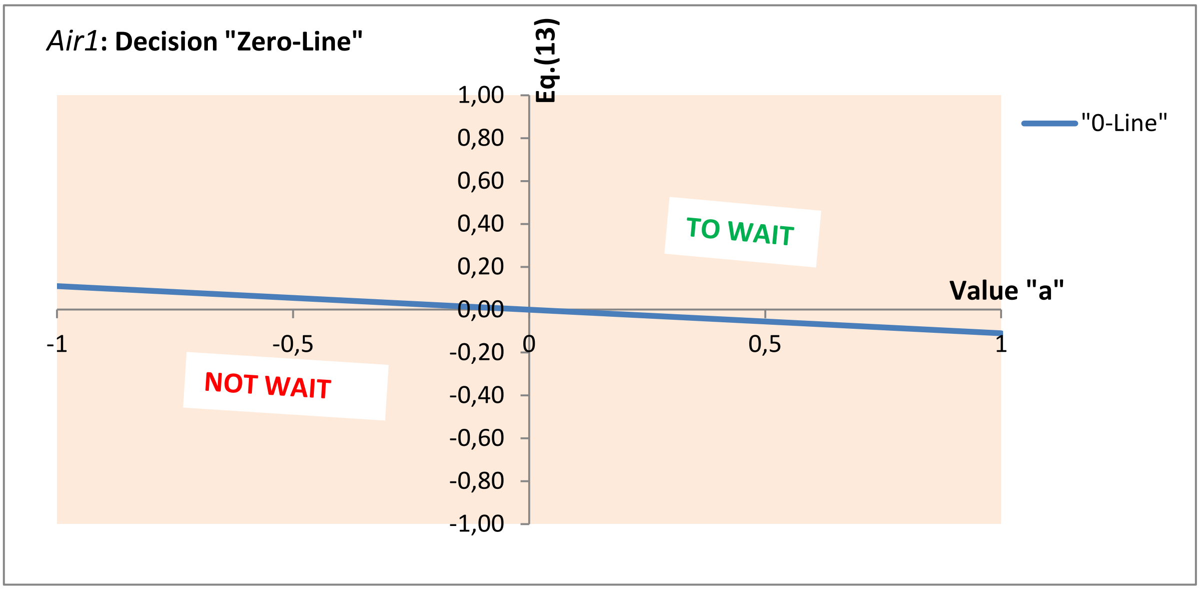
Zero-Line (a=0) for both Passenger-Importance Sets

	Pax-Groups Configuration	
The Passenger-Importance Value applied	Difference by 1 Pax	Difference by 2 Paxs
α1=0,45; α2= 0,35; α3= 0,2	VIPARR-VIPDEP = 1 --> 1.C.ARR - 1.C.DEP = -1,2727 VIPARR-VIPDEP = 1 --> [(BUS+FFP)ARR - (BUS+FFP)DEP] = -2,24 1.C.ARR - 1.C.DEP = 1 --> [(BUS+FFP)ARR-(BUS+FFP)DEP] = -1,76	VIPARR-VIPDEP = 2 --> 1.C.ARR - 1.C.DEP = -2,5455 VIPARR-VIPDEP = 2 --> [(BUS+FFP)ARR - (BUS+FFP)DEP] = -4,48 1.C.ARR - 1.C.DEP = 2 --> [(BUS+FFP)ARR-(BUS+FFP)DEP] = -3,52
α1=0,8; α2= 0,12; α3= 0,08	VIPARR-VIPDEP = 1 --> 1.C.ARR - 1.C.DEP = -6,75 VIPARR-VIPDEP = 1 --> [(BUS+FFP)ARR - (BUS+FFP)DEP] = -9,80 1.C.ARR - 1.C.DEP = 1 --> [(BUS+FFP)ARR-(BUS+FFP)DEP] = -1,45	VIPARR-VIPDEP = 2 --> 1.C.ARR - 1.C.DEP = -13,51 VIPARR-VIPDEP = 2 --> [(BUS+FFP)ARR - (BUS+FFP)DEP] = -19,6 1.C.ARR - 1.C.DEP = 2 --> [(BUS+FFP)ARR-(BUS+FFP)DEP] = -2,90

Airline Air1
Decision "Zero-Line"

Airline Air1
APP (Air1): 0,1*a + 0,9*(y-z)
For: APP (Air1) = 0
(y-z) = -0,1/0,9*a = -0,11a
"0-Line": (y-z) = -0,11*a, for

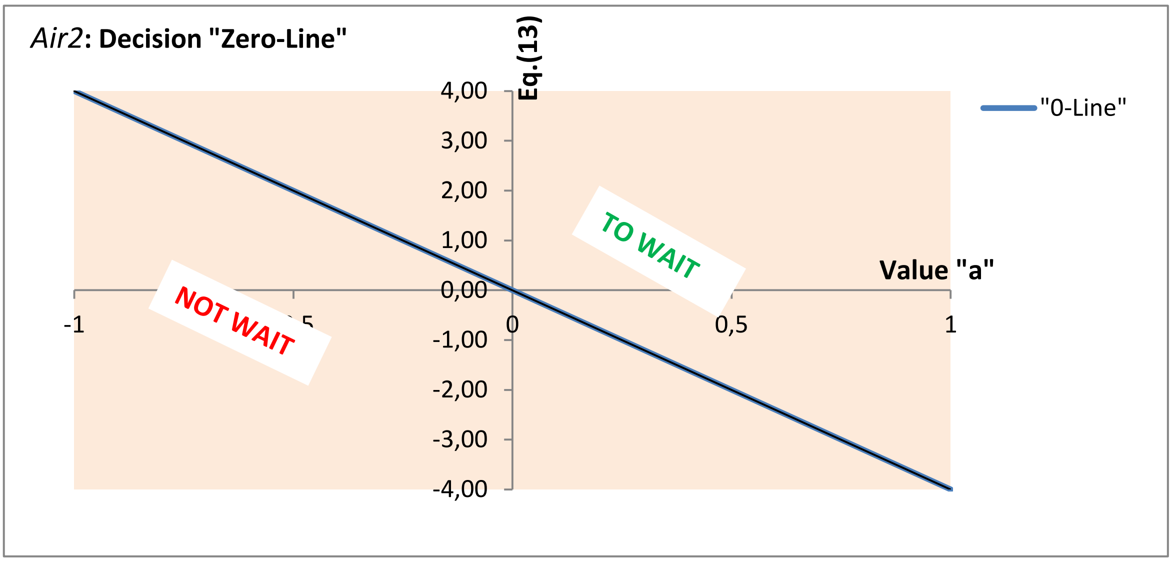
Value a	"0-Line"
-1	0,11
-0,75	0,08
-0,5	0,06
-0,25	0,03
0	0,00
0,25	-0,03
0,5	-0,06
0,75	-0,08
1	-0,11



Airline Air2
Decision "Zero-Line"

Airline Air2
APP (Air1): 0,8*a + 0,2*(y-z)
For: APP (Air2) = 0
(y-z) = -0,8/0,2*a = -4a
"0-Line": (y-z) = -4*a, for a ϵ [-1,1]

Value a	"0-Line"
-1	4,00
-0,75	3,00
-0,5	2,00
-0,25	1,00
0	0,00
0,25	-1,00
0,5	-2,00
0,75	-3,00
1	-4,00



3.1 DENIED BOARDING ASSISTANCE

You may choose between:

- rerouting to your final destination under comparable transport conditions as soon as possible as indicated by the airline, or at a later date at your convenience, subject to the availability of seats; and
- reimbursement for the part or parts of your journey that were not made, and for the part or parts already made if the flight no longer serves any useful purpose, taking into consideration the original flight plan, and also a return flight to the first point of departure as noted on the ticket (if applicable).

In addition, you will receive free of charge:

- meals and refreshments in reasonable relation to the waiting time;
- hotel accommodation in cases where an overnight stay or a stay in addition to that which you originally intended becomes necessary (transport included);
- one prepaid phone card or the cost of two telephone calls (limited to 5 minutes each), fax messages or e-mails.

3.2 DENIED BOARDING COMPENSATION

If you have been denied boarding against your will, compensation will be offered at the airport. You can choose between non-refundable transportation credit voucher/Electronic Miscellaneous Document (EMD) and refundable credit voucher (cash).

The non-refundable transportation credit voucher/Electronic Miscellaneous Document (EMD) amounts as follows:

A	Flights of 1500 km or less	EUR 350*
B	Flights within the EU of more than 1500 km, and all other flights between 1500 and 3500 km	EUR 500*
C	Flights not falling under A or B	EUR 800*

And the credit voucher refundable (cash) amounts as follows:

A	Flights of 1500 km or less	EUR 250*
B	Flights within the EU of more than 1500 km, and all other flights between 1500 and 3500 km	EUR 400*
C	Flights not falling under A or B	EUR 600*

* This compensation may be reduced by 50% if the arrival time of the alternative flight does not exceed the scheduled arrival time of the original flight by two hours (flights falling under A), three hours (flights falling under B) or four hours (flights falling under C).

This compensation scheme is based on EU Regulation 261/2004. If you are departing from an airport outside the EU (but to a destination in an EU country), local regulations and other compensation schemes may apply. For more information, please contact Customer Care (section 5).

4 DOWNGRADING

If you are involuntarily placed in a lower class than that for which your ticket was purchased, you may request reimbursement of:

A. 30% of the flight price for all flights of 1500 km or less, or
B. 50% of the flight price for all flights within the EU of more than 1500 km, and all other flights between 1500 and 3500 km, or
C. 75% of the flight price for all flights not falling under A or B.

In addition, Air France/KLM will offer you at the airport a non-refundable credit voucher (goodwill compensation) according to the length of your flight and your class of transportation.

5 REIMBURSEMENT REQUESTS, CANCELLATION COMPENSATION CLAIMS AND OTHER INQUIRIES

As described above, if you do not wish to pursue your initial travel plans because:

- your flight is cancelled, or
- your flight is delayed for at least five hours, or
- you have been denied boarding against your will,

You may request reimbursement for the part or parts of the journey you have not made and for the part or parts already made if the flight no longer serves any useful purpose, taking into consideration your original flight plan.

If you wish to get in touch with Air France/KLM regarding a reimbursement request, a compensation claim or with any other inquiry, please contact the local Air France/KLM Customer Care office, preferably by e-mail. Contact details can be found at www.airfrance.com or www.klm.com.

6 NATIONAL DESIGNATED BODIES

Each EU member state has designated a body responsible for the enforcement of the compensation and assistance rules as outlined in this Notice.

Contact details here:
http://ec.europa.eu/transport/themes/passengers/air/doc/2004_261_national_enforcement_bodies.pdf

We ask you to first contact the local Customer Care office of the airline that was your operating carrier (contact details are available through the website of the airline operating the flight).

AIRFRANCE KLM

Assistance And Compensation

In case of cancellations, delays, downgrading and denied boarding

This Notice is required by Regulation 261/2004 of the European Parliament and of the Council of the European Union.

Version 1
Valid from 1 September 2013

KLM5771-09.13

THE RIGHTS REFERRED TO IN THIS BROCHURE APPLY IN THE FOLLOWING CIRCUMSTANCES:

- Your operating carrier is:
  - Air France or KLM, or
  - either CityJet or Hop!, or
  - Delta Air Lines and Kenya Airways (when departing from an airport in the EU)
- You have a confirmed reservation on the flight;
- You are fully checked in at the time indicated or, if no time is indicated, not later than 45 minutes before the time of departure;
- You are travelling on a fare available directly or indirectly to the public, or on a ticket issued under a frequent flyer programme;
- You are travelling on a flight departing from an airport in the EU, or on a flight operated by a Community air carrier departing from an airport in a third country to an airport in the EU, unless local legal regulation applies in that third country.

1 CANCELLATION

1.1 CANCELLATION ASSISTANCE

If your flight is cancelled, you may choose between:

- rerouting to your final destination under comparable transport conditions as soon as possible as indicated by the carrier, or at a later date at your convenience, subject to the availability of seats; and
- reimbursement for the part or parts of your journey that were not made, and for the part or parts already made if the flight no longer serves any useful purpose, taking into consideration the original flight plan, and also a return flight to the first point of departure as noted on the ticket (if applicable).

In addition, you will receive free of charge:

- meals and refreshments in reasonable relation to the waiting time;
- hotel accommodation in cases where an overnight stay or a stay in addition to that which you originally intended becomes necessary (transport included);
- one prepaid phone card or the cost of two telephone calls (limited to 5 minutes each), or 2 fax messages or 2 e-mails.

1.2 CANCELLATION COMPENSATION

If the cancellation is brought to your attention less than two weeks before the planned departure date, you are not entitled to compensation, as long as the departure and arrival times of the new flight are close to the original departure and arrival times:

- a maximum of two hours before the scheduled departure time and a maximum of four hours after the scheduled time of arrival if you were informed between two weeks and seven days before departure;
- a maximum of one hour before the scheduled departure time and a maximum of two hours after the scheduled time of arrival if you were informed less than seven days before departure.

This cancellation compensation cannot be paid at the airport and therefore you need to contact Customer Care (see section 5). You can choose between compensation offered in non-refundable transportation credit voucher/Electronic Miscellaneous Document (EMD) and refundable credit voucher (cash).

The non-refundable transportation credit voucher/Electronic Miscellaneous Document (EMD) amounts are as follows:

A	Flights of 1500 km or less	EUR 350*
B	Flights within the EU of more than 1500 km, and all other flights between 1500 and 3500 km	EUR 500*
C	Flights not falling under A or B	EUR 800*

The refundable credit voucher (cash) amounts are as follows:

A	Flights of 1500 km or less	EUR 250*
B	Flights within the EU of more than 1500 km, and all other flights between 1500 and 3500 km	EUR 400*
C	Flights not falling under A or B	EUR 600*

* This compensation may be reduced by 50% if the arrival time of the alternative flight does not exceed the scheduled arrival time of the flight originally booked by two hours (flights falling under A), three hours (flights falling under B) or four hours (flights falling under C).

The airline operating the flight is not required to pay compensation if the cancellation is caused by extraordinary circumstances which could not have been anticipated by the airline and if the airline has taken all reasonable measures to avoid the cancellation.
This compensation scheme is based on EU Regulation 261/2004. If you are departing from an airport outside the EU (but to a destination in an EU country), local regulations and other compensation schemes may apply. For more information, please contact Customer Care (section 5).

2 DELAY

2.1 DELAY ASSISTANCE

The assistance as described in this section is provided in the event that a flight is delayed beyond its scheduled time of departure for 2h or more.
You will be offered free of charge:

- meals and/or refreshments in reasonable relation to the waiting time;
- hotel accommodation in cases where an overnight stay or a stay in addition to that which you originally intended becomes necessary (transport included);
- one prepaid phone card or the cost of two telephone calls (limited to 5 minutes each), fax messages or e-mails.

If you do not wish to continue with your initial travel plans when there is a delay of at least five hours, you may opt for reimbursement for the part or parts of the journey not made and for the part or parts already made if the flight no longer serves any useful purpose, taking into consideration the original flight plan. You may also opt for a return flight to the first point of departure as noted on the ticket (if applicable).

2.2 DELAY COMPENSATION

If you have been delayed at arrival equal or more than 3 hours, after the scheduled arrival time, you are entitled to compensation, except if the delay is caused by extraordinary circumstances which could not have been anticipated by the airline and if the airline has taken all reasonable measures to avoid the delay. The compensation cannot be paid at the airport and therefore you need to contact Customer Care (see section 5). You can choose between compensation offered in non-refundable transportation credit voucher/Electronic Miscellaneous Document (EMD) and refundable credit voucher (cash).

The non-refundable transportation credit voucher/Electronic Miscellaneous Document (EMD) amounts as follows:

A	Flights of 1500 km or less	EUR 350*
B	Flights within the EU of more than 1500 km, and all other flights between 1500 and 3500 km	EUR 500*
C	Flights not falling under A or B with a delay beyond 4h	EUR 800*

And the refundable credit voucher (cash) amounts for as follows:

A	Flights of 1500 km or less	EUR 250*
B	Flights within the EU of more than 1500 km, and all other flights between 1500 and 3500 km	EUR 400*
C	Flights not falling under A or B with a delay beyond 4h	EUR 600*

* This compensation may be reduced by 50% for flights of more than 3500 km if the arrival time of the delayed flight is between 3 and 4 hours after the scheduled arrival time.

This compensation scheme is based on EU Regulation 261/2004. If you are departing from an airport outside the EU (but to a destination in an EU country), local regulations and other compensation schemes may apply. For more information, please contact Customer Care (section 5).

3 DENIED BOARDING CONDITIONS

In the event of an overbooked flight, the airline will call for volunteers who are prepared to surrender their confirmed reservation in exchange for an agreed compensation in Transportation Credit Vouchers/Electronic Miscellaneous Document (EMD). We will also offer the appropriate assistance as described in section 3.1 below. If not enough volunteers can be found and you are denied boarding against your will, you are entitled to denied boarding assistance and compensation providing you have met the latest check-in time requirements. You are not entitled to this if there are reasonable grounds to deny boarding, such as reasons of health, safety, security or inadequate travel documentation.