Robust Scheduling for the Bay and Gate Assignment

A Kenya Airways Case Study

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J.O.Deken

Technical University Delft

Delft University of Technology

Kenya Airways
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Robust Scheduling for the Bay and Gate Assignment

A Kenya Airways Case Study

Master Of Science Thesis

For obtaining the degree of Master of Science in Aerospace Engineering at Delft University of Technology

J.O. Deken B.Sc

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Graduating professor:	Prof. dr. R. Curran,	Delft University of Technology
University supervisors:	ir. P.C. Roling	Delft University of Technology
	dr. B.F. Santos	Delft University of Technology
Industry supervisor	T. Omondi	Kenya Airways, Director Strategy and Performance
	Gordon Anymiu	Kenya Airways, Manager HCC
	Tom Ogendo	Kenya Airways, Head RS

Faculty of Aerospace Engineering - Delft University of Technology
Department Of Control & Operations - Air Transport & Operations

The undersigned hereby certify that they have read and recommend to the Faculty of Aerospace Engineering for acceptance a thesis entitled **"Robust Scheduling for the bay and gate assignment"** by **J.O. Deken** in partial fulfilment of the requirements of the degree of **Master of Science**

Dated: November 27, 2015

Graduating professor:

Prof. dr. R. Curran

University supervisor:

ir. P.C. Roling

University supervisor:

Dr. ir. B.F. Santos

Industry supervisor:

T. Omondi

Reader:

Dr. ir. M. Voskuijl

Summary

The aviation industry is known for its limited profitability margins. This drives the industry to continuously optimize their operations within an often constrained airport environment. Kenya Airways is not an exception in this case, especially when considering the current over-constrained resources both in the morning peak as well as in the evening peak. These resources include the amount of bays, the amount of gates and even the availability of man power. Where the bay is the parking stand of the aircraft and the gate is the position where passengers board their flight. Therefore, Kenya airways (KQ) wants to benchmark their operations and develop tools to optimize their use of resources.

One of these tools concerns the bay and gate assignment, which has influence on the on-time performance as well as on the required resources. Every major airport has to deal with this bay and gate assignment problem that consist of assigning flights to bays and gates under a certain set of objectives and constraints. Although assignment problems are well defined, they often can be hard to solve due to their size, constraints and conflicting objectives. These conflicting objectives are mainly resources that are interconnected such as: bays, gates, terminals, crews, baggage, flights and ground services. In addition to these points it has to cope with the dynamic operational environment. The cost of delays due to this dynamic property is enormous for airlines, so any solution that satisfies the objectives and can deal with the dynamic operational environment is valuable. Currently, Kenya Airways performs this process manually resulting in a high work load and non optimal transitions between shifts.

This thesis addresses these issues by developing a robust bay and gate assignment tool that improves the use of resources and reduce the operational complexity. The hypothesis can then be formulated as: *"A robust bay and gate assignment model can be developed which optimizes for minimum aircraft reposition as well as for minimum passenger transport time"*.

Literature has thoroughly addressed the bay assignment problem which belongs to the NP-hard class of mathematically complex problems. Meaning that it are time consuming problems to solve. Literature has proposed multiple optimization objectives seen from both the passenger, airline or a combined point of view. To solve these problems several solution methods were developed consisting of optimization, simulation, expert systems or a combination of those. However, limited research has been done in developing and comparing robust methods. In addition, no research has been done to the combination of the bay and gate assignment which for Jomo Kenyatta International Airport (JKIA) is an important point to consider since they have more bays then gates.

This thesis introduces the concept of combining the bay and gate assignment to complement the existing objective to minimize the operational cost and maximize passenger convenience. In addition, this thesis will investigate the use of robust measures and will introduce a novel robust scheduling method called robust optimization. The main idea is to use adjacency constraints for the bay assignment to take the main limiting constraints of the gate assignment into account. For the robust objective the strategy is to run multiple simulations containing various delay cases to analyse the robustness of the selected robust methods. The robustness is measured using two performance indicators: one being the amount reassignments required and second being the cost of the robustness.

The robust methods selected in this research are the use of fixed buffer times, the use of spare bays in combination with fixed buffer times and the use of robust optimization. The use of buffer times is set to 30 minutes since this is common in operations. Therefore it is an interesting way to measure the value of the other two robust methods compared to the actual operations. The need for a novel method is required since the use of buffer times in models are very static and cannot cope with historical data. The manual use of buffer times can take historical data into account, depending on the knowledge and quality of the bay planner.

Robust optimization is previously used for control algorithms and is becoming more common in use. The underlying principle is that the model tries to generate a solution based on multiple plausible scenarios. In this thesis the main flight schedule is used as a base with hard constraints and in addition soft constraints are added representing additional flight schedules including delays. These applied delays are randomly selected based on historical data and therefore have some advantages over the use of buffer times. Where buffer times are mostly fixed to 30 minutes this method is more dynamic.

Besides these robust methods it is important that the model provides feasible and valuable solutions to the main stakeholders. Although the bay assignment is a largely generic problem it is still influenced strongly by specific stakeholders, their procedures and other airport specific constraints. These all have to be correctly modelled. After a thorough analysis of the stakeholders objectives and the current preferred solutions, four optimization objectives were identified. These are:

1. Minimization of aircraft repositioning
2. Maximization of airline preferences
3. Minimization of passenger transport distance
4. Maximizing the robustness of the schedule

From these four objectives the first three are used in the objective function in combination with the airport specific constraints. This translates the physical problem into a linear model. The fourth considered objective is the main focus of this thesis. Since the maximization of robustness is a hard instance to measure the conclusions will be based on comparisons of the three baseline models with the use of simulations. For the use of buffer times and spare bays this requires the adjustment of constraints and for robust optimization it requires an additional penalty value in the objective function.

The constructed mathematical model is incorporated into a usable prototype software tool. The program code is written in python and linked to the offline data sheets of KQ. This constructed the base for the optimization model which is then solved with the use of IBM ILOG CPLEX. The output is the produced using an interactive html tool called Bokeh. This allows the results to be used in operations more effectively compared to the current situation where they work with tables only.

Operationalization of the bay and gate assignment is tested with two test cases at Jomo Kenyatta International Airport. These are Tuesday 02-06-2015 and Wednesday 05-07-2015. Where the Tuesday is an average day used for the comparison of robust scheduling and Wednesday is a peak day used for validation. Results show that the model produces similar results as the actual bay and gate assignment for both days.

With the model being validated results can be drawn for robust scheduling. Since the bay assignment of JKIA is very constrained with many flight preferences two cases are analysed. One including the use of flight preferences and one excluding the use of flight preferences. It can be concluded that the use of robust optimization does indeed outperform the use of buffer times in terms of the amount of reassignments for both cases. For the case including flight preferences the differences are minimal but for the case excluding the flight preferences the robust optimization (RO) model outperforms the use of buffer times significantly. This is as expected since the use of RO has advantages over the use of buffer times. However, the disadvantage is that the process is randomized and that not all the scenarios can be considered. This means that for each run different delay scenarios are considered which can make the model results unstable. With unstable is meant that the amount of reassignments required can vary from run to run, where the standard deviation is the measure of stability. For the case including preferences the model becomes unstable for the worst three simulation cases. It can then also be concluded that the selection of the robust method strongly depends on the current flight schedule (preferences) and the severity of the delays you want to design for. For the cases without flight preferences and the first 7 simulation cases of the model including flight preferences the RO model is stable and preferred.

The validation and verification process of the project proves that the bay and gate assignment produces correct and representable results. The process is based on an academically standardized verification and validation strategy to analyse the conceptual validity, the operational validity, the computational correctness of

both the model and the input data thoroughly. The operation validity is tested by comparing the amount of reassignments with the actual delay data of 02-06-2015. Results show that one reassignment less is required when using RO. This implies to the intended concept of RO which has it advantages over the use of buffer times. Note that this holds for automated solutions and not the the manual solutions.

Since the quality of the bay assignment is strongly depended on the tail assignment made, it is important to look into this connection. Therefore, embedding the bay and gate assignment tool with the tail assignment can be the next step towards operational excellence for Kenya Airways. This is then also recommended for further research.

Acknowledgements

This research project is the end product of my 2 year Master's program at Delft University of Technology and marks the formal end of 10 months of research. In this last period I did not only learn how to do proper research but I also gained a lot of experience on other fronts. Travelling and living in Kenya was one of these great lessons I gained and truly enjoyed. Therefore, I would like to thank all the people involved in making this long journey successful.

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Jakko Onno Deken
Delft, 27 November 2015

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ABBREVIATIONS

DCE Duty Control Engineer

DMO Duty Manager Operations

DRC Duty Ramp Controller

GAP Gate Assignment Problem

HCC Hub Control Center

JKIA Jomo Kenyatta International Airport

KQ Kenya Airways

MPS Mathematical Programming System

WB Wide Body Aircraft

NP Non-polynomial bounded problem

OCC Operations Control Center

RO Robust Optimization

SD Standard deviation

STPV State Pavilion Bays

WB Wide Body Aircraft

NOMENCLATURE

B Bay Compliance Matrix containing the information whether ac type and bay are compatible

D array containing the distances from the various terminals to all the bays

D2 array containing the distances from all bays to all the gates

DOM array containing the information whether a departure flight is domestic

F Array containing the information whether the bay has a fuel pit

i index representing the flight

k index representing the bay

l index representing the gate

P array containing the number of passengers for each flight

PARK Array containing the information whether a flight is a ”Full', Arrival, Parking or Departure activity'

PREF array containing all preferences for each flight bay combination

PREF2 array containing all preferences for each flight gate combination

S penalty value for adjacency constraints

T Time Matrix containing the information whether flight pairs are conflicting

TD Time Departure Matrix containing the information whether boarding activities of departing flight pairs are conflicting

term index representing the check-in terminal

U variable containing the the number of towings from arrival to parking in the night shift

V array containing the number of towings from parking to departure

W variable containing the number of towings during day time

X Binary Decision Variable

z1 bay objective function containing the passenger transport distance

z2 bay objective function containing the flight preferences

z3 bay objective function containing the penalty values for repositioning

z4 total bay objective function excluding penalty values

z5 total bay objective function including penalty values

z6 gate objective function containing the passenger transport distance

z7 gate objective function containing the flight preferences

z8 gate objective function containing the penalty values representing double scheduled gates

z9 Total gate objective function

1
INTRODUCTION

Every major airport has to deal with the Gate Assignment Problem (GAP) that consist of assigning flights to gates under a certain set of objectives and constraints. Although assignment problems are well defined, they often can be hard to solve due to their size, constraints and conflicting objectives. In addition, the still increasing demand for air travel is making the problem more complex and results in congested air traffic control and airport systems [4]. This increase in air traffic makes the airport resources scarce and valuable, although more airport resources are made available, they are still insufficient for the demands of future air traffic [5]. To be able to cope with the costs of these congestions, most airlines have developed their own tools to minimize the impact on the service [6]. Likewise, airports are also benchmarking their operations to improve capacity and prevent delays as best as possible. This to prevent extravagant expansions and reduce operational costs. In 2007 flight delays reached a peak and induced nationwide costs of over 30 billion dollar during that year [7].

These high numbers of delays have a large impact on the current gate assignment performance. To give a rough indication: last year at Amsterdam Airport 40% of the flights had at least one gate change compared to the initial optimized schedule [8]. Consequently, this will result in delays suffered by airlines, airports, ground handlers and passengers. In addition, the reassignments do not only require constant monitoring by gate planners, but also reduces the potential benefits from the initial solution. With the increased utilization and problem size of the airport systems, the need for robust solution methods are becoming more important [9]. Therefore, the focus of this thesis is not only on obtaining a good initial solution but also a solution that performs well on the day of operations. This is referred to as a robust schedule that is in a way insensitive to variations in the flight schedule.

This research is commissioned by Kenia Airways (KQ) and will therefore use Jomo Kenyatta International Airport (JKIA) as a study case. Because of the fact that JKIA has more bays then gates, the airport has to make a division between the bay assignment and the gate assignment. Bays are the parking stands for aircraft and gates are the locations where passengers board their flight. The introduction of this division comes together with the introduction of new objectives, resulting in a more complex model. Therefore, the project is called the bay and gate assignment since Kenia Airways wants to solve this issue and reduce the complexity of their daily planning. In the current situation they solve both the bay assignment and the gate assignment manually for the initial planning and the operational planning, resulting in a high work load and a low solution quality. This research project aims to tackle these issues by introducing a new solution method that can optimize the robustness of the bay and gate schedule while minimizing the passenger inconvenience and the operational complexity.

Although the context of this research is very specific for JKIA, with Kenya Airways operating at this airport, the aim of the research is to provide a generalized solution method for the robust bay and gate assignment problem, rather than just a solution to the specific airport bay and gate assignment. The approach used in this thesis is situated in the field of airline operations research. This approach is an integral part of operations research and is referred to as combinatorial optimization techniques.

The importance of this thesis is related to the main objective of each airline to achieve a profitable flight schedule. Profit driven by revenue and costs must be optimized as the aviation is an industry with only marginal profit margins. Therefore, to enhance the product quality of the airline and the airport a robust bay and gate assignment will help increase the on-time performance and decrease the costs of operations. This research will investigate the different methods from literature to provide a robust schedule and will compare them using one test case with the same performance indicator (something that is missing in literature). In addition, it will introduce and develop two new methods obtained from other fields and compare it to the working of used methods in the literature on the bay assignment. The first new method is based on the relative new concept of robust optimization [10], where the uncertain constraints are formulated with a robust counterpart taking into account multiple scenarios. The other novel approach will be the use of spare bays to be able to absorb flight delays and prevent the snow ball effect of delays, which is a common approach in multiple fields [11].

As already mentioned Kenia Airways is used as test case to be able to validate the results of the different models. Kenya Airways is currently one of the largest airlines in Africa and continuously trying to improve its quality. Furthermore, Kenya Airways has just confirmed that it will be allowed to fly routes to the United States in the near future. These new plans in combination with their already ambitious expansion plans, their on-time performance criteria and their overall product quality, pressurizes the bay and gate assignment at their main hub JKIA. This stimulated the start of this thesis, that tries to improve their current on-time performance criteria while taking operational cost and product quality into account.

The outline of the remainder of this thesis is as follows. First, Chapter 2 will deal with the problem description in more detail including an overview of the existing work in the research field of the bay and gate assignment. This is followed by Chapter 3 that will elaborate on the scientific set-up and the research methodologies of this thesis. As third, Chapter 4 provides the background information necessary to understand the specific objectives and constraints of KQ and JKIA. This is done through a stakeholder analysis, description of the current procedures of the bay and gate assignment and an identification of the specific airport constraints. Next Chapter 5 translates the physical problem into a linear model, meaning that a objective function is constructed and all constraints are identified and set. From the linear model, the next step is to construct the software program and analyse the first results which will be done in Chapter 6. Chapter 7, will then proceed with a more thorough analysis of the results and will draw conclusions on the applicability of the model. When the model is working as expected the results for robust scheduling are drawn in chapter 8. Lastly, to check if the model is stable and working as expected Chapter 9 will verify and validate the results followed by the conclusion and discussion in Chapter 10. The chronological of information is displayed in Figure 1.1.

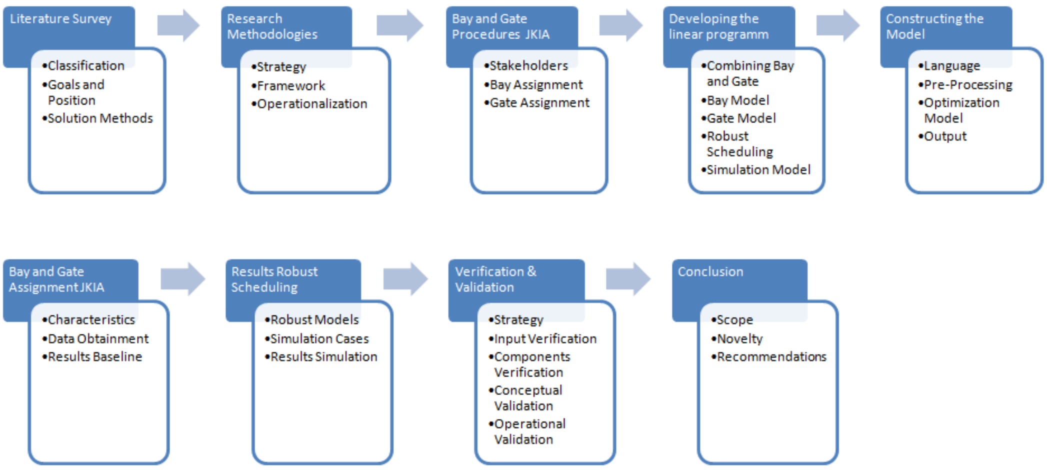


Figure 1.1: Chronological order of the outline of this thesis

2

Literature Survey

The still increasing demand for air travel and the marginal profits in the airline industry requires airlines to effectively and efficiently use available resources at hand. The bay and gate assignment can help airlines to increase these profits which ultimately is the high end objective of the airlines. This high end objective can be further divided into sub objectives of which some are applicable for the bay and gate assignment. Increasing the on-time performance is one of them and will increase the value of the product and decrease operational costs due to the reduction of delays. Another objective applicable is the minimization of the direct ground operations costs. This can be achieved by centralizing services and minimizing additional operations such as towings. Again achieving a satisfying on-time performance is crucial for the reduction of costs and the product quality. More specifically flight delays have proven, based on the method described by Cook et al. [12], to cost Kenya airways $0.32 per passenger per minute [13].

One aspect where the airline can improve its on-time performance is by having a sound bay assignment, which is able to deal with disruptions in the operational flight schedule. The bay assignment is the art of assigning flights to bays while coping with all airport specific constraints. In this chapter relevant literature for the research to the bay and gate assignment will be elaborated. In Section 2.1 a similar classification of Cheng [1] is used to address and sort all used formulations. Each formulation comes with its own unique solution methods which will be given in Section 2.2. Lastly, in Section 2.3 the location of the bay assignment process within the airline processes will be explained and a brief summary of the literature study with all still active goals will be given.

2.1. Bay and Gate Assignment Classification

The formulation of the bay and gate assignment is usually divided into two categories, namely static and stochastic/robust models. As the name already indicates the main difference between the two is that the static model deals with a deterministic formulation. It does not cover any disturbances such as flight delays and flight disruptions, as the stochastic/robust models do. However, in this research a further distinction will be made between the used objectives. First the objectives are classified as robust or as non robust. Then for the non robust class all the static objectives of the stakeholders are included. These are the minimization of passenger walking distance, towings, etc.. Then the robust class is divided in stochastic programming and robust modelling. The main difference between the two is the fact that stochastic programming starts by assuming the uncertainty has a probabilist description where in robust optimization the uncertainty is rather deterministic and set-based. They both deal with handling uncertainty with is refereed to as dynamic models. A schematic overview of the bay assignment classification is given in Figure 2.1. Note that under robust models only two methods are used where in literature there exist various interesting methods to be used such as robust optimization [14]. Independent of this classification the bay assignment can be classified as NP-hard problem. This will be further elaborated in subsection 2.1.3.

2.1.1. Static Models

The first static model that was developed for the bay assignment was published in 1988 by Braaksma [15]. His article was the base for research on the bay assignment. Where at the beginning much effort was put on the

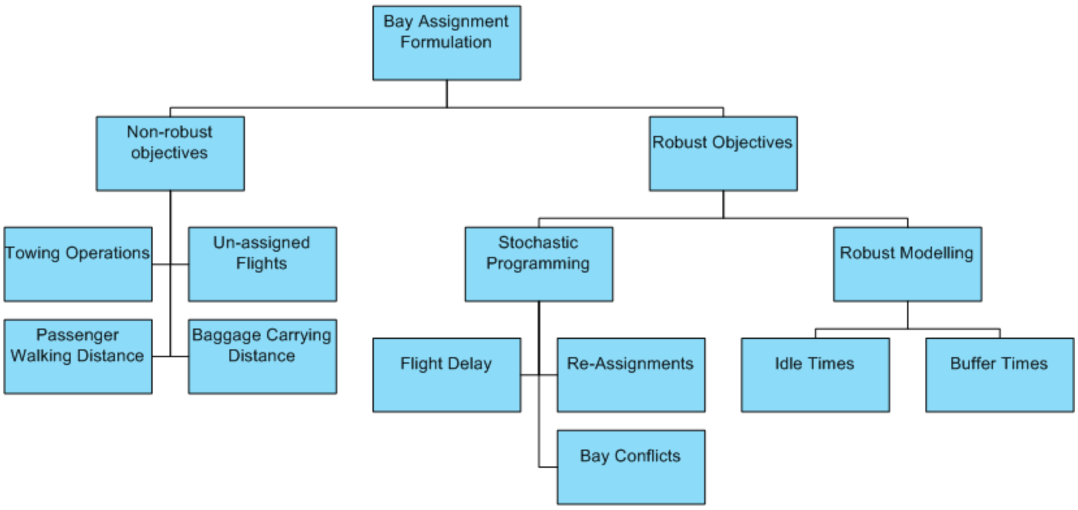


Figure 2.1: Bay assignment classification an extension on Cheng et al. [1]

reduction of complexity and lately the focus is more on the development of robust multi-objective models. Within the static category a further subdivision can be made based on the used objectives. These objectives on its own can also be classified to the three main drivers/stakeholders: the passenger, the airline, the airport or a combination of those.

The objective of the first developed model ”the minimization of passenger walking distance” is strongly passenger driven and is still one of the most considered objectives. Other models that consider this objective are the work of Babic et al. [16], Mangoubi and Mathaisel [17], Haghani and Chen [18] and Xu and Bailey [9]. Although, the models consider the same objective they still differ in their use of solution methods and also their ability to consider transfer passengers. To optimize for the transfer distance information is needed from two flight bay combinations requiring a quadratic term to solve. Mangoubi and Mathaisel noted the complexity of the model and tried to solve this by estimating the location of the second flight with probability functions based on historical data. Xu and Bailey, did solve the quadratic assignment within a certain time bound by using meta -heuristics. However, until now this objective is still a problem to solve within a certain time bound. Van Goethem [2] developed a functional heuristic for the quadratic problem to be able to solve the problem within a certain time bound. However, functional heuristics come with many assumptions and are less exact. In addition, the running times still exceeded 1 hour to reach a certain offset from optimality. Other similar passenger related objectives are the ”minimization of baggage carrying” as in the work of Chang[19] and the minimization of the total passenger waiting time as in the work of Lim et al. [20] and Yan and Huo [21].

The second subcategory contains the airline driven objectives. The main objective from airline perspective is of course the maximization of profit. For the bay assignment this can be translated to the minimization of operational costs and the maximization of passenger convenience. This implies that all passenger oriented objectives are also airline oriented. The minimization of operational cost within the static category is often formulated as the minimization of aircraft movements. However, no emphasize is put on the operational efficiency yet. In many cases and fields the centralization of services can minimize operational costs. In operations, Kenya Airways want to centralize their boarding services to mainly Terminal A to minimize the need of ground personnel. For the bay assignment and gate assignment this can result in a reduction of the number of ground personnel.

The last subcategory involves the airport driven objectives. In research no direct link with airport driven objectives can be found. However, many used objectives are indeed also airport driven. For example, as in the case of the airline driven objectives the passenger convenience also influences the revenue of the airport making all used passenger driven objectives also airport driven objectives. An other example is the number of aircraft movements, this can influence the maximum throughput capacity of the taxi way which the airport want to optimize. Making the minimization of the number of towings also an airport related one.

2.1.2. ROBUST/DYNAMIC MODELS

The second main category involves handling uncertainty in the formulation. This to take the dynamic effects due to delays in airline operations into consideration. Several objective functions are developed in the literature of the bay assignment to take these effects into account. Most of these are multi-objective formulations including static objectives. This makes it hard to accurately classify this literature as is the case in the work of Yan and Huo [21], Dorndorf et al. [22], Drexl and Nikulin [23] and Hu and Paolo [24].

The different formulations to deal with the uncertainty can be classified into two subcategories. The first category is the use of robust scheduling methods to adopt delays. In literature often use is made of static buffer times to avoid delays or to adopt delays. Hassounah and Steuart[25] concluded in their research that the use of buffer times can indeed decrease the impact of delays. However, no research was done to the length of the buffer times and what affect is has on the optimality of the solution. In addition, Yan et al. [26] developed a simulation model to be able to adjust buffer times and make them flexible to analyse the effects of different buffer times on the robustness and on the objective function. This is also known as solution robustness and model robustness. Another used concept of modelling robustness is the minimization of the range and variance of the idle times as in the work of Bolat [27–29]. In his first research he used the former objective the maximization of minimum idle times, which resulted in unwanted long idle times at the beginning and ending of the schedule. Therefore, he developed a new model to minimize the variance that unfortunately requires a quadratic objective function. The second category contains the objective functions used to minimize flight delays, reassignments or bay conflicts as in the work of [26, 30, 31]. It must be noted that to use these types of formulations predictions are needed to model the uncertainty. These predications can be developed by hand[26], by simulation[26, 32] or use is made of stochastic programming[30, 31].

Stochastic programming is a conventional mean for optimization problems with probabilistic information in the field operation research. It has undergone many theoretical developments since the 1950s. Starting with the pioneering work of Dantzig [33] and Beale [34]. Although, stochastic programming has been studied for decades, conventional stochastic programming models are severely limited owing to its inability to handle risk aversion or decision-makers preference in a direct manner. Subsequently, the main challenge is that of computational complexity and required data on probability. Where the computational complexity can be attributed to the presence of multi-dimensional integration (to calculate either expectation or probability) within the optimization algorithm and the presence of chance-constraints.

Two other approaches have been proposed to deal with the uncertainties in engineering optimization problems. The first is the well-known sensitivity analysis which is a method to measure the sensitivity of the model after disturbances are inserted. However, this is a very reactive method to achieve robustness. In order to achieve proactive models that are insensitive to variations in the problem data, robust optimization can be used. Robust optimization (RO) provides a range of powerful risk-averse methods to cope with uncertainty in mathematical programming problems. It is in contrast to stochastic programming which starts by assuming the uncertainty has a probabilistic description. RO is a more recent approach to optimization under uncertainty, in which the uncertainty model is not stochastic, but rather deterministic and set-based. The motivation for this approach is twofold. First, the model of set-based uncertainty is interesting in is own right and in many applications an appropriate notion of parameter uncertainty. Second, computational tractability is a primary objective and goal.

The theory of RO can be categorized based on three historical waves. The first wave was started by Mulvey et al. [10] in 1995 by proposing robust optimization models based on the scenario-based stochastic programming approach. The second wave, was introduced by Ben-Tal and Nemirovsi [35] and El-Ghaoui et al. [36]. Their work is later published in the book "Robust Optimization" [37] that is now known as the most important resource of robust convex programming. Last but not least, Pishvaee et al. [38] introduced different "robust possibilistic programming methods". This third wave is prominent as it extends the scope of RO theory into fuzzy mathematical programming. Unfortunately, many research considered scenarios/disturbances as hard worst case, as soft case or with random possibilistic bounds. Rare is the research which combines the use of probabilistic bounds and fuzzy programming to develop realistic scenarios as is used in the work of Califiore and Campi [39].

This article tries to make a reasonable balance between the model robustness and the feasibility robustness, which is the balance between robustness and the cost of robustness as in the work on robust control design of Calfiore and Campi [39]. Use is made of a robust counterpart in the uncertainty constraints that depending on the goal, can be violated and optimized with the use of soft constraints. This enables the possibility to balance the solution between the cost of robustness and the robustness itself. The balance can be obtained by the diversification between min-max scenarios used to set the counterpart of the constraint. He showed that using more scenarios increased the model robustness but decreased the solution robustness. In his research he tries to find a bound on the number of scenarios to obtain a feasible balance between the two. This makes the key step of this approach the development of scenarios.

In this thesis a new randomized method for a robust bay assignment is proposed, which is able to deal with model uncertainty. Similar to stochastic programming techniques, information is exploited on the statistics of the uncertain parameters to set bounds on the values. This concept is used in many applications and is named "Probabilistic Robust Design" as in the work of Campi and Calafiore [39]. A key step in the algorithm is the development of scenarios, which as already mentioned is partly randomized. To be able to solve the problem not all possible scenarios can be considered, and only a finite number can be selected. In research often use is made of Monte Carlo simulations to develop scenarios. However, Monte Carlo approaches are computational demanding. In research there is no guideline on how to choose the scenarios in order to have the guarantee that the probability of success is as least a certain factor. In this research the link between the number of scenarios and the satisfactory value of robustness will be investigated. This is also done in the work of Campi and Calafiore. In addition, this research introduces soft constraints to model the constraint/scenario violation and be able to measure and optimize the cost of the model robustness. Noteworthy, linearity and tractability of the proposed model is not destroyed due to the introduction of new variables and constraints.

Another research gap that can be identified from the use of robust scheduling methods is the lack of comparison. In the literature on the bay assignment no uniform performance measure is used (number of reassignment, flight delay, uniform idle time distribution, bay conflicts, etc) and no identical test case is available. Therefore, in this research the novel approach of robust optimization will be compared with the previous robust methods such as the use of buffer times.

2.1.3. COMPUTATIONAL COMPLEXITY

The mathematical formulation of the bay assignment is considered a NP-hard problem [40]. Lim and Wang [30] also proofed that the problem belongs to the NP complex models, by constructing a linear problem formulation. A NP-hard problem stands for a non-deterministic polynomial-time bound and it means "that is less likely to find an optimal solution without the use of an essentially enumerative algorithm" [41]. The idea behind NP problems is related to the computational complexity and is a measure of the relation between the increase of computational time over the increase of the problem size.

2.2. SOLUTION METHODS FOR THE BAY ASSIGNMENT

The solution methods used to solve the diverse formulations of the bay assignment can be classified according to the classification of Cheng [1]. These are the use of expert methods that bridge the gap between total automation and human required preferences, the use of simulation methods to design for uncertainties and the use of optimization methods.

2.2.1. EXPERT METHODS

Expert systems are software based systems that stimulate the interference of human experts. A database, which contains rules generated by human knowledge in a specific problem domain, is used to provide suggested solutions. A system operator may adjust existing rules or input new rules to improve the capability of the system to handle different problem situations and produce better solutions. Relevant work that make use of expert models can be found in the work of Brazile and Swigger [42], Su and Srihart [43], Gosling [44] and Cheng [45].

Although an expert system approach can handle more complicated constraints in realistic operations, it lacks optimization capability. To solve this Cheng [45] proposed a knowledge-based gate assignment system which integrates the expert method with optimization techniques. Cheng divided the problem into several smaller problems and used a linear programming method to solve the smaller problems. The knowledge-based component generates parameter values for the assignment problem, which creates the possibility for the gate planner to feed his preferences.

2.2.2. Simulation Methods

Simulation methods use a simulation approach to solve the bay assignment problem. Simulation methods are in some way a bridge between the operational planning and the baseline bay assignment. In the simulation use is made of expert rules to model the real life scenarios and be able to analyse the effects of these rules and disturbances as in the work of Yan et al. [26]. Other papers that made use of a simulation tool for the bay assignment are written by Hamzawi [32] and Yan et al. [26].

2.2.3. Optimization Methods

Most papers solved the bay assignment using heuristic approaches. The research to exact algorithms is still very rare. Three exact methods that are used are: the Primal-dual simplex [46], Linear Programming relaxation [17] and Branch and Bound techniques [9, 21, 27, 28, 47]. From these articles, the four most recent also developed a meta-heuristic to be able to use the algorithm on real size problems. It can be concluded that they recognize the need of heuristics to be able to have a model that can be used in practice.

Normal heuristics still require a lot of computational time and do not guarantee the optimal solution. Two relatively new heuristic methods used for the bay assignment are column generation [48] and ejection chain heuristics[22]. Although the methods converge fast, the problem formulation is still very problem specific and not able to consider over-constrained flight schedules as is the case at JKIA.

Meta-heuristics, also known as modern heuristics, are therefore becoming more and more popular in solving complex problems. Some common used meta heuristics are the Tabu Search (TS), Simulated Annealing (SA), Genetic Algorithm (GA) and various types of Colonization Algorithms (CA).

Xu and Bailey [9] used a tabu search algorithm to solve a single time slot mixed integer quadratic gate assignment problem. The algorithm exploits the special properties of different types of neighbourhood moves and creates effective candidate list strategies. Ding et al. [20] also used the tabu search but adjusted the model of Xu and Bailey to be able to handle over-constrained flight schedules. The objectives were to minimize the amount of unassigned flights and the passenger connection times. Drexl and Nikulin [23] studied a very similar problem. Instead of the tabu search algorithm they used simulated annealing to solve their multi-criteria objective function. The GA is applied by Gu and Chung [49].

A comparison of GA, TS and SA applied to the GAP is given by Cheng et al. [1]. They do not consider the use of CA since until then it was not used in research on the bay assignment. In 2015 Marinelli [50] developed a Bee Colonization Optimization(BCO) Algorithm to solve the bay assignment at Milan airport considering multiple objectives. This meta-heuristic represent an interesting methodology in the field of swarm intelligence for its capability to solve high level combinatorial problems with fast convergence performances. The BCO differs from other meta-heuristics, because it is based on a solution construction approach that always generates feasible solutions. This can be beneficial in the case of the bay and gate assignment with very strict constraints. Another used type of CA is the Ant Colonization Algorithm, which is used in the book of Pintea [51]. The book also combined this with the local search procedure of the tabu search to create a hybrid model. The results showed points of improvement in terms of solution quality, but the computational time increased.

2.3. Goals and Position of the Bay and Gate assignment Research

The quality of the on-time performance is ultimately realized on the day of operations and can be influenced by a sound bay and gate assignment. However, the bay assignment is dependent on many other factors such as the tail assignment or even the entire flight schedule. This makes the bay assignment only a small part in a larger process of the optimization for on-time performance that is dependent on many other planning processes. The interrelation between the various planning phases is an important aspect to consider as airline. In Figure 2.2, the overview of the different planning phases is shown.

To take the interrelation into account, many airports use long-term bay planning to see whether the capacity of the bays is capable of handling the proposed flight schedule. If this is sufficient the next step is to perform the tail assignment. This is done a day in advance to plan for maintenance and optimize usage of aircraft. When the tail assignment is known a detailed bay assignment planning can be made, creating an optimized initial schedule for the entire day. In this baseline schedule it is important to take into account stochastic variations to make the planning as reliable as possible. The last phase is then the operational phase where disruption management reassigns bays and gates if necessary.

The disruption management is the last phase in the airline operations chain. In this phase the plan is in execution and it is now important to adhere to the initial bay and gate assignment. However, as the nature of the airline business is inherently confronted with stochastic flight delays, airlines have the task to handle these disruptions. Therefore, this thesis is conducted to reduce the gap between the baseline schedule and operational schedule by implementing robust solution methods.

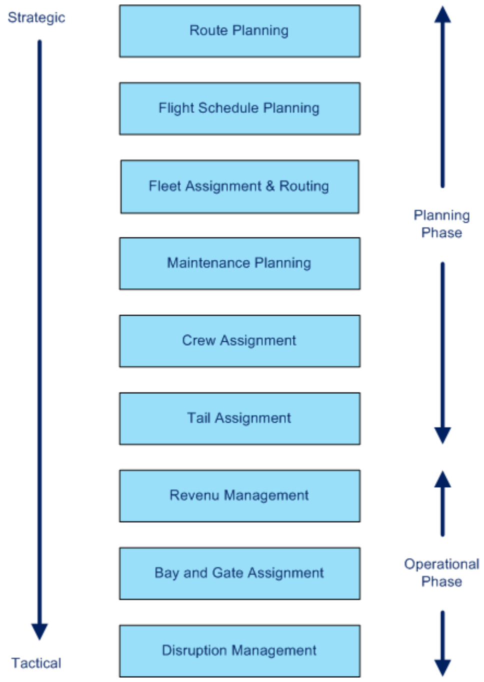


Figure 2.2: Position of bay assignment in airline planning processes [2]

3

Research Methodologies

Looking to the introduction and the literature study, it can be clearly stated that the development of a sound baseline bay assignment can help improve airport operations. This makes the development of a sound bay assignment model of great value to all airlines operating at a specific airport. For JKIA this means that Kenya Airways will benefit from the development of such tool.

To contribute both to the research and to the Kenia Airways, a sound research framework is required. The research framework will be the topic of this chapter and elaborate on the relevant topics. This includes: the setting of the project goal and the hypotheses in Section 3.1, the methods used to achieve the project goal in Section 3.2, the research questions in Section 3.3 and lastly the approach to achieve the contribution to actual operations.

3.1. Research Strategy

Kenya Airways is one of the largest airlines in Africa and has ambitious expansions plans for the future. In order to maintain their promise "An airline ticket is the promise to safely bring a person and their luggage from a certain origin to a certain destination, at a specified time and service level" and minimize operation costs, they focus specifically on their on-time performance. The on-time performance in general is also claimed to be one of the most important selling points of an airline.

To maintain or improve the on-time performance a range of areas are identified at Kenya Airways by Schellekens which influence the on-time performance [3]. The main areas that affect the on-time performance are found to be the network, turnaround execution, load connectivity, technical state of the aircraft, weather, ATC constraints and crew rotation as is shown in Figure 3.1.

Until now the airport related on-time performance driver have not yet been investigated at JKIA. But the fact that 51% of the delays are caused by previous delays [3] together with the fact that the current airport capacity is already limited makes it worthwhile to consider the development of a robust bay assignment to improve the on-time performance. This will then also be part of the research context of this thesis. The other part is to consider it in combination with other common objectives such as the minimization of operational costs or the minimization of passenger inconvenience. This combined will be referred to as a sound bay assignment and makes the development of a sound bay assignment the main focus of the research in this thesis.

The bay assignment is made on three different time instances. The two important time instances considered in this research are the baseline schedule and the operational schedule. The other bay assignment is made well in advance to analyse demand versus capacity and is referred to as long term bay planning. Van Goethem [2], a former student already developed a model for Kenya Airways to consider the long term planning and the next step, logically, is then to develop the planning a day in advance known as the baseline schedule. The main difference between the baseline schedule and the operational schedule is that the former handles a deterministic assignment of flights to bays and the latter has to deal with variations in operations. The development of real-time allocations models for the operational schedule is actually well researched but is

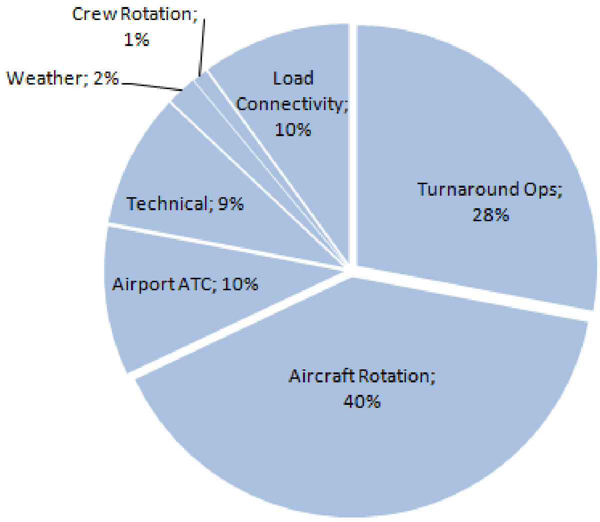


Figure 3.1: Main drivers of on-time performance at KQ [3]

still very constrained in use, due to limitations of computational time. Therefore, to design the schedule as optimal as possible, models are developed to bridge the gap between the baseline schedule and the operational schedule that involves robust planning for the baseline schedule. But the question that remains is when is the baseline schedule considered sound in terms of on-time performance? For Kenya airways an important point to consider is the operational complexity which has a significant affect on the on-time performance. This complexity is mainly measured in the number of required repositioning to allow for fuelling and feasible solutions. The other common point to consider for KQ is the robustness of the baseline schedule.

Looking back to the literature review a few methods are developed in different fields to incorporate robust measures in baseline schedules to improve the performance during operations. The main difference between these fields and the bay assignment is the use of performance indicator for robustness. For example, when scheduling machines to assignments robustness is usually measured by the total idle time used between assignments. For the bay assignment where all flights have to be handled on the same day the total amount of ground time is more or less constant. The availability of bays during the day is also constant which makes the total amount of idle time available constant. This is different from other fields and makes it hard to use it as performance indicator. Bolat [29] uses the idle time as performance indicator by minimizing the variance of the idle times. However, this assumes that the length of the delay and the possibility of a delay are constant for all flights which in a realistic scenario is not the case. Other methods to compute the performance of the bay assignment problems is the use of passenger waiting times, number of bay conflicts and the number of re-assignments. All require simulations or scenario analysis of the actual day of operations but seem to be realistic measures of robust performance for the bay assignment.

Of course, the reality of the performance lies in the quality of predicting uncertainties. To minimize the impact of these assumptions test cases can be used to analyse the performance under a wide range of plausible situations representing different severities of delays . It can be concluded from the above problem context that the main research goal of this thesis can be formulated as following:

Research Goal: *"Develop a robust model to perform the bay and gate assignment a day in advance while optimizing for passenger convenience and reducing operational complexity."*

1. Robust model To be able to achieve this research goal in terms of developing a robust schedule a clear performance indicator should be selected for the bay assignment and a method to achieve robustness should be used or developed. Since the concept of robustness is becoming more important in commercial products and the particular field is still undergoing major changes, it will be good to analyse the different methods on a similar test case with the same performance measure to be able to compare the results. This will then also be the additional research goal which is formulated as following: *"Analyse the use of robust measures for the* *bay assignment*".

2. Bay and Gate Assignment The division between the bay and gate assignment is unusual since they are usually identical. However, in the case of JKIA there are more bays than gates which requires a separate bay and gate assignment. In this research both should be considered in the model simultaneously to optimize for passenger convenience and efficient operations. For the gate assignment, this can be seen as minimizing the amount of simultaneous flights boarding at the same gate. And for the bay assignment this can be seen as minimizing operational complexity and maximizing passenger convenience.

2. Total passenger Transport distance Under the total passenger transport distance is understood the distance a passenger has to cover to reach the bay from the check-in terminal and the distance a passenger has to cover from the bay to the baggage reclaim area. Note that the distance for transfer passengers is not considered due to the computational complexity of the problem. Instead, preferences are given to allocate the main feeders and receivers to beneficial gates as is the case in the current bay assignment process. This objective is part of the higher end objective of providing a certain level of service to passengers.

3. Airport operational complexity As third the research goal mentions the reduction of airport operational complexity. This takes into account the total amount of aircraft reposition due to fuelling and gate constraints. Another aspect that is taken into account is the service centralization of Kenya Airways. Since the opening of the new terminal their focus is to handle all their passengers by this terminal to minimize personnel costs in terms of check-inn services and ground handling. This objective can be traced back to both high-end objectives. It minimizes operational costs in terms of the required man power, equipment and the on-time performance where the latter one also has a positive influence on the passenger convenience

To measure whether the project goal is achieved after the completion of this thesis the following hypothesis is considered.

Hypothesis: "A robust bay and gate assignment model can be developed which optimizes for minimum aircraft repositioning as well as for minimum passenger transport distance."

3.2. Robust Scheduling

To develop a robust baseline bay assignment multiple methods can be used. In the literature research on the bay assignment multiple methods are developed and analysed as can be found in subsection 2.1.2. The problem is that the methods are used on different specific airports and that the performance indicator is not identical. This makes it hard to draw conclusions on the use of the different methods. Therefore, in this thesis multiple robust scheduling methods will be analysed with the same problem case (JKIA) and the same performance indicator. The methods that will be analysed in this thesis will be elaborated in subsection 3.2.1 followed by the selection of a performance indicator. To have a proper performance indicator and comparison use should be made of real time scenarios that can occur to analyse the effects of these scenarios on the initial developed bay and gate assignment. This can be done by generating test cases or by a simulation tool based on probabilities. The use of test cases will be elaborated in the last subsection.

3.2.1. Robust Scheduling Methods

The methods that will be analysed depend on the applicability of the method in terms of computational complexity and required data. Therefore, no use will be made of stochastic scheduling techniques and no use will be made of the minimization of variance of the idle times. The former one is disregarded both to the increased computational complexity and to the requirement of extensive delay data. The latter one is disregarded due to the fact that it assumes the same probability of delay and the same probability of impact of delay for all flights which in real-life is not likely to be the case. The cases from literature that will be analysed are the use of buffer times [26].

Beside this robust scheduling technique, two novel techniques will be developed based on literature from other fields. The first one is the use spare bays to be able to absorb delays in a certain extend, this technique can be found in multiple fields such as in machine scheduling [11]. For the bay planning this means that certain unfavourable bays are blocked during the bay assignment, making them usable to assign conflicting flights due to stochastic variations. This can reduce the impact of counteracting delays making the baseline assignment more stable.

The other novel method is based on the relative new research field robust optimization, which makes use of robust counterparts in the uncertain constraints. Different models exist and the one that will be used is based on the insertion of additional soft constraints that represent various delay cases. In the research on the robust optimization these delay scenarios are randomized with certain bounds. In this research use will be made of a probabilistic model that uses recent historical delays as possibilities for the random scenarios. The use of soft constraints enables you to analyse the difference between solution robustness and model robustness. The former one represents the cost of the use of robustness and the latter on represents the actual robustness of the schedule.

3.2.2. PERFORMANCE INDICATOR

The solution robustness and the model robustness are eventually the two performance indicators you want to measure. The solution robustness can be obtained very straight forward. First the model will be run without any additional objectives on robustness, this optimal solution can then be compared to the solutions including robustness methods. Note that since use is made of soft constraint, penalty values have to be omitted from the objective value to be able to compare the solutions.

The model robustness, in contrast, is a difficult instance to measure without making assumptions. One of the first performance indicators used in literature is the range of idle times [27–29]. As already mentioned this method is based on assumptions that are not likely to hold. Two other performance indicators used in literature are the minimization of bay reassignments and the minimization of total passenger waiting time. They both require information of the flight behaviour on the day itself which can be obtained with simulation or can be sketched with the use of scenarios. The minimization of total reassignments is a straight forward method easy to implement and a good indicator to see the effect of the baseline schedule under stochastic variations. Therefore, in this thesis use is made of the minimization of bay reassignments during operations.

To compute both the model robustness and the solution robustness, the baseline schedule will be tested with generated test cases representing possible variations in the flight schedule. The baseline schedule together with the test cases will be the input for a new optimizing model that minimizes the amount of reassignments on the day of operation. The number of reassignment is then the indicator of the solution robustness. This makes the development of test cases a crucial aspect of this thesis.

3.2.3. SIMULATION CASES

To develop realistic test cases for simulation that are both useful and valuable to draw conclusions on the use of robust methods in terms of model robustness, it is important that a wide range of possible scenarios are covered. Allowing you to analyse the performance of the methods under low delay cases and hard delay cases. In order to develop such cases (including early arrivals), use is made of the method introduced by Yan et al. to analyse use of flexible buffer times [26]. The method first divides the original delay patterns into several categories, each denoting a range of delays with its occurrence percentage. In this research it will be divided into two categories based on the mean.

Because they used delay data from Taiwan Civil Aviation the results will not be necessarily applicable for JKIA, or in other words it will not guarantee realistic test cases. To sketch the cases in this thesis use is made of the available recent delay data at JKIA where for many flights historical delays are known. In this report two months of historical data will be used to develop a range of test cases. For each inbound and outbound flight historical data will be searched, this data will then be divided into two categories. Then based on a certain probability the delay attached to the flight will be randomly selected from either the low delay case or the high delay case. For each test case the probability of selecting a high delay will be increased. For flights that do not have historical data use will be made of the average of all historical data from JKIA. For more information on the development of the test cases see subsection 8.2.1.

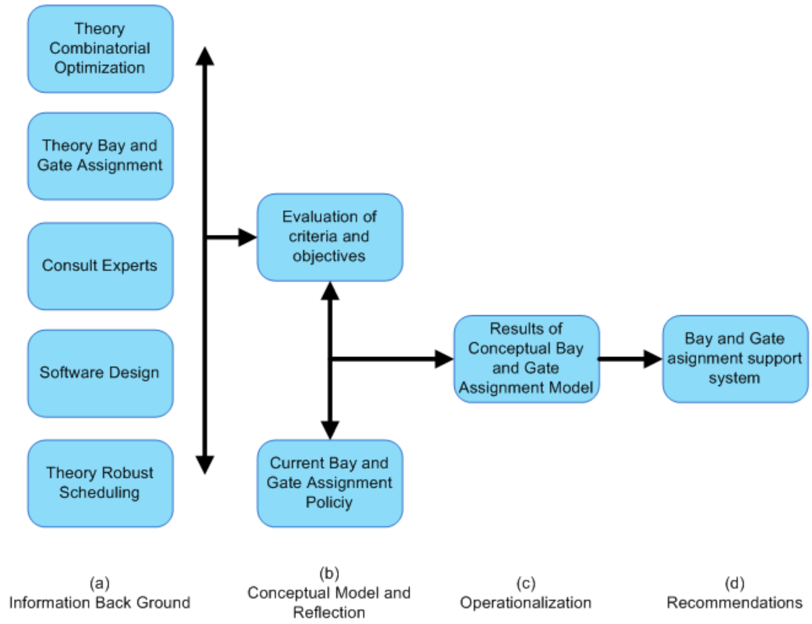


Figure 3.2: Presented research framework

3.3. RESEARCH FRAMEWORK AND ASSOCIATED RESEARCH QUESTIONS

The previous information including the research goal and associated hypothesis form the basis of the research framework as given in Figure 3.2. This framework represents the steps that need to be taken to achieve the project goal. The research framework results from the evaluation of critical bay and gate assignment criteria, objectives of the developed model and the current use of the assignment. To be able to evaluated the models first a robust scheduling method is selected using comparison methods between the various chosen methods. Finally, an analysis of the results of the conceptual bay assignment model will lead to an automated bay assignment assignment method.

The research framework roughly identifies the knowledge required which can be reflected in research questions and sub questions. In parentheses is indicated the chapter where the answer to the research question is covered.

1. What are the relevant criteria and objectives for achieving an efficient bay and gate assignment plan?
   (a) Who is affected by the bay and gate assignment problem? (Chapter 4)
   (b) What is considered as an efficient bay and gate assignment plan? (Chapter 4)
   (c) What are the relevant bay and gate assignment objectives? (Chapter 4)
   (d) What are the relevant bay and gate assignment constraints? (Chapter 4)
2. What is the current quality of the bay and gate assignment with respect to the set of criteria and objectives?
   (a) Who is responsible for the gate and bay assignment? (Chapter 4)
   (b) What is the current bay and gate assignment procedure? (Chapter 4)
3. What is the best method to combine the bay and gate assignment?
   (a) What are the possible options to combine the bay and gate assignment? (Chapter 5)
   (b) What is the best method to combine the bay and gate assignment? (Chapter 5)
4. What is the best method to provide a robust static bay and gate assignment? (Chapter 5)
   (a) What are the different possibilities to provide a robust schedule? (Chapter 2)

   (b) What are the pros and cons of the different types of methods? (Chapter 2,8)
   (c) What are the methods to measure the pros and cons? (Chapter 3)
   (d) Which criteria should be measured?(Chapter 3)
   (e) Which selected method performs best in terms of solution robustness and model robustness? (Chapter 8)

5. What is achieved with the conceptual bay and gate assignment model with respect to the current assignment policy?
   (a) What should the bay and gate assignment look like? (Chapter 5)
   (b) What are the bay assignment model inputs? (Chapter 7)
   (c) Should a bay and gate assignment manager prioritize between objectives? (Chapter 7)
   (d) When is the bay and gate assignment plan successful? (Chapter 7)

3.4. OPERATIONALIZATION

Apart from the academic framework, robust optimization for the bay assignment, there is a strong industrial perspective due to the fact that this thesis is commissioned by Kenia Airways. To take this industrial perspective into account and bridge the gap between research and a commercially viable product, an operationalization strategy is added to this thesis.

This strategy is based on the work of Hillier [52] that provides a general approach to an operations project. This strategy is divided in six steps starting with the identification of the problem definition and ending with the implementation of the model. It must be noted that the actual implementation of the model, independent of the importance and personal satisfaction, requires a lot of extra time and resources. Unfortunately, the resources are still not available and time was also scarce due to the tight schedule of the master thesis. Therefore, the main focus lies on steps one till four and leaves step five and six open for future implementation. The first four steps will be briefly summarized in the following paragraphs.

The first step in a general research project is to identify the main problem at hand and see which stakeholders are involved and what their (conflicting) objectives are. For example at JKIA, KLM is an important stakeholder that compels Bay 7 daily. When the results of this thesis show that this should be different or does not take this into account the model becomes useless for commercial ends. This is independent of the valuebility of the research itself but can lead to a unusable product. When the problem context is set, the research framework, including the research questions and the method, can be developed. The research framework also includes the dependency on required data and a plan to obtain the data. If this is known, the last step is to gather the required data.

The second step is to formulate the problem in a mathematical model that covers the real life situation. This formulation of this model includes the selection of decision variables, constants, constraints and the objective function.

The third step generates solutions from the model. This requires the selection of a software platform, implementing the mathematical model and inserting the input data. Next a satisfying solution needs to be found. A ”satisfying” solution is according to Herbert Simon [53] a contradiction between satisfying and optimizing. This indicates that the optimal solution must be considered with respect to the costs it takes to find the optimal solution. For this thesis this compromise between the two plays an important factor. It will start with developing a satisfying solution for the current bas assignment procedure and will then proceed with the implementation of delay scenarios to optimize for robustness. The cost of a robust solution can then be seen as such a compromise and this thesis will investigate the cost needed to develop a robust bay assignment. The fourth step is testing the model, which normally is done during the development of the model, but should always be re-evaluated at the end. This includes the model verification and the model validation.

4

Current Bay and Gate Assignment at JKIA

Since this research is commissioned by Kenya Airways, a test case will be conducted for Jomo Kenyatta International Airport. It is therefore of utmost importance to have all the knowledge and understanding of the specific airport characteristics to come up with a valuable and satisfying solution to the industry problem at hand.

This chapter will provide this information, giving the reader the necessary background information. In addition, this chapter will clarify the need for a sound bay and gate assignment at JKIA. This together will be accomplished by performing a stakeholder analysis, identifying the current bay and gate assignment procedures and lastly to come up with all operational constraints limiting the solution space.

The chapter is structured in three sections. First the relationships, interests and power of the various stakeholders will be elaborated. Secondly, the current bay assignment process combined with its limitations and constraints will be covered. Lastly, the gate assignment process will be elaborated including its current procedure and operational constraints.

4.1. Stakeholders

In literature the bay and gate assignment is considered a multi-criteria problem meaning that multiple objectives are conflicting [23]. These conflicting objectives can be found within one stakeholder but can also come from different stakeholders. For the bay and gate assignment four main stakeholders can be identified in literature. These are the passenger, the airline, the airport and the ground handler. However, in literature the ground handler objectives are not used once and in this specific case the "home carrier" KQ handles the majority of the flights. So their interest in the bay assignment from a ground handler perspective will be briefly mentioned in the section about airlines. It must be noted that the current trend in airport operations is the growth of smaller ground handlers such as 'Swiss Port', which is operating most non-KQ handled flights, since they often provide lower handling fares than the ground handler of the airport/home carrier. This may require a change in the future to take this change in industry into consideration.

The major stakeholders involved at JKIA which have an interest in the bay and gate assignment are the airlines, airport authorities and the passengers. The airport authorities are represented by the Kenya Airports Authority (KAA). This section discusses the stakeholders based on their interest and influence in the determination of the bay and gate assignment plan.

4.1.1. Kenya Airports Authority

The Kenya Airports Authority (KAA) wants to have a good image to be able to keep growing and attracting new clients. It is therefore of utmost importance to satisfy all airlines. This include ensuring efficient and safe operations with a minimal amount of delays and listening to the requirements of different airlines. One major process where they can influence these selling points is the bay and gate assignment. In the end the airport authority is responsible for this process and therefore also has the major influence on this process.

However, looking to the current operations they only have a moderate interest in the need for an efficient bay and gate assignment. Currently, they let KQ be in charge of the bay and gate assignment for all KQ-handled flights where the solution is approved with a quick visual check. All non-KQ handled flights have standard bays as required by those airlines and are just blocked for certain time intervals. Besides these time intervals the bays can be used for KQ-handled flights. The airport authority does indicate the need for better tools as frequently errors are made, but till today still no action is taken on this by the KAA.

The airport as stakeholder represents many objectives of other stakeholders. This has to do with the fact that the passengers and airlines are customers. Meaning that the airport wants to satisfy the needs of their clients to a certain extend. For passengers this means that the airport wants to give a certain level of service which is also a primary objective of the airlines.

4.1.2. AIRLINES

As already mentioned the airlines have as main promise a certain level of service. On the other hand it wants to maximize their profit resulting in a minimization of operational costs. This can be achieved by having an efficient use of resources. The bays and gates are two examples of these resources which should be benchmarked to increase the level of service and in the end also to ensure a proper on-time performance.

One way of increasing the on-time performance is by reducing the operational complexity. This lowers the potential risks of delays. Another important method to improve the on-time performance is the implementation of robustness. Therefore, for both passenger perspective and cost perspective, increasing the on-time performance is very valuable. This objective can be traced back to two smaller objectives for the bay and gate assignment which holds: minimizing operational complexity and maximizing operational robustness. Where the operational complexity is mainly concerned with the amount of repositioning and the amount of bussing.

Normally, airlines have a small say in the allocation of their bays and gates. However, at JKIA all non-KQ handled airlines have certain agreements with the airport resulting in many fixed flights. Unfortunately, this strongly affects the flexibility to provide more stable and robust solutions. Since KQ has the majority of the flights it does have a huge say in the allocation of their flights. Currently, they make their own bay and gate assignment which have to be approved by the KAA using certain time slots on bays to allocate the non-KQ flights.

In terms of the bay and gate assignment the airline and airport have different stakes. For Kenya Airways it is important to only look at their customers and not to other non-KQ handled airlines as KAA does. However, for both KAA and KQ it is of importance to have a proper use of these scarce resources due to the over-constrained flight schedule. From passenger perspective the airline shares all their objectives to maintain or increase their level of service and give passengers a comfortable experience at their base JKIA.

4.1.3. PASSENGERS

The third stakeholder group represents the passengers. In the end the passengers provide the income of all the stakeholders and is therefore a major stakeholder to consider. To satisfy the passenger a certain level of service is required, this expected level of service differs from passenger to passenger. But it is mainly influenced by the promise of the airline product. Two major factors which determine the level of service and can be influenced by the bay and gate assignment are: the transport distance and the on-time performance.

The transport distance as already discussed is a common objective used to model the value of the bay assignment. It can be discretized in walking distance from the check-in terminal to the gate, the walking distance from the gate to the baggage reclaim area and the distance between the initial gate and the gate of the transfer connection. Minimizing this distance will enhance the service level.

The on-time performance is dependent on many factors. The most important is the robustness of the schedule, as is the main aim of this research, which is influenced by introducing stability. Another factor can be the operational complexity, such as the minimization of towings, or the minimization of ground handler movements which on it self will ensure a more efficient ground handling operation. An important example of this is the minimization of the number of bussing required to transfer the passenger between the gate and the aircraft.

4.2. BAY ASSIGNMENT

It is of utmost importance to have a good understanding of the current bay and gate assignment processes before developing the model. This section will therefore describe the current procedures for the bay allocation process including the limitations and objectives. First the overall process will be visualized in detail. Secondly, the important and main limiting predecessor the tail assignment will be elaborated followed by a detailed overview of the manual bay assignment allocation process including the main constraints.

4.2.1. BAY ASSIGNMENT PROCESS

The current bay assignment process at JKIA is entirely performed manually. This process is mainly done by the Duty Ramp Controller (DRC) of KQ.

Their are two DRC's each day one working the night shift from 8 PM to 8 AM and working the day shift from 8 AM to 8 PM. They are both responsible for the bay assignment process where the night shift prepares the morning wave and the day shift prepares the evening wave. This indicates that the two waves are treated separately where the bay assignment can benefit from a sound interrelation of the two.

As already mentioned the night shift starts a 8PM. Since the DRC's are also responsible for the turn around process they first manage all flights until the last one leaves. This is usually the CDG flight departing around midnight. After this the DRC starts with the bay assignment for the next day. The beginning of this process starts with gathering all the required input information. Which includes printing the turn around schedule that the Duty Manager Operations (DMO) publishes around midnight and obtaining all flights (Non-KQ) from the KAA.

The third required input is the current location of all corresponding tails. The DRC usually performs this task before midnight and writes all the tails in combination with the bay down. When these three inputs are established the DRC allocates all flights to bays and publishes the report. This manual allocation process is explained in more detail in subsection 4.2.3

The published report of the DRC is send to the KAA which performs a quick visual check. When this final plan is satisfactory the DRC checks with Duty Control Engineer (DCE) whether the amount of repositioning is feasible with the current man power. Note that this repositioning is required to free up as many serviceable bays for the morning peak.

The previous processes are all done before 3 AM when the morning meeting is scheduled. In this meeting all the main stakeholders of KQ are attending to discuss the next day including all the special cases such as short connections. When this all is set the OCC and HCC take over control and will monitor the rest of the bay assignment process. This is done in combination with the DRC and the available Kilo 1's. Note that the Kilo 1's are responsible for the turn around process of each flight individually.

When changes do occur in the 3 AM meeting the DRC has to resolve this in a very short time frame.

4.2.2. TAIL ASSIGNMENT

As already mentioned the tail assignment is an important predecessor of the bay assignment. It also limits the solution space significantly by publishing the turn around schedule as late as possible and not taking into account current bay positions and preferences.

The tail assignment problem is the problem of deciding which individual aircraft should cover which flight. Each aircraft is thus assigned to a route consisting of a sequence of lights, and possibly other activities such as maintenance, to perform. The tail assignment deals with individual constraints, flights which are fixed in time, as well as individual rules for each tail. This implies that the tail assignment is dependent on many factors. One which is the current position and the on-time performance. To cover these two points the tail assignment is post phoned to the latest moment possible where most information is known. For KQ this moment is at 03:00 AM where all night flights have been departed and where all information of the maintenance department is set. For the bay assignment this moment is to late to cope with all repositioning during night. Therefore, a preliminary turn around schedule is posted at 0:00 AM where the information has a high reliability. However, minor changes can then still occur.

Such changes can have a large impact on the bay assignment. As already mentioned the latest changes are posted at 03:00 AM where the repositioning process of the night has already been started. Often this requires for additional repositioning during night or day increasing the operational complexity.

4.2.3. WORKING OF MANUAL BAY ASSIGNMENT

The DRC performs the manual bay assignment is multiple steps. Note that he does not use any artificial tools and only uses the printed turn around schedule which limits the capability to see optimal solutions and requires a high work load.

The first step the DRC performs is allocating all flights without an inbound flight, meaning all night stay flights or flights standing at maintenance. At this moment he does not know whether domestic flights exceed domestic capacity resulting in the possibility that a remote bay is used where it was not needed.

The second step then is to allocate all the major feeders and non-KQ flights to their dedicated bays. This way a large part of the solution is already determined and makes it easier to see possible solutions.

The third step then allocates all the domestic flights to domestic bays where possible. During this step he already looks to the amount of idle time allocated in between flights. The minimum idle time used varies between 20 minutes and 30 minutes depending on the flight type.

The last step now is to allocate all other flights to their bays. In this step transfer connections are not taken into account. Usually, first all the low value flights are allocated to remote bays and then the nose-in bays will be filled with the flights left. Again this assumes that all bays will be used where in practise this is not always the case. Therefore, the final step is to review the results and see whether certain flights can be relocated to nose-in bays.

One advantage of such a manual bay assignment is that the bay planner knows all the flights and which flights are more likely to be delayed. This information can then be used to allocated more idle time. Unfortunately, this requires a lot of knowledge and a high work load. New DRC's can usually not use this information in the bay assignment process and will stick to the use of fixed buffer times.

4.2.4. SPECIFIC BAY CONSTRAINTS

JKIA has various types of bays all requiring their own specific constraints. These types of bays are: international and continental bays, domestic bays, squeezing bays, serviceable and non-serviceable bays and finally remote bays. All these types of bays can be attributed to certain bays. These bays and locations are indicated in Figure 4.1. Note that the general aviation bays are not used by JKIA and that the cargo bays are not indicated since they are not used as well.

INTERNATIONAL & CONTINENTAL BAYS

These bays has mainly to do how the gates are set-up. Some gates have a closed boarding surrounding which is preferenced above an open gate. Therefore, the more important international flights are allocated to these gates/bays. Three terminals are used for international and continental flights and one terminal is used for domestic flights. This implies that these bays are preferred for international and continental flights but are not always used for these flights depending on the situation. For JKIA all nose-in bays from Bay 4 till Bay 20 are dedicated international and continental bays. In the morning peak often bay 4 is used for domestic flights to cope with the large amount of domestic flights.

DOMESTIC BAYS

For this type the same holds as for the international bays. Domestic flights are preferred but are not always standing on the domestic bays. When a domestic arrival will become a continental departure the chances are

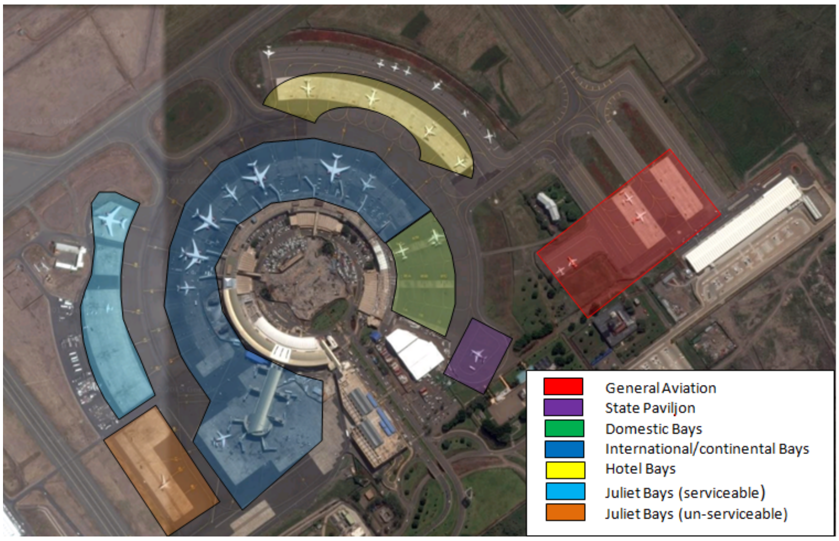


Figure 4.1: Overview of the lay-out of JKIA indicating the various types of bays

high that this flight stays on a domestic bay to minimize the amount of repositioning. For JKIA the dedicated domestic bays are: 1A,1B,1C,2A,2B,2C,3A,3B,3C where bays one are under construction.

SQUEEZING BAYS

Many airports have these types of bays that can be used for wide body flights, but when demand requires it can be used for two narrow body flights. For JKIA these are the bays: B4,B9, STPV, J2, J3, J4. In this model these bays are only used as squeezed bays since the strong morning and evening demand requires this. An special exception is made for the wide body of Turkish Airlines which is dedicated for bay four and can then during this time only be used for this flight.

SERVICEABLE AND NON-SERVICEABLE PARKING BAYS

Previously JKIA had a lot of problems with the low amount of serviceable bays. Indicating the availability of fuel pits to fuel the aircraft, since JKIA does not have any fuelling trucks. Nowadays, only four bays are not equipped with fuelling pits which are: J7, J8, J9 and the STPV bays. The non-serviceable bays are used a lot during the night to have a maximum amount of serviceable bays available for the morning wave.

REMOTE BAYS

Remote bays are bays not located next to the terminal building. These bays are never preferred since they require bussing and additional movements of resources. However, JKIA uses these bays a lot to be able to handle the current demand. The remote bays are: hotel bays, juliet bays, state pavilion and the cargo bays.

4.3. GATE ASSIGNMENT

The second allocation process that has to be performed to ensure valuable use of resources is the gate assignment. In this section first the current gate assignment process will be discussed followed by an elaboration of the current gate properties and their limitations.

4.3.1. GATE ASSIGNMENT PROCESS

In the current process the gate allocation procedure is a post processor of the bay assignment. When the bay assignment is made the gate assignment may require some minor changes but normally these are not considered due to the constrained properties of the bay assignment. When the bay assignment does allow for these changes the bays can be adjusted.

The Kilo 4's are responsible for the gate assignment and makes this assignment in collaboration with the DRC after the meeting. Meaning that the gate assignment allocation is usually performed around 3:30 AM and that the gates assignment is also made twice a day.

The gate assignment process is an easier process which is done on a flight by flight basis. The Kilo 4 tries to minimize the amount of double scheduled gates and to optimize for preferred solutions in terms of the amount of man power and required bussing. With optimal use of bridges and gates these resources can be minimized. The main idea behind the process is to link dedicated gates to the assigned bays and when this results in conflicts bussing gates will be preferred.

4.3.2. SPECIFIC GATE CONSTRAINTS

The airport JKIA has various types of bays. These are open/closed gates and bussing gates. In addition some gates have special restrictions as will be discussed in the following paragraphs.

OPEN AND CLOSED GATES

Closed gates are gates with a dedicated surrounded boarding area. Open gates are the contrary of the closed gates. Meaning that the boarding area is located inside the main terminal where all other passengers can come. This makes the boarding process of open gates more complicated and more likely to get disturbed. One major disadvantage of the open gates is that passengers are checked in on the last moment, where at closed gates you already have an early indication of how much passengers still need to enter the boarding area. This means that bags can only be offloaded ad hock and no precautionary measures can be taken as in the case of the closed gates.

The open gates at JKIA are gates 1,2,3,14,16,20,21,22,23,24. Where gates 1,2,3 are the domestic gates and gates 21 till 24 are separate bussing gates downstairs. This leaves gates 14,16 and 20 as less preferred bays.
A special constraint is needed for bay 17 and 18 which are located in the same closed environment.Therefore, it cannot be used to board large international flights simultaneously as well as different airline carriers.

BUSSING GATES

At JKIA all gates can be used for bussing. However, there are a few dedicated gates for bussing which are gates: 15,20B,21,22,23,24. In the evening peak when all KQ handled flights have to be boarded through terminal A all these gates are occupied and even gates: 16,17,18,19,20B are sometimes used for bussing.

DOMESTIC GATES

The domestic gates are part of a separate domestic terminal. This means that these gates can be used for domestic flights only. This Terminal 1D consist of three gates 1,2 and 3 where currently gate 3 cannot be used for boarding. All three gates do not have dedicated bays. When looking to Figure 4.1, you can clearly see that the domestic bays are remote bays that can be boarded by walking from one of the three domestic gates.

5

Developing the Linear Programming Model

Now that the airport specific characteristics and procedures are known it is time to translate this into a model. Such an optimization model consist of an objective function and constraints. In this chapter three separate optimization models are developed which represent the bay assignment, the gate assignment and the reassignment process respectively. In addition, the former two baseline models will be adjusted to represent the three different robust methods selected. These are the use of buffer times, the use of spare bays and the use of robust optimization techniques.

This chapter starts with an explanation why the bay and gate model are developed individually in section 5.1. It will than proceed with the development of the bay model in section 5.2. When the objective function of the bay assignment is known and all constraints and control variables are selected, the same procedure will be repeated for the gate assignment in section 5.3. This is followed by section 5.4 which will elaborate on the required adjustments to develop the three robust scheduling methods. Lastly, the simulation method/model to measure the robustness in terms of the number of re-assignments will be elaborated in section 5.5

5.1. Combining Bay and Gate Assignment

The bay and gate assignment is currently still manually constructed. This requires a high workload of the planners resulting in a schedule that is only partly constructed. The partly constructed schedule makes the transition from the night planner to the day planner not optimal. Besides the fact that that the transition is not optimal, the bay planner is limited to rule-based solutions where computers are capable of optimization techniques considering additional (historical) data. In addition, the gate assignment is made as successor of the bay assignment only looking at feasibility and not taken into account the prefer-ability of the solution.

Combining these in the same model formulation will eventually lead to an improved bay and gate assignment. However, this requires an additional index in the control variables, representing the gate, resulting in an increased problem size in terms of variables and constraints. In addition, this will require extra terms in the objective value making the problem more complicated limiting the possibilities of robust solutions. Therefore, the decision is made to still use the bay assignment as predecessor of the gate assignment but taking into account specific gate constraints.

This difference creates the possibility to develop a sound bay assignment that will lead to a proper gate assignment. Such a sound bay assignment has to take into account certain aspects of the specific airport lay-out and constraints. Specifically, these are the connection possibilities between bays and gates.

To give an example of these connections at JKIA: there are two non-remote bays without a dedicated gate, these are bay 6 and 11. This has to do with the fact that these gates are the transition areas of the different terminals[1]. Note from chapter 4 that bay 11 can only be boarded by gate 10 and that bay 10 can only be

[1]Gate 11 is the transition of terminal A with terminal B and Gate 4 is the transition of terminal B with terminal C

boarded by gate 10. For the gate planning this means that if two simultaneous departing flights are allocated to bay 10 and 11, one has to be boarded through a bussing gate or two flights have to be boarded through the same gate. The former one requires additional bussing where the latter one increases the risk of delays. To avoid these scenarios adjacency constraints can be used.

5.2. BAY MODEL

Due to the fact that there will be two individual models for the bay and gate assignment, the development of the models is divided in two sections. In this first section the development of the bay assignment will be elaborated. The bay assignment is the predecessor of the gate assignment and eventually determines the quality of both assignments.

To start elaborating the development of the model, first the objective function should be designed based on the preferences of the various stakeholders. This will be done in subsection 5.2.1 where the objective function is build. When the objective function is developed it is important to generate feasible solutions. This will be assured by the use of various constraints, discussed in subsection 5.2.2.

5.2.1. OBJECTIVE FUNCTION

To develop the objective function as realistic as possible a proper analysis of stakeholders is required. In the end, it is the objective function that determines the placements of aircraft, which should cover the interests of the stakeholders. To gather the information a few interviews where taken at KQ, the bay planner was joined multiple nights shifts and finally historical data is used to analyse the various solution possibilities. As already mentioned the high end objective of an airline is to minimize operational cost and passenger inconvenience. This can be further translated in the following important objectives for the bay and gate assignment of KQ:

1. Minimize aircraft repositioning
2. Minimize amount of Bussing
3. Focus non-domestic flights to Terminal A
4. Take into account transfer connectivity

The first point "minimize aircraft repositioning" can be seen from two points of view. The first point can be seen as the amount of repositioning in the baseline schedule and the second one can be seen as the amount of repositioning needed to solve conflicts on the day of operations. Both are strongly related to operation complexity and induced costs. For the baseline schedule there are two exceptions to allow for repositioning. The first is the need to provide fuel and thus represent a feasible solution. Where the second is the switch of flight dedication or flight preference[2]. If the amount of domestic bays are over-constrained, flights with a continental departure parked at a domestic bay this should be repositioned to a new bay. This to make sure that the preference of the incoming domestic flights for domestic bays can be given.

As will be explained later there are 4 reference points to measure the passenger walking distance. These are Terminal A,B,C and Terminal D. For domestic flights the reference point is Terminal D where all domestic bays have small distances and all non-domestic bays have larger transport distances. To cope with all this what if scenarios it is important that a good hierarchy of objectives is represented in the objective function with the use of weights. This will be soon addressed in the section on weights determination.

The other type of repositioning is the the number of repositioning on the day itself. This strongly influences the on-time performance and the passenger convenience. It is also the focus of this thesis to provide a schedule that is insensitive to variations in the initial flight schedule. In other words the minimization of aircraft repositioning and the maximization of robustness. To achieve this in the model multiple methods can be used. As already explained in the research methodologies three methods will be developed and compared. This to finally be able to select the best method and use this in practice.

The second point is very straight forward. Bussing increases the operational cost and complexity but also the passenger inconvenience. To avoid this the model should allocate flights to nose-in bays with dedicated gates

[2]A change in flight dedication means that a domestic arrival becomes a continental departure or vice versa

if possible. This can achieved on various ways. The one used in this thesis is the minimization of passenger transport distance, which in this case can partly consist of bussing distance. Since all the remote bays have a larger distance compared to the reference points (terminals) it will be automatically avoided when possible. The other point when bussing can be required is when bays are used without dedicated gates as explained in the previous section. This can only be avoided by the use of adjacency constraints.

For Kenya Airways one important aspect is to use their new terminal as efficient as possible, to minimize the amount of required manpower. To do this all non-domestic flights are handled in terminal A. To also concentrate resources on the airside it is important to allocate flights near Terminal A. This can also be achieved by the minimization of passenger transport distance. Terminal A can then be used as the reference point. Note that non-kq handled flights and domestic flights need other reference points since they are entering the airside on different locations. An important point to repeat is the fact that KQ does not use any gates of terminal B in the evening due to manpower constraints.

The last point takes into account the transfer connectivity. An important selling point for a hub airport such as JKIA. A former student already developed a model to allocate flights based on transfer connectivity. However, the amount of time required to solve the problem with already strong heuristics still remained above 1 hour. Unfortunately, this cannot be solved in combination with the robustness objective developed in this thesis. Therefore, this model allocate these flights with a rule based approach that is currently used by KQ. It actually requires the main feeders to be allocated to beneficial gates and does not put any additional constraints on receiver flights. This rule will be modelled with the flight preference objective which was already necessary to push non-KQ handled flights to their dedicated bays and gates, see next paragraph.

Summarizing the above, will result in an objective function that consist of only one term and that is the passenger ”walking distance”. However, this is assuming that KQ allocates all flights and that there are no agreements between airlines and the airport or KQ. Unfortunately, in real life such agreements do exist and airlines have preferences for gates. To solve this in the model you can constraint these flights to their preferred gate. Another possibility is to add airline preferences as second term in the objective function. The latter one is chosen for the model since is allows more flexibility to generate feasible solutions and can indicate the preferences for each bay/gate individually. For example, when the afternoon Qatar Airways flight cannot be allocated to bay 5, preferences of such airline can push the flight to bay 4 or 6 which in the case with constraints would result in an infeasible solution.

Therefore, the objective function consist of two objectives. One is the minimization of passenger walking distance and the other represents the preferences of airlines. This followed from the importance of a proper bay assignment in terms of on-time performance and product quality which are the main drivers of the large stakeholders. In addition, one penalty value will be added in the objective function to minimize the operational complexity in terms of the amount of aircraft repositioning. This with the main reason, that it can significantly affect the throughput capacity of runways and that it brings large amounts of additional costs with it.

MINIMIZATION OF PASSENGER TRANSPORT DISTANCE ($z1$)

As already mentioned this objective consist of the transport distance from the check-in terminal to the bay. Normally in literature this consist of two terms: one representing the departing passengers and one representing the arrival passengers. However, the current situation of JKIA does not allow arriving passengers into the terminals A,B and C. These arriving passengers are transported with bus to the arrival hall where you can pick your luggage and leave the airport. Therefore, in the current model this term is not included but this distance can be easily added when construction works are finished since it is a linear term. For domestic arrivals there is a separate arrival hall in terminal D, but again this can only be reached from one point.

The quadratic term needed for transfer passengers is excluded from the objective function since their are many feasible solutions with almost identical objective values which makes the model very hard to solve and not applicable for this research. To still provide a realistic bay assignment, the same procedure as in the current manual method is used to incorporate preferences of transfer flights. This procedure assures that all main feeders are allocated to their preferred nose-in gates.

Table 5.1: Preferences of flights to bays and gates

Flight:	Dest:	Bay:	Gate:
KQ116	AMS	18	18
KQ310	DXB	19	19
KQ210	BOM	18	18
KQ112	CDG	19	19
KQ102	LHR	18	18
G9735	SHJ	10	9
EY642	AUH	7	7
SA185	JHB	5	5
SN463	BRU	5	5
ET	ADD	8,9	8,9
WB	KGL	4,5	4,5
SV430	JED	8	8
QR	DOH	4	4
EK720	DXB	8	8
BA064	LHR	11	10
TK6492	IST	4	4
LX295	DAR	5	5
MS850	CAI	7	7

The last note that should be taken into account when analysing the objective function are the different distances to the bays. At JKIA there are 4 terminals (1A,1B,1C,1D) each with its own distance array. To incorporate this all flights are assigned to an airline group indicating the terminal used that can then be used to select the correct distances.

The final objective function is given in Equation 5.1. Where D has one index term representing the different terminals and one index representing the different bays.

$$z1 = \sum_{i=0}^{i_{max}} \sum_{k=1}^{k_{max}} P_i * X_{i,k} * D_{term,k} \tag{5.1}$$

MAXIMIZATION OF AIRLINE PREFERENCES ($z2$)

In order to push certain airlines or certain flights to their required bays and remain a flexible schedule, airline preferences are used. This tells the model to push the flights to their wanted bays but when there is no other possibility it can be altered to the next favourable bay. The objective function is given in Equation 5.2. Where pref represents the preference of the flight to the particular bay. This function is only used for non-KQ flights and the main feeders of KQ which have standard bays. Table 5.1, entails all the departing flights that are used in the preference function in combination with their wanted bay and gate.

$$z2 = \sum_{i=0}^{i_{max}} \sum_{k=1}^{k_{max}} X_{i,k} * PREF_{i,k} \tag{5.2}$$

The following step in determining the objective function is adding weights to both objectives. This is done by adding a weight factor α and β to both objectives respectively as given in Equation 5.3. However, the penalty value for repositioning should also still be added with an own penalty value. This is shown in Equation 5.4, where z3 is the summation of all the penalty values U, V, W.

$$z4 = \alpha * z1 + \beta * z2 \tag{5.3}$$

$$z5 = \alpha * z1 + \beta * z2 + \gamma * z3 \tag{5.4}$$

BAY ATTRIBUTES WEIGHT DETERMINATION

Determining the optimal solution within a multi-objective optimization problem is challenging. Two different objectives are often conflicting. This means that optimizing one objective can result in deterioration of the vale in the other objective. This conflicting effect is also existent while considering the minimization of passenger transport distance versus the minimization of aircraft repositioning.

In operation research three methods exist from which one is a priory determination and two are posteriori determinations. In this case is chosen to determine a priory weight of the objectives by introducing objective hierarchy. This means that the importance of the objectives is determined in advance. This can be defended by the fact that the number of aircraft repositioning is always more important than the minimization of passenger transport distance and the flight preference objective is always more important then the other objectives.

Since all exceptions are already excluded by the proper use of flight preferences the selection of weights is rather straight forward. First you look to what the maximum value per flight can be in terms of passenger transport distance. For this you pick the highest walking distance and multiply it with the amount of passengers. This value is then the maximum value which the next objective should counter. For example, take a B737 with 140 passengers on board and a maximum distance to a certain bay of 20 minutes. This makes the maximum objective value 2800. The next objective range should then start with a minimum value of 2800. Meaning that the cost of a repositioning should at least be higher then 2800. On this way weight β is determined and weight α is just set equal to one

The last weight γ is know determined by calculating the maximum value of both objectives combined. This maximum value is reached when the aircraft is repositioned twice during its ground time at JKIA. Meaning that 3 times 2800 will do for the B737 with 140 passengers. One time represents the passenger transport distance and the other two times represent the two repositioning at a cost of 2800. This way all weights are calculated for each flight separately.

Decision Variables and Control Variables

With the objective function developed, the decision and control variables are already partly determined. In this section a short motivation and clarification of the selected control and decision variables will be given. Starting with the selection of decision variables followed by the use of control variables.

Decision Variables The linear program uses binary decisions variables as can be seen from the objective functions. Since the model is initially linear no linearisation methods are required and one type of decision variable is used. Another observation that can be made based on the objective function is the independence of time in the variables making the model a single-time-slot model. The decision variable is referred to with an X and has two indices, one for the flight and one for the bay ($X_{i,j}$).

Note that in the real model more decision variables are defined. These represents the penalty values from all the soft constraints representing the amount of repositioning of long stay flights. In total there are 3 penalty indices. The first one being (U), representing the towing from the set arrival bay to the still to determine parking bay for night stays. Second and third one (V,W) representing the towings from the parking bay to the departing bay for night stays, and all towings for non-night stays. Summarizing, three decision variables are need to model this constraint due to the limitations of binary values and the formulation of the equality constraints. For information see Equation 5.2.2.

Control Variables The main control variables with respect to the bay assignment are the assignment of a bay to an aircraft, the start and end times of each flight and the start and end times of the intermediate parking activities for long stay aircraft. Where only the first variable is effectively controllable and the second one is only controllable when changing the flight schedules of the airlines. The third control variable can affect the results when not formulated properly. In this thesis the assumption is made that it is a deterministic input variable instead of decision variable. This is achieved by setting a certain length for the arrival part and departure part respectively. It is assumed that both activities last 90 minutes. Further research is recommended to analyse this control variable as dynamic variable instead of deterministic in this thesis. The main problem of this formulation is that it requires non-linear constraints for the translation into time objects. Not using this control variable still requires a bay planner to analyse the results.

Long Stay Flights The control variable for the long stay flights is chosen such that flights staying longer than 5:40 hours are splitted in three sections. This exact time is based on the validation of van Goethem[2], which showed that the break even point for the cost and benefits of towings lies around 5:40 hours. The first section is the arrival part followed by the parking part and finally the third section represent the departing part. As already mentioned the departure part and the arrival part are assumed to last 90 minutes. This way there is enough time for the offloading and loading process at the bay and flexibility is included to widen the solution space as it is used now. Van Goethem used 60 minutes for these activities, however since the operational complexity is to be reduced quick turnarounds are to be avoided. Note as already mentioned that KQ wants to minimize the amount of towings and only use two exceptional cases to split flights over multiple bays.

It is important to have this information in the model and therefore for each flight this additional information is computed. It is important to differentiate this since they all need their own specific constraint and have their own value to the objective function. For example, the arrival and parking part do not contribute to the passenger transport distance objective since bussing is required anyway. Another example is the need of fuelling for the departing part which not hold for the arrival activity and the parking activity.

Use of Bays Another restriction in the use of control variables is the use of bay combinations. JKIA has many bays which can be doubled parked if the aircraft type allows it. Taking this into account a few assumption where made. The possibilities and the actual use was already extensively discussed in the chapter on the layout and the protocols of the bay assignment. However, to include all the possibilities in the model quadratic terms are required since the combination is dependent on two aircraft bay combinations. To avoid this the normally used configuration is applied in the model. In the following enumeration the used configuration is explained. Only the special bays which allow for combinations are discussed.

1. State Pavilion: In operations this bay is usually used splitted which allows for two narrow body aircraft. It is also possible to allocate three smaller flights to this bay but this is not included in this model since it is not common in operations. Summarizing, STPV is splitted in two bays STPV1 and STPV2 allowing for all narrow body aircraft to be parked here including the Boeing 737 with wing lets (73J)

2. Bay 4: In operations it is referred to as bay 4 left or bay 4 right already indicating that it are two separate bays. In my model they are referred to as 4L and 4R and are always used as splitted bay and there is not possibility to park a wide body (WB) aircraft on bay 4 singular. Bay 4L can handle all narrow body flights up to the B738 excluding variants with wing lets. Where bay 4R cannot park aircraft with sizes of the B737 and B738. Note the exception for a wide body flight when the TK flight is on the ground.

3. Bay J2,J3,J4: All three bays are remote bays in between J1 and J5 which are primary used for narrow body flights. To improve bay capacity it is possible to split these three bay into two bays each. Not restricting the possibilities of narrow aircraft types. All narrow body (WB) aircraft can be parked here. The bays are referred to as J2A,J2B, etc.

5.2.2. Bay Constraints

To ensure that the model produces feasible solutions for the test case at JKIA, constraints have to be implemented. These can be airport specific constraints but also general constraints which are typical for the bay assignment problem. General constraints that are always used in research are the concurrently constraints, the bay compliance constraints and the single bay per aircraft constraints. Some more airport specific constraints are the fuelling constraints, blocked bay constraints, splitting of the flights constraint and adjacency constraints. Where the adjacency constraints and the splitting flights constraints are already mentioned to be needed in the development of the objective function. All constraints used in the model will be elaborated in this subsection. Note that examples of all the constraints are showed in LP format in section A.3.

Single time-slot constraint

Concurrently constraints are needed to ensure that that only flight is allocated to one bay at the same time. Due to the fact that it is impossible to have two flights at one bay this constraint is implemented as hard constraint. Within research two methods exist to formulate the problem. The first one is the use of a multi-time slot model where for each time instance the summations of flights standing on ground at one bay should be less or equal to one, it can be less than one if no flights are assigned but it cannot be more than one (conflicting flights). Both methods have their advantages and disadvantages. For the use of multi-time slots constraints the major drawbacks are the increased amount of decision variables and the applicability for robust optimization. Where for the single time slot model the amount of constraints is the major disadvantage. Therefore, to be able to select the best method both constraints are modelled and compared.

The multi-time slot model consist of certain slot lengths that need to represent the flight schedule. When for example time slots of 15 minutes are chosen, flights with normally 15 minutes in between can now be classified as conflicting since they can both appear in the same time slot. This results in a inexact model. Looking to the flight data time slots of 5 minutes should be representable. The basic idea is that for every time slot at every bay all flights that are compatible with that bay and are within the slot will be summed up. Since not every bay should be occupied every time slot the summation should be less or equal then 1. Modelling one day with slots of 5 minutes and 40 bays in total will results in 12 * 40 * 24 = 11520 time constraints.

The use of single-time slot models comes down to one idea and that is that no overlapping flight pairs are allowed at the same bay. To ensure this, one constraint have to be formulated for all flight pairs per bay to compare the arrival times with the departure times. In this model use is made of a pre-processing block that first analyses all the flights and put the results in a matrix where the result is a one if the flights are overlapping and a zero otherwise. This way only one constraint is needed for each flight pair per bay, which is a large advantage for the use of RO later in this thesis. The formulation is displayed in Equation 5.5. Note that $T_{i,j}$ is the pre-processed time matrix that contains the information whether flights are overlapping. Also the notation that i should not equal j is important since the same flight is always overlapping and not relevant for the model since it cannot appear twice. Lets assume their are 2700 unique conflicting flight pairs (which is the case on 02-06-2015), this times 40 bays results in 108000 constraints. You can immediately see the difference with multi- time slot models. However, multi-time slot models are less exact and are not capable of writing new constraints for new flight pairs individually which causes all the time slots constraints to be repeated when designing for additional scenarios. Therefore, the single-time slot constrained is used where Table 5.2 will show the results for the different models in terms of sizes and solving time. You can clearly see that when you try to model more exact with time slots of 1 minute that it results in a larger model and that when using RO the single time slot model is performing better.

Table 5.2: Comparison single vs multi-time slots constraints

Model	Time Constraint	Size Lp File	Writing + Solving Time (sec)
Buffer	single	5859 kB	92
	multi (1min)	12760 kB	153
	multi (5min)	3233 kB	76
RO	single	35511 kB	266,7
	multi (5min)	75208 kB	478

$$X_{i,k} + X_{j,k} \leq 1 \qquad \begin{array}{lll} \forall \quad k = 0, \ldots., k_{max} & & \\ \forall \quad i = 0, \ldots., i_{max} & \text{if} & T_{i,j} = 1 \\ \forall \quad j = 0, \ldots., j_{max} & \text{if} & i \neq j \end{array} \tag{5.5}$$

BAY COMPLIANCE CONSTRAINT

The bay compliance constraint ensures that all aircraft are allocated to suited bays. To do this a similar approach is used as in the case of the time constraints where first as pre-processor a matrix is made which shows the combination of aircraft with bay and entails with a one that it is suited and with a zero that it is not suited. It is implemented as hard constraint to ensure that only feasible solutions are generated. The constraint is shown in Equation 5.6, where B represents the bay compliance matrix.

$$BC(i): \quad \sum_{k=0}^{k_{max}} X_{i,k} = 1 \qquad \begin{array}{lll} \forall \quad i = 0, \ldots, i_{max} & & \\ \forall \quad k = 0, \ldots., k_{max} & \text{if} & B_{i,k} = 1 \end{array} \tag{5.6}$$

SINGLE BAY PER AIRCRAFT CONSTRAINT

This constraint is in a way similar to the concurrently constraint, the concurrently constraint states that two aircraft cannot stand at one bay while this constraint states that only one bay per aircraft is allowed. This constraint is required to avoid double-scheduled tasks and is therefore implemented as hard constraint. It must be noted that in practical cases this constraint is often violated. This has to do with long stay aircraft that are often temporarily parked at remote stands to allow the bay to be used in the mean time. When the flight departures again it is often towed back to a bay to avoid bussing and increase passenger convenience.

To implement this practical case in the model long stay flights are splitted in three parts: arriving, parking, departing. This way the model considers each part as separate flight and will assign this to only one bay. This division does require additional constraints to take into account the costs of splitting flights and consider the regular fuelling constraints. These both will be described in the section on splitted flight constraints.

Equation 5.7, shows the normal formulation of the constraint and as can be seen it is an equality constraint. All flights has to be assigned to a bay and is therefore in contradiction with the concurrently constrained where the resource "bay" does not have to be allocated to flights. Note that this constraints is similar as the bay compliance constraints.Writing constraints smart with the use of pre-processors and knowledge a lot of constraints can be combined as can be seen in this section. Note that this constraint is therefore not written in the LP file since it otherwise will be a double constraint with the bay compliance constraint.

$$SB(i): \qquad \sum_{k=0}^{k_{max}} X_{i,k} = 1 \qquad \forall \quad i \tag{5.7}$$

FUELLING CONSTRAINT

Most flights need fuelling at an airport. In the case of JKIA not all bays are provided with fuelling services and fuelling trucks are not available. Therefore, a hard constraint is required to ensure that all flights that need fuelling are assigned to a fuelling bay. The constraint is very rare in use and the layout really depends on the lay-out and services of the bays and the flight schedule.

Fuelling is only required for departing flights and therefore the constraint should only be written for departure activities. So for all flights that are not departing) Equation 5.8 should be written.

However, to allow for more flexibility some long stays can also be fuelled in the parking activity. This strongly depends on the per flight where most flights can only be fuelled when the flight plan is known. For this the pilots need to be on duty and will constraint the possibility of fuelling to the time span just before departure. An assumption is made that all non-domestic flights can only be fuelled in the departure part of the splitted flight. And domestic flights can be fuelled in one of the two activities as shown in Equation 5.10.

Summarizing, the first constraint is used for all non-domestic departing flights and "Full" domestic flights. Where the second constraint is used for long stay domestic departing flights.

$$F(i): \qquad \sum_{k}^{k_{max}} X_{i,k} = 1 \qquad \begin{array}{l} \forall \quad i = 0, ..., i_{max} \\ \forall \quad k = 0, ..., k_{max} \quad \text{if} \quad F_k = 1 \end{array} \tag{5.8}$$

$$F(i): \qquad \sum_{k}^{k_{max}} X_{i,k} + \sum_{k}^{k_{max}} X_{i-1,k} \geq 1 \qquad \begin{array}{l} \forall \quad i = 0, ..., i_{max} \\ \forall \quad k = 0, ..., k_{max} \quad \text{if} \quad F_k = 1 \end{array} \tag{5.9}$$

SPLITTED FLIGHT CONSTRAINTS

As mentioned before the long stay flights are splitted in three parts. To limit the amount of towings to just the cases where fuel is needed or preferences are at stake a penalty value have to be linked to the objective function. The splitted flight constraint introduces this penalty term and this term is then also included in the objective function with a certain weight. Since the splitted flights are chronological and follow each other in the data use can be made of the indices (i), (i+1) and (i+2) when parking equals zero. For the night stays a separate constraint is needed to include the position of the operations a day in advance. So flight (i) is set to a bay, where it is currently parked, and flight (i+1) and (i+2) have to be allocated. The allocation constraint of this night stay arrival is shown in section A.3 and is just a simple equality constraint.

For long stay day flights all three parts can be allocated. For each combination a constraint is written and when the bays are different this results in a penalty value. In total three penalty values are written. One for the combination of night stay flight (i) with (i+1) and two for the combination (i+1) with (i+2). This has to do with the fact that the function can result in negative or positive values. So one penalty values is positive and implemented when the function is negative and the other represent the opposite situation. For the day flight the two penalty values are needed for both combinations.

$$\begin{aligned} &SP(i,k): \quad X_{i,k} - X_{i+1,k} - V_{i,k} + W_{i+1,k} = 0 \qquad \forall \quad i = 0,....,i_{max} \quad \text{if} \quad PARK_i = 0 \\ &SP(i+1,k): \quad X_{i+1,k} - X_{i+2,k} - V_{i+1,k} + W_{i+2,k} = 0 \qquad \forall \quad k = 0,...,k_{max} \end{aligned} \tag{5.10}$$

ADJACENCY CONSTRAINTS

As already mentioned the adjacency constraints are required to optimize for gate usage. The constraint is added for the bay combination: bay 11 with bay 10 and bay 5 with bay 6 since gates 5 and 10 are the only non-bussing gates able to board bay 6 and 11. To optimize for gate uses it is important to note that the adjacency constraints should not be hard but soft. This can be explained with the following example: when no other nose-in bays with dedicated gates are available a hard constraint will push the flight to a remote bay also requiring bussing and having a less preferred bay which make the solution worst. Therefore, this soft constraints should limit the adjacency constraint to the case where it can be solved without additional use of remote bays.

Equation 5.11, shows the adjacency constraints for both combinations. Where the first equation is for bay 11 and the second is used for bay 6. Note that the bay index number is not the same as the bay number it self and that indexes i and j are not representing all flights but only the departing flights. The constraints state that when two departure activities conflict, $TD_{i,j} = 1$, that the sum of the two flights for the combination should be less or equal to one. Meaning that the two flights cannot both be assigned to both bays. To be able to allow for this the constrained is made soft with penalty value S that can get the value one allowing the conflicting flights to stand on the bays.

$$\begin{aligned} &ADJ(11,i,j): \quad X_{i,9} + X_{j,10} - S_{11,i,j} \leq 1 \quad \text{if} \quad TD_{i,j} = 1 \quad \forall \quad i = 0,....,i_{max} \\ &ADJ(6,i,j): \quad X_{i,14} + X_{j,15} - S_{6,i,j} \leq 1 \quad \text{if} \quad TD_{i,j} = 1 \quad \forall \quad j = 0,....,j_{max} \end{aligned} \tag{5.11}$$

5.3. GATE ASSIGNMENT

Now that the bay model is developed the next step is to construct the gate model. The basic principle remains the same but the control variables and the constraints will be altered. The main set-up of this section will be similar to the previous one where in the first part the objective function will be scoped and developed and in the second part the specific gate constraints will be constructed.

5.3.1. OBJECTIVE FUNCTION

With the results of the bay assignment the input of the gate assignment is set. The output, however, is yet to determine with the use of the objective function and constraints. To develop these the same method is used as in the previous section. The main requirements were already discussed in detail and will be summarized below:

1. Maximize KQ handled flights to terminal 1A
2. Minimize Bussing
3. Take into account preferences of non-KQ flights and KQ flights
4. Minimize passenger transport distance

The maximization of KQ handled flights to terminal A is an important objective for KQ, since they want to maximize the usage of their investment and want to optimize for efficient operations. The latter statement is actually mainly pushed due to the limited manpower. With all flights centralized around one terminal less personnel is required. However, the objective is in conflict with the minimization of bussing. In the morning wave all gates can be used by KQ and bussing is minimized, but in the evening wave manpower limits the possibilities and requires all flights standing at terminal B or C to be bussed from terminal A.

Since all flights already have been allocated to bays the options are limited. However, the bay assignment already took this objective into account and maximized the amount of passengers to terminal A. Both for the morning wave as for the evening wave. Meaning that only the distance between the bay and gate should be minimized during day and evening flights should be boarded through terminal A. To assure this all departing flights of KQ after 6 PM must be boarded by terminal A and constraints are added to assure this.

Summarizing, the distance between bay and gate should be minimized.This takes into account the minimization of bussing, the minimization of passenger walking distance and the maximization of KQ flights to terminal 1A. In the evening additional constraints are required to push KQ handled flights to terminal A even when the flight is standing at another terminal. Note that the minimization of bussing has preference over the maximization of flights to terminal 1A. Where in the evening this is not possible due to manpower constraints.

The last part to consider is again the airline preferences. In the previous section all flight preferences for certain bay and gates were already tabulated in Table 5.1. The preference for bays is already pushed but now the preferences for the gates should also be adhered to. In this model this is implemented again with the use of preferences in the objective function. It is necessary since some flights require gates at an non optimal distance of bays. This for example holds for Precision Air which is standing at terminal D and boarded through terminal A. KQ has higher preferences for de-boarding which pushes the PW flight to domestic bays and requires the departing passengers to be bussed to the other side of the airport.

Concluding, again two terms are required to model the situation at JKIA. These are the minimization of distance between bay and gate and the maximization of airline preferences. In addition, one additional constraint is required to assure that no gates at terminal B and C are used after 6 PM. Both functions will be displayed and elaborated in the following two paragraphs. Note that these two terms are without the required penalty value for double scheduled gates.

MINIMIZATION OF DISTANCE BETWEEN BAY AND GATE

This objective function is identical to the one used in the bay assignment. The only difference is the measurement of distance. In the bay model the distance from the check-in terminal to the bay was the input and now the difference between the bay and the gate is used. This requires a matrix containing all the distances between feasible bay gate combinations. This matrix is represented by D2 and has two indexes on for the bay and one for the gate. Note that the bay is not a decision variable but a deterministic value since this is the solution of the previous model. See Equation 5.12, for the entire formulation.

$$z6 = \sum_{i=0}^{i_{max}} \sum_{l=1}^{k_{max}} P_i * X_{i,l} * D2_{bay_i,l} \tag{5.12}$$

MAXIMIZATION OF AIRLINE PREFERENCES

In Table 5.1, all flights with gate preferences are given. To adhere to this objective, the same approach is used as in the preferences for bays, see Equation 5.13. Where i represents all departing flights and l is the index for the gates. Pref represents the preferences of the flight for a gate in a number between 0 and 1, where the closer to 0 the higher preference the gate has.

$$z7 = \sum_{i=0}^{i_{max}} \sum_{l=1}^{k_{max}} X_{i,l} * PREF2_{i,l} \tag{5.13}$$

MINIMIZE DOUBLE ALLOCATED GATES

At JKIA there are less gates then bays which makes it common that one gate is used to board multiple flights simultaneously. However, this is only when no other solution can be found. To allow for this property and minimize it a soft constraint is written for the gate compliance. Meaning that a penalty value M is included in the objective function with a certain weight.

The following step in determining the objective function is adding weights to the three objectives. This is done by adding a weight factor δ,ϵ and η to all objectives respectively as given in Equation 5.3. The weight attribution method is the same as used for the bay assignment. Note that objective z8 is the sum of all penalty values M.

$$z9 = \delta * z7 + \epsilon * z6 + \eta * z8 \tag{5.14}$$

5.3.2. GATE CONSTRAINTS

As already mentioned the gate constraints are needed to assure feasible solutions. For the gate assignment three types of constraints are required. These are: all departing flights must be assigned to feasible gates, domestic flights to domestic gates and vice versa, KQ-handled flights after 6 PM and the soft constrain to allow for double scheduled gates. All will be elaborated in this subsection.

ALL DEPARTING FLIGHTS MUST BE ASSIGNED TO FEASIBLE GATES

Each bay has specific gates by which it can be boarded. Therefore, per bay a list of feasible gates is given. The model can then read the bay which is assigned to the flight and constraint the gates to be one of the feasible ones. This is done by making a summation over the feasible bays and set it equal to one. This immediately pushes all the departing flights to be assigned to a gate.The same constraints is written for the bay model. Note that the only difference is that for the gate assignment the maximum feasible value can be two instead of 1. This has to do with the fact that simultaneous flights can be boarded through the same gate where they cannot be allocated to the same bay since this will be conflicting. To cover this possibility and minimize the occurrences a penalty value as mentioned is introduced.

DOMESTIC FLIGHTS TO DOMESTIC GATES AND VICE VERSA

Domestic flights can only be assigned to gate 1 or 2 and non-domestic flights can only be assigned to all other gates. Since some continental flights can be assigned to domestic bays it is important to constraint the boarding of these flight to non-domestic gates. Otherwise the model will search for the closest distance and will assign a domestic gate which is not feasible in practice. This is also the other way around.

To assure feasible solutions the summation of all domestic flights individually over gates 1 and 2 should be equal to one. For all the other flights the summation should be equal to zero. The constrains are given in Equation 5.15 and Equation 5.16.

$$\sum_{l}^{l_{max}} X_{i,l} = 1 \qquad \begin{array}{ll} \forall & i = 1, ..., max \quad \text{if} \quad DOM_i = 1 \\ \forall & l = 1,2 \end{array} \tag{5.15}$$

$$\sum_{l}^{l_{max}} X_{i,l} = 0 \qquad \begin{array}{ll} \forall & i = 1, ..., max \quad \text{if} \quad DOM_i = 0 \\ \forall & l = 1,2 \end{array} \tag{5.16}$$

KQ-HANDLED FLIGHTS AFTER 6PM

Since a function already exist from the bay assignment that divides the airlines into groups that use different terminals, the KQ-handled flights can easily be separated. Since this is the group checking in at terminal A. Doing this another division should be made to separate the flights departing after 6PM from the other flights. This is done by an if statement that only loads flights with an departure time larger than 6PM. When these flights are separated constraints are written to block the allocation of these flights to terminal b and c. To recall from chapter 4 Terminal b and c consist of gates 4,5,7,8,9,10. Knowing this the summation of each flight on these gates should be zero, since it may not be allocated to these flights. Equation 5.17, displays the constraint written in the model. Where k represents the gate 4,5,7,8,9,10 and i represents all departing KQ handled flights after 6PM.

$$\sum_{l}^{l_{max}} X_{i,l} = 0 \qquad \begin{array}{ll} \forall & i = i, ..., max \\ \forall & l = 4, 5, 7, 8, 9, 10 \end{array} \tag{5.17}$$

5.4. ROBUST SCHEDULING MODELS

The baseline model described before does not include any robust measures. In this section the selected robust methods for analysation will be elaborated in terms of alternate constraints and objective functions. In the first subsection the use of buffer times will be elaborated and in the second and third subsection the robust optimization method and the spare bay method will be explained respectively.

5.4.1. BUFFER TIMES

The use of buffer time is a simple and straightforward method where the time constraints are widen. The time used as buffer time is 30 minutes per flight where 15 minutes are added before arrival and 15 minutes are added after departure. This results in more conflicting flights and a different resulting bay and gate assignment. In Figure 5.1, an indication is given of two flights that initially could be assigned to the same bay and with the insertion of buffer times(arrows) cannot be assigned to one bay. Note that no change is required in the objective function and no new penalty values are introduced.

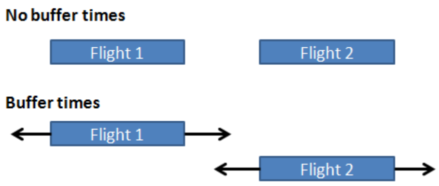


Figure 5.1: General working principle of buffer times

5.4.2. ROBUST OPTIMIZATION

In contrast to buffer times this method does need the introduction of extra constraints and penalty values. Extra delay scenarios will be included and the model will design the schedule based on all these possible delay scenarios. To avoid the case where no feasible solution exist and the scenarios where you actually do not want to handle possible delays due to the small possibility of occurrence and the high introduced cost in terms of objective function, penalty values are introduced that can determine whether a single time constraint (flight pair) have to be violated or not. Meaning that for every delay scenario there exist a M number of penalty values that is equal to the length of the amount of additional time constraints. The delay scenarios are all randomly generated based on the historical data. Basically, when the time matrix from the baseline schedule equals zero and in the new scenario equals one there is a new conflict to design for and this is then added as new constraint with penalty value.

To provide a feasible and valuable solution a minimum buffer time is used in combination with the new objective function. This buffer time is based on the minimum buffer time used at JKIA of 10 minutes.

5.4.3. SPARE BAYS

The use of spare bays can result in a positive effect on delays. In the manual assignment process this is actually already used in order to cope with the unexpected variations in cargo flight placement and other flights such as military flights. In this model it is assumed that two narrow body bays are not available for the initial baseline schedule, these are bay J2A and J2B. In order to this the capacity of the bay is altered from 1 aircraft to zero aircraft. When analysing the results with the test scenarios this is changed back to the original capacity of one. This way you can analyse the costs of this solution and the results of the solution. In practice the initial model not considering any robust measures already design such a schedule due to the low value of the bays.

Since the use of spare bays does not result in representable solutions (no buffer times) and logically also result in a high amount of repositioning, it is analysed in combination with the use of buffer times. The buffer times used are the same as in the model with buffer times (30 minutes) to be able to compare the additional value of spare bays which can absorb the reactionary delays.

5.5. SIMULATION MODEL

To be able to analyse the performance of robust methods a simulation of the operations on the day is required. As already explained this will be done with the use of simulation cases, which represents 10 cases with different delay schedules. These baseline solution should then be run for each individual case measuring the feasibility of the initial solution and the amount of reassignments required. The amount of reassignments is in the end the most important performance to measure and should be minimized.

The minimization of reassignments can be used as objective by constraining the flights to be assigned to its previous assigned bay, and when this is not possible introduce a penalty. This penalty is then used in combination with a very high weight to minimize the number of reassignments. When a reassignment is required it is important that it sticks to the old objective function and old constraints. Therefore this new soft constraint is implemented in the baseline bay model. This also enables you to compare the objective values of different solutions.

6

Constructing the Model

With the problem being translated into a mathematical formulation, it is now necessary to develop the actual software in order to produce results. From the previous chapter it can already be seen what type of software is preferred and used. This chapter will start with the verification of the software language chosen. Next to the software language, tools are required to build the model and optimize the model. These tools will also be elaborated and verified in this chapter.

To do this the remaining of the chapter is divided in the lay-out of the overall model which consists of 4 major programming blocks. In Figure 6.1, the overview of the four blocks are given in combination with the function of the blocks. The first block that will be discussed is the raw input where the main data is loaded and the resources such as bays and gates are defined. Secondly, the input is pre-processed where all the flights characteristics will be added to the flights. This include the preferences for bays, the compliance with bays, whether it is a long stay, etc.. The third block will then use this information to generate the actual optimization model and write this to a Lp file. This Lp file will then be used to optimize the problem and write the solution of the problem to a SOL file.

Now the final step is to make the results graphical and usable for Kenya Airways. For this interactive Gantt Charts are constructed from the SOL file and tables are written as they are using it now. Finally, all the information will be saved and the model is finished.

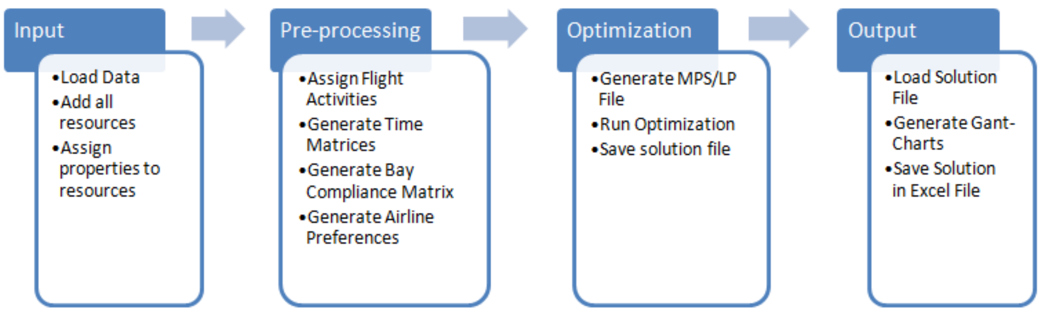


Figure 6.1: Software lay-out

6.1. Programming Language

The first decision that should be made when designing the model is the selection of the programming language. The programming language is needed to build the model, analyse data and analyse the results. To make this decision, all advantages and disadvantages of common used languages are tabulated in Table 6.1.

Table 6.1: Trade-off between available programming languages, an extension on the work of van Goethem [2]

Language	Application field	Strength	Weaknesses
Java	General Programming	Extremely fast code Platform independent	Complex High level programming
C ++	General Programming	Extremely fast code Platform independent	Complex High level programming
C	Web applications	Fast code Works well in Microsoft environment	Complex High level programming
VB.NET	Microsoft based applications	Extremely easy to use Works well in Microsoft environment	Not fully object oriented Completely locked in Microsoft environment
Matlab	Engineering applications	Analytically strong Easy to understand	Data structuring memory intensive Not real programming language
Python	General Programming	Analytically strong Easy to understand Open-Source	Not well-known (yet)

As can be seen from the table the six most common languages are: Java, C, C++, VB.NET, Matlab and Python. Some of them are well-known and others are becoming more popular. From the pros and cons you can clearly state see that some are performing better than others, which is also dependent of the purpose. Due to the non-existing experience in Java,C, C++ and the complexity of these codes the decision is made to not use one of these. The other language that can be disregarded is Matlab, the primary reason for this is the required licence which KQ does not want to buy.

The choices remaining are VB.NET and Python. Both are great and relative easy programming languages, where VB.NET is a long known programming language from Microsoft and Python is a relative new open-source language. Open-source means that many people write their own specific modules which you then can use to safe time. This in combination with the announcement of google that it recognizes python as one of their official programming languages made the decision to choose Python.

In python itself you also got a variety of versions. They are promoting their newest version 3 a lot, but there is still plenty of criticism about the working of it. Therefore, the more developed Python 2.7 64 bit version is used.

6.2. PRE-PROCESSING MODEL

For the pre-processing model it is important that all data is loaded and handled correctly. For this project use is made of two data sheets, one containing all the historical data and one containing the turn around report for the entire day. Both can be acquired from the Siba server containing all the operational data. This server is SQL based and should in the end be linked to python to have an operational model. However, since no accessibility to Siba was given all reports used were extracted to an excel database. Meaning that the current model uses a link with an offline excel data sheet where in the end an online link with the a SQL database is required. The obtainment of the data with python is not that different for both types. Therefore, this link can be easily altered to link the model with the online data when the accessibility is provided.

With the link being provided all data is sorted and assigned to separate arrays. When the loading is done this results in an array containing all departure times, an array containing all destinations, etc.. Enabling you to obtain all flight information of a specific flight with only its index. While assigning all information to the arrays, immediately a difference is made between long stay flight and short stay flights. Long stay flights are added three times representing the arrival, parking and departure activity respectively. In addition, the aircraft type details are assigned to certain aircraft groups to be able to generate the bay compliance matrix fast and it is checked whether it is a departure activity and what time the boarding should start.

When all the information is stored in the correct arrays, the last step is to do some pre-processing. This include the generating of the time and bay compliance matrices. The time matrix consist of the information whether flights are overlapping and the bay compliance matrix entails the information whether a certain flight/aircraft is capable of being parked to a specific bay.

Another type of information that has to be pre-processed concerns the airport lay-out. Meaning that it is not dependent on the database but on the specifics of the airport, like bays and gates and their properties. To put the characteristics in the model, arrays are made representing the different sort of information for the different bays just as in the case for flights. For example the array called baynames contains all the bay names, where the index represents the bay itself. Other properties that are loaded for the generation of bays in separate arrays are: the bay distances to different terminals, fuel capability and aircraft type compatibility. For the generation of gates the same procedure is followed but other properties are required. These are stored in separate arrays and consist the connecting bays, and the distances to connecting bays.

Lastly, the preferences of certain flights should be included in the model. In Table 5.1 these were already given and this is now included in the model. For each airline or flight number that requires preferences an array is created which stores the preferences for all the bays and gates. In this array the index represents the specific bay/gate.

6.3. WRITING OPTIMIZATION MODEL

Now that all information is stored in the program the next step is to write the optimization model. As already explained in this model three optimization models are written: one representing the bay assignment, one representing the gate assignment and one representing the simulation model. For all three models constraints, variables and objective functions should be written as is explained in the previous chapter. Such optimization models are usually written to a Lp file or a MPS file. This can be achieved on multiple ways in Python, one is the use of Cplex or for example Gurobi. However, a free alternative is chosen called Pulp. This is a basic module for optimization programs which works very straight forward.

6.4. SOLVING OPTIMIZATION MODEL

Now the MPS/Lp file is written the model can be solved. Initially, Cplex version 12.6 was used to analyse the feasibility of the model and the solution. This was done since Cplex was available for research purposes and is the best developed optimization programming [1]. However, since Cplex licenses are very expensive another free solver called LPsolve will be tested.

The working principle of both tools are similar. They require a LP or MPS file as input and solve this problem to optimality. However, LPsolve is significantly slower in solving and has a lower solution quality. When results are found they both are able to write it to a solution file which can be loaded by the output function block.

6.5. GENERATING OUTPUT

In Python there are many modules to display the results. For this report a Gantt chart of all flights at the bays would provide the best overview. The problem now is that the Gantt chart will become really chaotic if all information is included as text in the bars. Therefore, a different module called Bokeh is used.

Bokeh is a Python interactive visualization library that targets modern web browsers for presentation. Its goal is to provide elegant, concise construction of novel graphics in the style of D3.js, but also deliver this capability with high-performance interactivity over very large or streaming datasets. Bokeh can help anyone who would like to quickly and easily create interactive plots, dashboards, and data applications.. This enables the user to gather all the data required by pointing the mouse on the specific task.

In addition, the results are written to an excel file including all flights with their corresponding bay and gate. Such data sheets are currently used by KQ and are used to store data and during operations. For storage pur-

[1]This is proven in the benchmark test conducted by Mittelman [54]

poses of KQ it would be handy if the data is stored directly in the Saba Server. This is not the only connection required by the Saba server and therefore the first step before implementing would be the establishment of this link.

7

Bay and Gate Assignment at JKIA

With the model being developed and the data being available the results can be drawn and the model can be verified and validated. In this chapter the results of the baseline model including buffer times will be elaborated in terms of the bay assignment and the gate assignment. Reason being the fact that the current procedure is to use buffer times. This allows the results of this chapter to be used as part of the validation process.

The results will be analysed in three sections. First section 7.1 will elaborate on the flight schedule of JKIA and select the design day for the model. Secondly, section 7.2 will provide all the necessary data to generate the output. Lastly, section 7.3 will elaborate on the results of the bay and gate assignment with a specific focus on the two chosen days with the use of fixed buffer times.

7.1. Characteristics of the Flight Schedule

Jomo Kenyata Airport is the base for Kenya Airways. Because Kenya Airways' schedule can be seen as a hub and spoke network the airport is considered a hub airport. In Figure 7.1, you can see the number of movements per hour both for both inbound flights and outbound flights. It is very clear that the schedule consist of waves, in the morning and at 12 AM there are two high peak waves and in the evening the wave is more spread. In addition, Figure 7.3 shows the number of aircraft on ground on each time of day. You can clearly see that during the morning most aircraft are standing on the ground. Therefore, the morning wave is considered as the most constraint case for the airport and KQ.

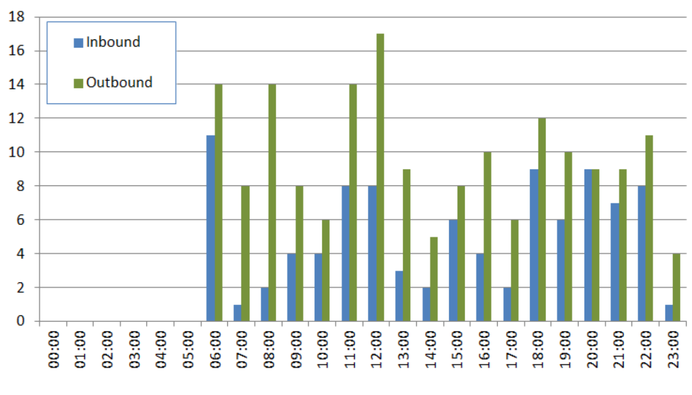


Figure 7.1: Number of inbound and outbound movements on Tuesday 2-6-2015

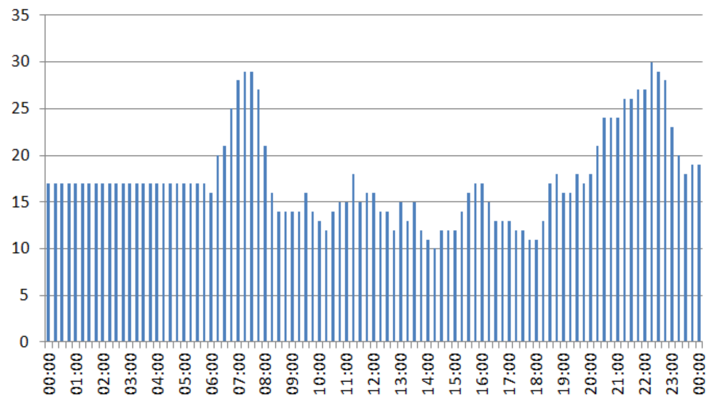


Figure 7.2: Number of aircraft on ground on Tuesday 2-6-2015

The major challenge, therefore, lies in the preparation of the morning wave. This includes developing the baseline schedule and reposition night flights to allow for fuelling and reduce operational complexity. The main focus of the results will therefore lie on:

1. **Schedule Robustness:** minimize number of required reassignments during operations

2. **Night Preparation:** in order to prepare bays for the morning wave and allow for refuelling

The only information left to start the test case is the flight schedule itself. Since the model should be based on the actual flight schedule, data from Kenya Airways should be obtained. In addition, one would prefer to run the model for a specific day when the traffic loads are at their highest. This will be a summer day when traffic is most severe. However, due to the current closure of the runway during night, the data of 2014 does not represent the current flight schedule. Therefore, the most recent available data is used which was the entire month June and the beginning of July. In Figure 7.3, you can see the number of KQ movements per day starting on Monday first of June. It is clearly visible that Wednesdays and Sundays are one of the busiest days. Where Wednesday 5 July has the overall highest number of movements in the graph.

Now the question remains what day to choose, normally you do not design for the maximum number of movements but somewhere 10% lower. However, to be able to analyse the possibilities of robust scheduling the schedule should not be fixed/over-constrained. In the case of JKIA this is unfortunately mostly the case and the day chosen is therefore an average day (Tuesday 02-06-2015) which allows some flexibility. This to see the value of the model when there is a certain amount of flexibility. However, for KQ the model would be useless if it is not capable of solving its most complicated days. Therefore, the model will also be ran for Wednesday 5 July to see whether the model is able to handle such over-constrained cases and also to validate the model results with an extra day. This way conclusions can be drawn on the possibilities of robust scheduling for severe cases and for less severe cases.

Furthermore, data is only available for KQ handled flights. To solve this bay experts and Flightstats.com are used to identify all relevant flights and insert these in the data of the fifth of July and the second of June.

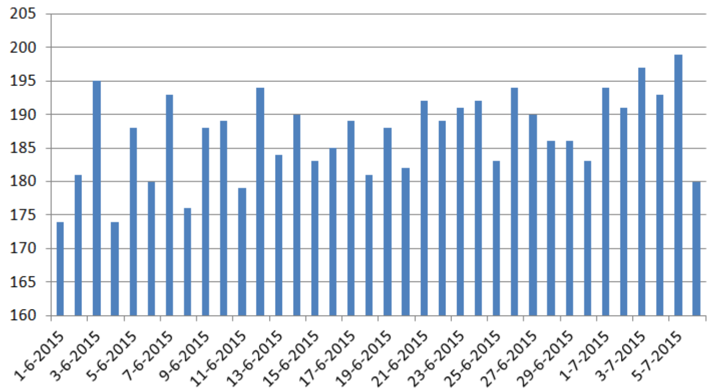


Figure 7.3: Number of KQ-handled aircraft movements per day

7.2. Data Obtainment

The bay and gate assignment model needs several input parameters to construct the objective function, the constraints and the decision variables. The information required for the mathematical model is indicated by the following enumeration:

1. The scheduled flight schedule of Tuesday 02-06-2015 and Wednesday 05-07-2015
2. The delay data of flights during the past few months
3. The bay connection time between bays and the four terminals
4. The bay compliance matrix indicating feasible aircraft bay combinations
5. The additional non-KQ handled flights for the two design days

7.2.1. Flight Schedule

The product developed in this thesis should in the end be able to operate on KQ databases. However, since time did not allow for a direct link to their various databases, such as the Sabre Movement Control system, historical data is used. This data is all obtained from the Sabre tool and contains all the information required. Including the allocated bays, the aircraft type, the registration number, the arrival time, the departure time and the amount of passengers.

When using the Sabre database with a direct link this should allow for implementation. Not only for implementing this model as baseline schedule but also for using it as real time assignment tool. Since this was not the initial scope of the project this is not taken into account in the model, but it should be a small step to transform this baseline schedule to a real time assignment tool.

7.2.2. Delay Data

The data used for the construction of the flight schedules is actually very large and contains the entire month May, June and the beginning of July. In this dataset all delays are available for all KQ-handled flights. It is important that the delay data is recent since it is very dependent on the time of year and on the current flight schedule. Therefore, when implementing, this data should be refreshed accordingly. The exact length of this delay data should still be established based on preferences of KQ.

7.2.3. The bay connection time between bays and the four terminals

As already mentioned the distances are measured from four references points in minutes, these are terminal A,B,C and D. Figure 7.4, shows the airport lay-out indicating the four terminals. The exact distances are included in Appendix A.

Note should be taken that it does not matter that the distances are exact. It is most important that the distances represented the hierarchy of the bays the same from each terminal. An exception is made for the Hotel bays, which as can be seen have larger values for the distance. These distances were exactly measured but in the end increased to add the preference of not using these bays.

Figure 7.4: Reletative position of different terminals at JKIA

7.2.4. THE BAY COMPLIANCE MATRIX

The bay compliance matrix is an important requirement to assure feasible solutions. The obtainment of the matrix was, however, not that straightforward. Different bays have certain operation modes where they can be divided in two separate bays. These exceptions were already discussed and the assumption was made to only take into account the most used operation modes. This included the division of bay 4,J2, J3, J4 and STPV into two separate bays. Special note should be taken on bay 4 which in this set-up is not able to handle wide body flights. However, Turkish Airlines has to be allocated to bay 4 and operates a wide body A330 so a special constraint is included that reserves both bay 4L and 4R only for the TK flights.

In addition, the bay compliance matrix from JKIA differs significantly from the one in operations. Therefore, it was very worthwhile to join the operations a few nights and update the bay compliance matrix accordingly. The final result can be found in Table A.1 in Appendix A . Note that the propeller driven airplanes are not compatible with nose-in bays. This has to do with the fact that the props will put a significant wind on the passenger building, blowing dust particles damaging the building.

7.2.5. THE ADDITIONAL NON-KQ HANDLED FLIGHTS

The airport JKIA has multiple airlines flying a standard weekly or seasonally routine. All these flights have to be allocated to bays and gates which makes it of utmost importance to have the entire flight schedule. However, KQ only has access to their own handled flights and does not have any information on the additional flights. The DRC knows the additional flights by head but the model needs them to generate a representable output.

As already mentioned the non-KQ handled flights have a standard routine. Therefore, based on each day the flights are obtained from experts or from Flightstats.com. Table 5.1, shows the required additional flights on Tuesday 02-06-2015. For Wednesday the China Souther flight should be included with preference for bay 19. Note that the weekly routines can change every single season so the file with the non-KQ handled flights should be updated constantly when changes occur.

7.3. RESULTS BASELINE BAY AND GATE ASSIGNMENT

Now that the model is developed and the input is established the results can be analysed and validated. The best way to do this is to develop the results with the same current procedures. Meaning the use of fixed buffer times of 30 minutes where 15 minutes are added in front of the flight and 15 minutes at the end. This solution can be used to validate the model and the objective function used. Firstly, the results for 02-06-2015 will be elaborated followed by the results for Wednesday 05-07-2015. After the construction of these results, these

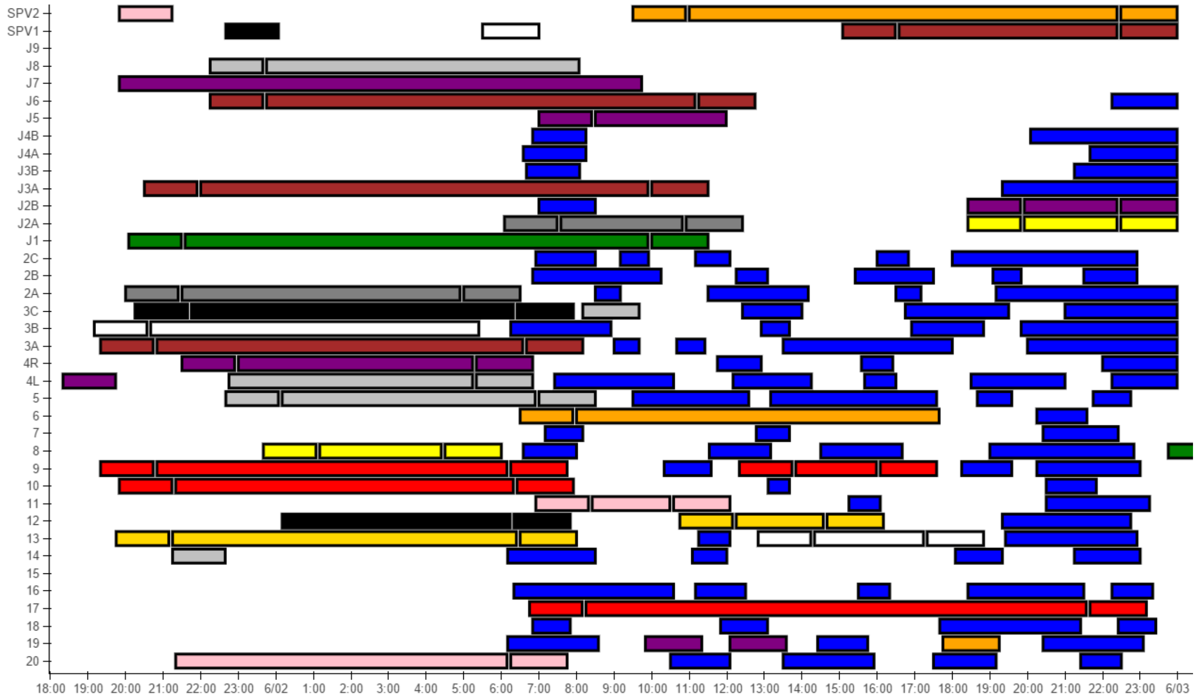


Figure 7.5: Baseline results 02-06-2015 including buffer times

models will be tested in the next chapter with real life scenarios to analyse the performance of the robust measures. Lastly, this chapter will conclude on the applicability of the automated developed application.

7.3.1. RESULTS USING CURRENT PROCEDURES 02-06-2015

The entire developed model discussed in previous chapter is now able to generate results. The result for 02-06-2015 can be seen in Figure 7.5. Note that it does only display the tasks and not their names since this will become chaotic to display. Therefore, also to have it operational, a html tool is developed that shows all the information of the particular task by pointing the mouse on it. The figure shows the interface of this html tool. If more information is required for the reader all results are tabulated in Appendix B.

To start with an explanation of the graph you first need to understand the colours. In general, a blue tasks represent a full flight and not a splitted flight. All the other colours represent splitted flights and the colour is there to see the links between the splitted flights more quickly. Due to the objective minimizing the amount of towings only the cases that are needed for feasibility or high preference must be splitted. Most splitted flights are on the same bay as can be seen from the colours so no towings are required. The last flight that have to elaborated is KQ524. It is repositioned twice due to the fact that it departs after the morning wave. To be able to handle all morning wave flights at serviceable bays this flight have to be parked at a non-serviceable bay temporally in the morning wave.

Another important aspect are the flights that landed a day before operations and the flights that are leaving the day after operations that do not have the outbound information yet. The arrival part of the flights arriving a day in advance are pushed to the bays where there were assigned to. The flights that do not have an outbound are set to depart at the beginning of the following night shift. This is a point to further look into but this is very dependent on the tail assignment. The current method assigns these flights to non-beneficial bays where at night they often need to be repositioned to the correct bay. If this information or part of this information can be obtained earlier or this flight can be communicated with the tail planners it can result in a better overall planning with less repositioning. The actual validation of the model and the objectives will be done in the end of this project and can be found in Chapter 9. However, some general conclusions and validations can already be drawn and will be given in the following subsections.

Table 7.1: List and reason of repositioning on 02-06-2015.

Inbound	Colour	Initial Bay	Reason For Repositioning
KQ671	Pink	SPV2	Fuelling
KQ619	Black	SPV1	Fuelling
KQ8609	Silver	J8	Fuelling
CZ633	Purple	J5	Airline Preference
KQ8665	White	3B	Feasibility
KQ524	Purple	4L	Feasibility
KQ524	Purple	J7	Feasibility
KQ101	Orange	6	Flight Preference
KQ444	Silver	14	Domestic Preference

NUMBER OF REPOSITIONING

From the graph you can identify 9 towings in total. All these towings are given in Table 7.1 with their according flight number, colour in graph and reason for repositioning. Note here that SPV1,SPV2,J7,J8 and J9 are the non-serviceable bays and the Hotel bays are not used if possible (even when it requires repositioning).

Starting from the top the first flight to be repositioned is KQ671. It is allocated to SPV2 the day in advance and has to be relocated for fuelling purposes. It was allocated to SPV2 since the origin was domestic but the destination changed to a continental flight. Since it is a 738, which is the largest aircraft able to park at B20, it is allocated to this bay since it is the most favourable bay for continental KQ flights. The second and third flights are repostioned with the same reasons. The fourth flight is an exception which has to do with the flight preferences of CZ as airline. They have a deal with KQ which allows them to depart from B19 but since this bay is no free for arrival it is offloaded at a remote bay where J5 is the closed able to park WB aircraft from B19.

From the graph you can also see the need for repositioning. Generating the results of the particular day also requires the allocation of the next night stays. These are the flights that suddenly stop at 11:59 PM. When this departure time is given it means that no route is linked to the tail yet. For the transition of 02-06-2015 to 03-06-2015 this consist of 15 flights. The model tries to put the flights on serviceable bay if feasible and tries make use of the STPV bays for the smaller aircraft. This because AT7 planes or Embraer's are likely to be assigned to domestic destinations. You can see from results that the non-serviceable Juliet bays are not assigned and the STPV are both assigned for small aircraft.

PASSENGER TRANSPORT DISTANCE

To give a clear overview of the passenger transport distance a new Gantt chart is generated indicating the various flight types. In Figure 7.6, yo can see the result where the blue color represents a non-domestic KQ flight, the green colour indicates a domestic flight, the purple colour indicate flights from Terminal B and lastly the red colour represents flights checked in Terminal C.

Looking to the graph keeping the walking distance in mind you can see some nice trends. Most KQ flights that are not domestic are focussed around their new terminal, unless no other option is available such as in the morning or evening wave. Domestic flights are all assigned to domestic bays and non-KQ handled flights are centred around terminal 1B and 1C. All arriving flights with transfer passengers are assigned to beneficial gates to minimize their walking distance and the operational complexity such as bussing and baggage carrying, this is the accomplishment of the flight preference function discussed in the following subsection.

BAY PREFERENCES

As already mentioned all flight preferences are adhered to. In Table 7.2, you can see all the preferences of certain flights in combination with their assigned bay and gate. It can be concluded that weight and the working of the preference objective is adhering to the intended purpose.

GATE ASSIGNMENT

Since the bay and gate assignment are two individual models it is important to analyse the results of the gate assignment individually. The main assumption made, was that the use of adjacency constraints can minimize double scheduled gates and bussing. This assumption should be validated. Two other points that need

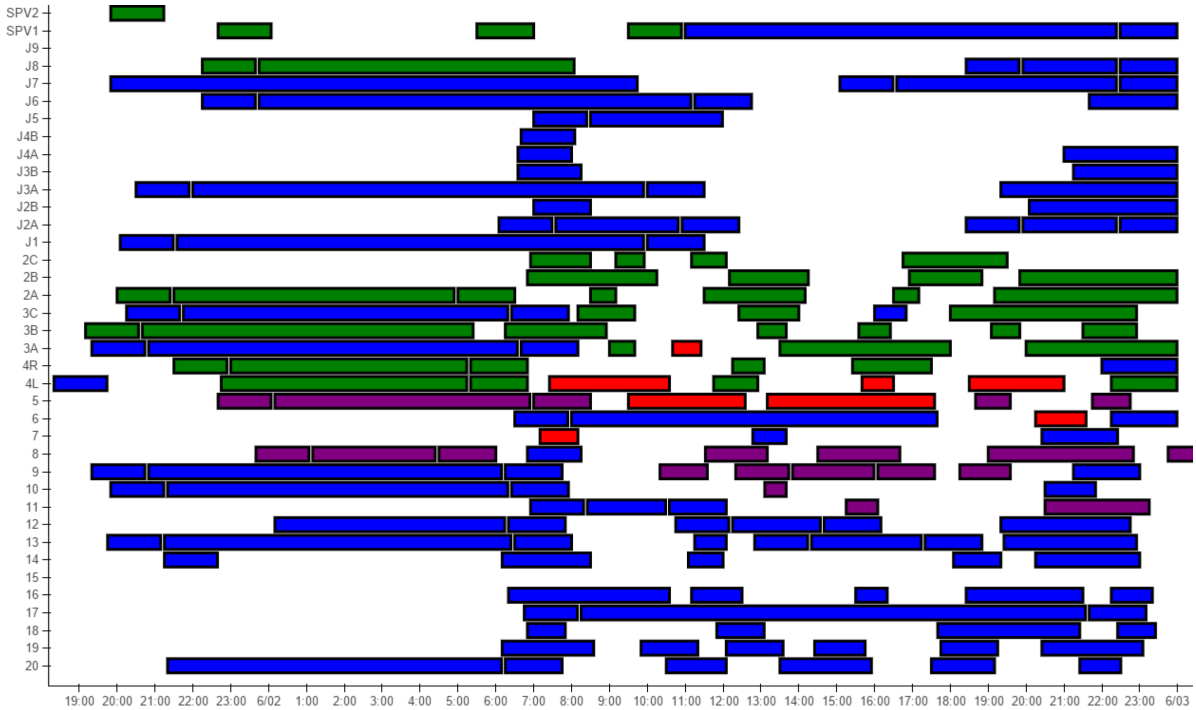


Figure 7.6: Baseline results 02-06-2015 displaying the various flight types

Table 7.2: Preferences of flights to bays and gates for 02-06-2015

Flight	Dest	Preferred Bay	Actual Bay	Preferred Gate	Actual Gate
G9735	SHJ	10	10	10	10
EY642	AUH	7	7	7	7
SA185	JHB	11	11	10	10
SN463	BRU	5	5	5	5
SA181	JHB	5	5	5	5
SV430	JED	8	8	8	8
QR	DOH	5	5	5	5
EK720	DXB	8	8	8	8
BA064	LHR	11	11	10	10
TK6492 & TK607	IST	4	4	4	4
LX295	DAR	5	5	5	5
MS850	CAI	7	7	7	7
CZ634	CAN	19	19	19	19
ET	ADD	8/9	8/9	8/9	8/9
KQ117	AMS	19	19	19	19
KQ112	CDG	19	19	19	19
KQ102	LHR	18	18	20B	20B(25)
KQ310	DXB	19	19	19	19

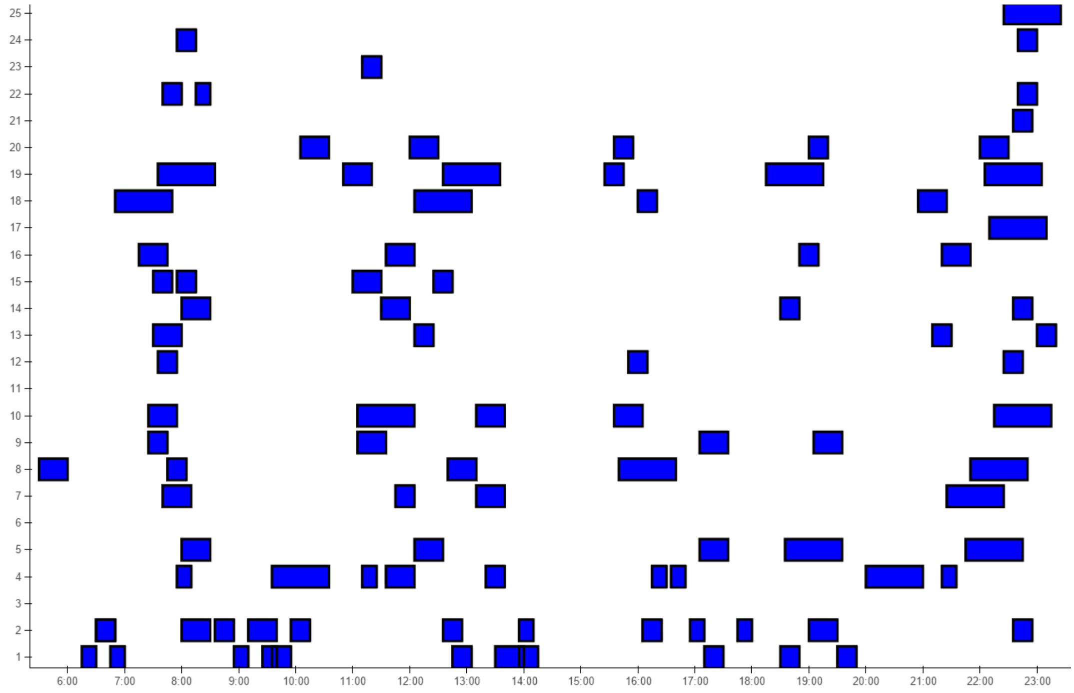


Figure 7.7: Gate assignment results for 02-06-2015 with buffer times

to be analysed are the two objectives used which were the minimization of the transport distance between bay and gate and the maximization of flight preference. In Figure 7.7, you can again see the html plot of the gate assignment with all departing task. The detailed tabulated overview can be found in the appendices.

The first point to validate is the use of flight preferences. Of course the bay assignment results already showed the value of the objective and in the same table (Table 7.2) you could see that results comply to the gate preferences. Note that gate 20B is indicated with gate 25 in the graph and that it is not the dedicated gate for bay 18. However, this is the preferred gate since gate 18 and 19 cannot be used to board two wide body flights simultaneously where the flight to CDG is boarded simultaneously at gate 19.

The second point to validate is the use of adjacency constraints. From the results you can see that two flights are conflicting at gate 1, this is however a very satisfactory results due to the fact that gate 3 is closed and all domestic flights have to be handled by gate 1 and 2. Looking to bay 6 and 11 where adjacency constraints where used will give the validation of the working principle. Bay 6 is allocated to two flights, where the first flight is repositioned for departure (no boarding process) and the second flight is boarded after 6PM meaning that bussing is already required for this bay and is therefore allocated to gate 24. However, the adjacency constraints still makes sure that no conflicting departure flight is allocated to bay 5 as can be seen. Bay 11 has three flights allocated where two flights are highly preferred for gate 10 which are the BA flight and the SA flight as can be seen from Table 7.2. You can see that during the departure of these two flights no conflicts are assigned to bay 10. For the other flight bay 10 is not occupied so gate 10 can be used without additional bussing.

The last point to validate is the passenger transport distance. This can be checked by the use of dedicated gates for dedicated bays. Unfortunately, due to the man power limitations after 6PM all KQ handled flights are bussed from terminal A affecting the use of dedicated gates and thus the objective. However, besides this 8 flights are allocated to a non-dedicated gate which are all located on domestic bays. This is a logical result since dedicated gates can not be used for non-domestic flights standing on domestic bays. For these flights gate 4 or a bussing gate is required and used.

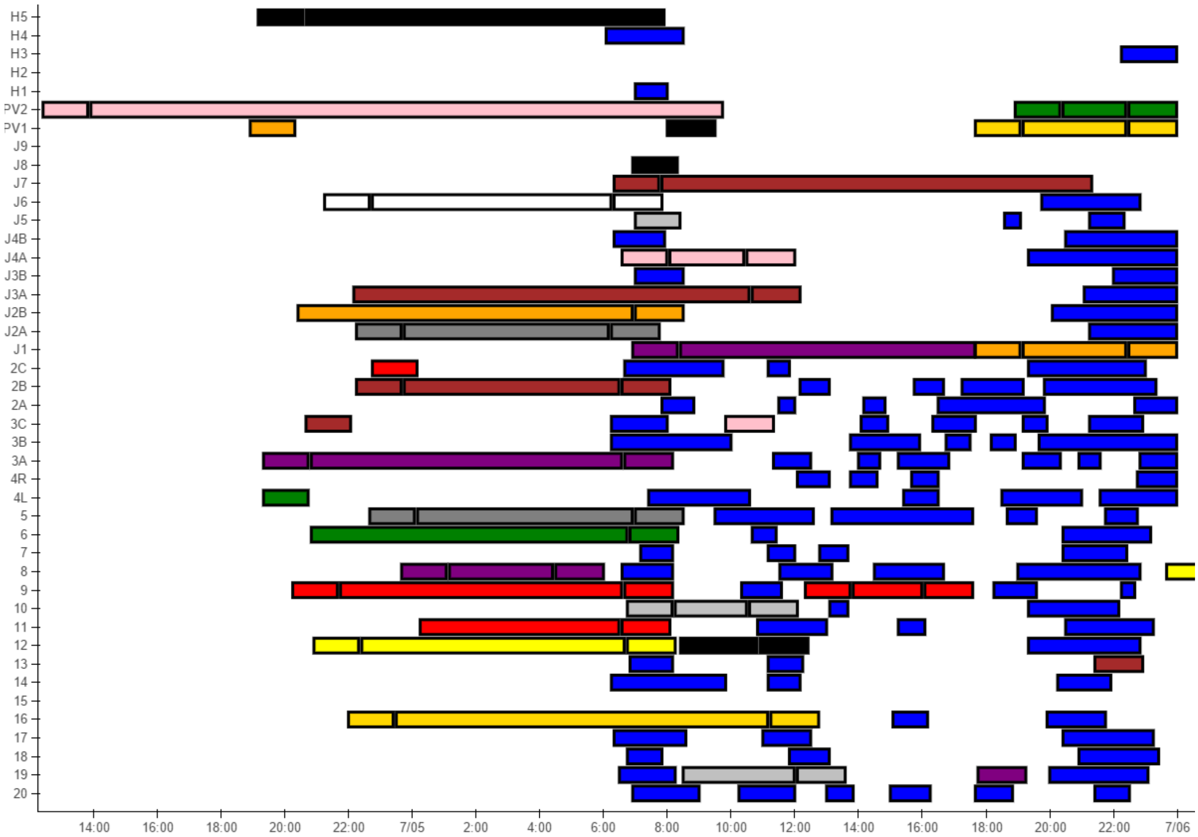


Figure 7.8: Bay assignment results for 05-07-2015 with buffer times

7.3.2. RESULTS BAY AND GATE ASSIGNMENT 05-07-2015

As already mentioned the previous analysed day was an average day and therefore the day 5th of July is also analysed to check the ability of the model to handle more constrained schedules. The generated result is shown in Figure 7.8. You can immediately see the need for the hotel bays. One full flight is assigned to H3 and 3 long stay flights are temporarily allocated to hotel bays to provide feasible solutions. Note that again bay 4R is not used in the morning peak. This is due to the fact that the TK flight is allocated to 4L and does not allow for an additional flight on bay 4. The same procedure as in the previous section is used to take you through the results for 05-07-2015. The main difference is that all departure times of the morning wave are around 8PM where normally this is to spread to an earlier time. This was probably the case due to the current runway maintenance.

NUMBER OF REPOSITIONING

From the graph you can identify 10 towings in total. These towings are shown in Table 7.3 in combination with the reason for repositioning. From these towings 3 are needed due to fuelling constraints on bay SPV1,SPV2, J7 and J8. Not all of these flights are night stays meaning that the current assignment of the arrival activity to a non-serviceable bay is required for feasibility. From the other 7 towings 1 is required for feasibility. The pink flight at bay SPV2 is a good example of such situation. Where the departure activity is not set to a serviceable bay to open up the serviceable bay for an incoming "full" stay flight. The other repositioning all have to do with the fact that certain flights have preferences for certain bays.

PASSENGER TRANSPORT DISTANCE

To give a clear overview of the passenger transport distance a new Gantt chart is generated indicating the various flight types. In Figure 7.9, yo can see the result where the blue colour represents a non-domestic KQ flight, the green colour indicates a domestic flight, the purple colour indicate flights from Terminal B and

Table 7.3: List and reason of repositioning on 05-07-2015.

Inbound	Colour	Initial Bay	Reason For Repositioning
KQ8665	Black	H5	Domestic Preference
KQ8603	Pink	SPV2	Feasibility
KQ251	Orange	SPV1	Fuelling
KQ331	Black	H4	Fuelling
KQ521	Brown	J8	Fuelling
CZ633	Grey	J5	Flight Preference
KQ311	Purple	J1	Flight Preference
KQ619	Red	2C	Domestic Preference
KQ704	Brown	3C	Domestic Preference
KQ485	Green	4L	Flight Preference (TK)

lastly the red colour for flights checked in Terminal C.

Looking to the graph keeping the walking distance in mind you can see some nice trends. Most KQ flights that are not domestic are focussed around their new terminal, unless no other option is available such as in the morning or evening wave. Domestic flights are all assigned to domestic bays and non-KQ handled flights are centred around terminal 1B and 1C. All arriving flights with transfer passengers are assigned to beneficial gates to minimize their walking distance and the operational complexity such as bussing and baggage carrying, this is the accomplishment of the flight preference function discussed in the following subsection.

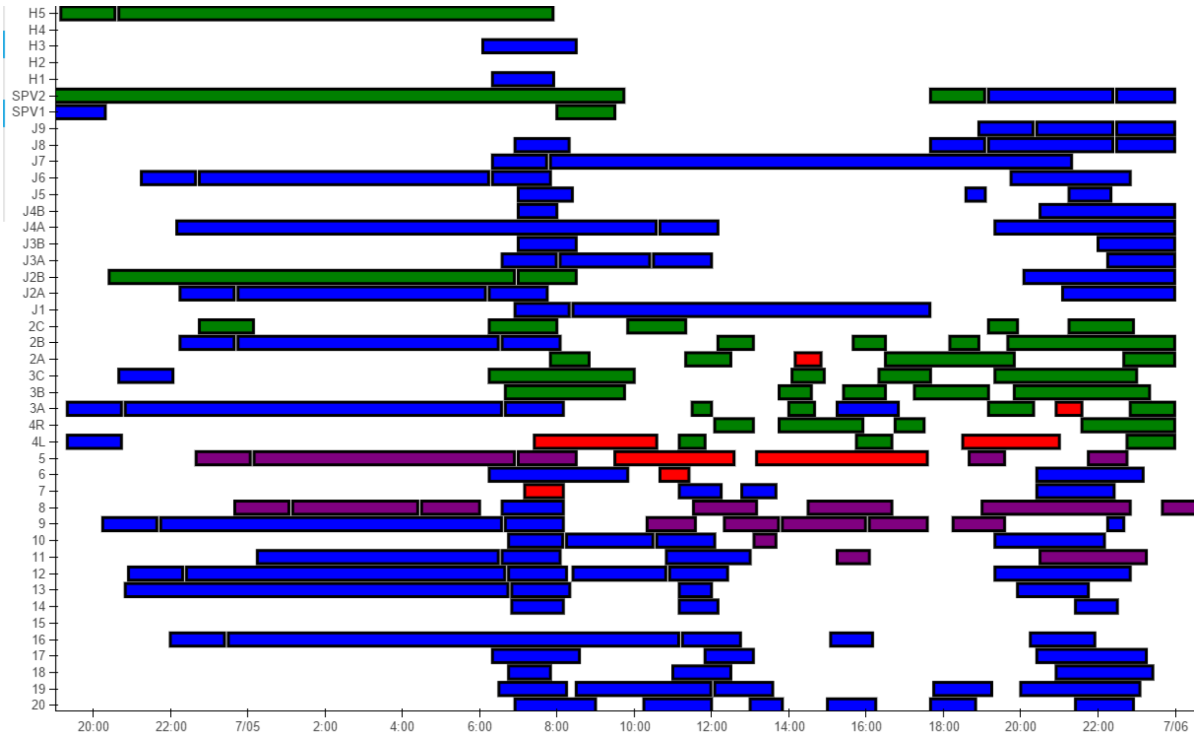


Figure 7.9: Baseline results 05-07-2015 displaying the various flight types

BAY PREFERENCES

As already mentioned all flight preferences are adhered to. In Table 7.4, you can see all the preferences of certain flights in combination with their assigned bay and gate. It can be concluded that the working of the preference objective is validated and behaving as expected.

Table 7.4: Preferences of flights to bays and gates for 05-07-2015

Flight	Dest	Preferred Bay	Actual Bay	Preferred Gate	Actual Gate
G9735	SHJ	10	10	10	10
EY642	AUH	7	7	7	7
SA185	JHB	11	11	10	10
SN463	BRU	5	5	5	5
SA181	JHB	5	5	5	5
SV430	JED	8	8	8	8
QR	DOH	5	5	5	5
EK720	DXB	8	8	8	8
BA064	LHR	11	11	10	10
TK6492 & TK607	IST	4	4	4	4
LX295	DAR	5	5	5	5
MS850	CAI	7	7	7	7
CZ634	CAN	19	19	19	19
ET	ADD	8/9	8/9	8/9	8/9
KQ117	AMS	19	19	19	19
KQ112	CDG	19	19	19	19
KQ102	LHR	18	18	20B	20B(25)
KQ310	DXB	19	19	19	19

GATE ASSIGNMENT

Since the bay and gate assignment are two individual models it is important to analyse the results of the gate assignment individually. The main assumption made was the use of adjacency constraints to minimize double scheduled gates, which should be validated. Two other points that need to be analysed are the two objectives used which were the minimization of the transport distance between bay and gate and the maximization of flight preference. In Figure 7.10, you can again see a general overview of the task where the detailed tabulated overview can be found in the appendices.

The first point to validate is the use of flight preferences. Of course the bay assignment results already showed the value of the objective and in the same table (Table 7.4) you can see the compliment to the gate preferences. Note that gate 20B is indicated with gate 25 in the graph and that it is not the dedicated gate for bay 18. This has the same reason as in the results of 02-06-2015, which is that two wide body flights cannot be boarded simultaneously at gate 17 and 18.

The second point to validate is the use of adjacency constraints. From the results you can see that two flights are conflicting at gate 1, this is however a very satisfactory results due to the fact that gate 3 is closed and all domestic flights have to be handled by gate 1 and 2. Looking to bay 6 and 11 where adjacency constraints were used will give the validation of the working principle. Bay 6 is allocated to three flights. The first flight occurred in the morning wave and is conflicting with the departure of bay 5. This requires bay 6 to be boarded through bussing. The reason for this is that the penalty value S is activated since no other nose-in bays are available without additional use of Hotel bays. The other two flights both have no conflicts with bay and can thus be handled by gate 5 for departure.

Bay 11 has three flights allocated where two flights are highly preferred for gate 10 which are the BA flight and the SA flight as can be seen from Table 7.4. For all three flights bay 10 is not occupied so gate 10 can be used without additional bussing.

The last point to validate is the passenger transport distance. This can be checked by the use of dedicated gates for dedicated bays. Unfortunately, due to the man power limitations after 6PM all KQ handled flights are bussed from terminal A affecting the use of dedicated gates and thus the objective of the minimization. However, besides this fact 6 flights are allocated to non-dedicated gates which are all located on domestic bays. This is a logical result since dedicated gates can not be used for non-domestic flights. For these flights gate 4 or a bussing gate is used.

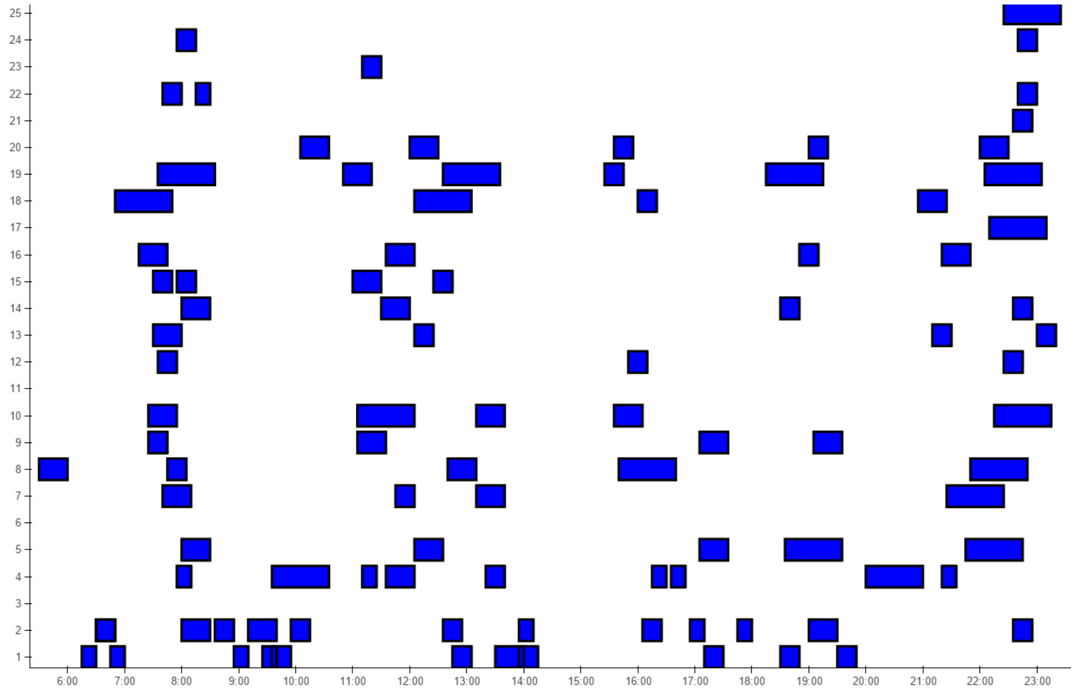


Figure 7.10: Gate assignment results for 05-07-2015 with robust buffer times

7.4. CONCLUSION

From the generated results some valuable conclusions can drawn on the applicability and the usefulness of the model. To start you can see from both analysed days that the model is able to cope with different flight schedules and generate automated results. This is a valuable improvement over the current manual process. This is also part of the validation where an increase in demand does still results in a valuable representable solution.

However, it must be noted that the results still have to be analysed by the DRC daily to see whether a change in the 90 minutes duration of splitted flight activities can positively affect the solution. Longer durations are always possible, but for shorter durations it is important to keep complexity at a minimum. The DRC himself can judge this the best on the day of operations by checking the utilization of the taxiways and the availability of man power.

In addition, these two days are analysed to verify and validate the results. This is possible since the DRC applies the same method of buffer times which allows for a comparison between the intended solution and the outcome. It can be concluded that the model adheres to the developed objective function and constraints. Where the objective function is validated to represent the real scenario correctly. In Chapter 9, a further verification and validation of the developed objective function is included.
Lastly, no information yet is given on the applicability of the model. As already mentioned the model is able to handle various flight schedules and is representing the objective function accordingly. The only difference now is the represent ability of the objective function for the real life case. This will be validated in the chapter verification and validation. The model is able to be solved to optimality within one minute which is fast considering the complexity. This fastness of the model is important for KQ since it has a very small time span where the bay assignment has to be developed.

8

Results Robust Scheduling

Now the model has been partly validated with JKIA as test case it is time to draw conclusions on the different working principles of the robust scheduling methods. This will be done by first elaborating on the selected methods in section 8.1. Secondly, the chosen approach will be constructed in section 8.2, including the development of all simulation cases. When the simulation cases are set the next step is to run the various simulations. The results of these simulations are elaborated individually in section 8.3. This is followed by the comparison of the individual models in section 8.4. Lastly, the conclusion of all the comparisons will be drawn in section 8.5.

To recall the approach from the research methodologies Figure 8.1 shows the general steps of the model. Where first the baseline schedules are developed as done in the previous chapter. Secondly, the simulation model is generated and all requirements for this simulation are obtained. Lastly, the results of simulation are shown enabling you to draw conclusions.

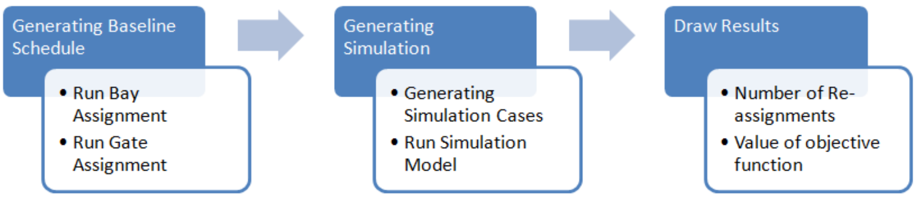


Figure 8.1: Overview of the used approach to analyse results

8.1. Robust Models

Three methods to implemented robustness are developed and analysed. These are the use of fixed buffer times, the use of fixed buffer times in combination with spare bays and the novel method called robust optimization. In this section the models will be elaborated in the respective order.

8.1.1. Fixed Buffer Times

The method of fixed buffer times is commonly used and well known in many areas. Most research in literature use static buffer times ranging from 30 minutes to 60 minutes for the bay assignment. As already mentioned 30 minutes fixed buffer times are used for all flights complying to the current procedures of KQ.

The buffer times are implemented by adjusting the time constraints and are hard constraints meaning that it cannot be violated. It must be noted that the use of fixed buffer times in a model is a static method not looking to any historical data. While used in operations the bay planner is able to take this into account based on experience. This is a strong con coming with the use of buffer times in an automated process compared to the manual process. However, this strongly depends on the experience of the bay planner.

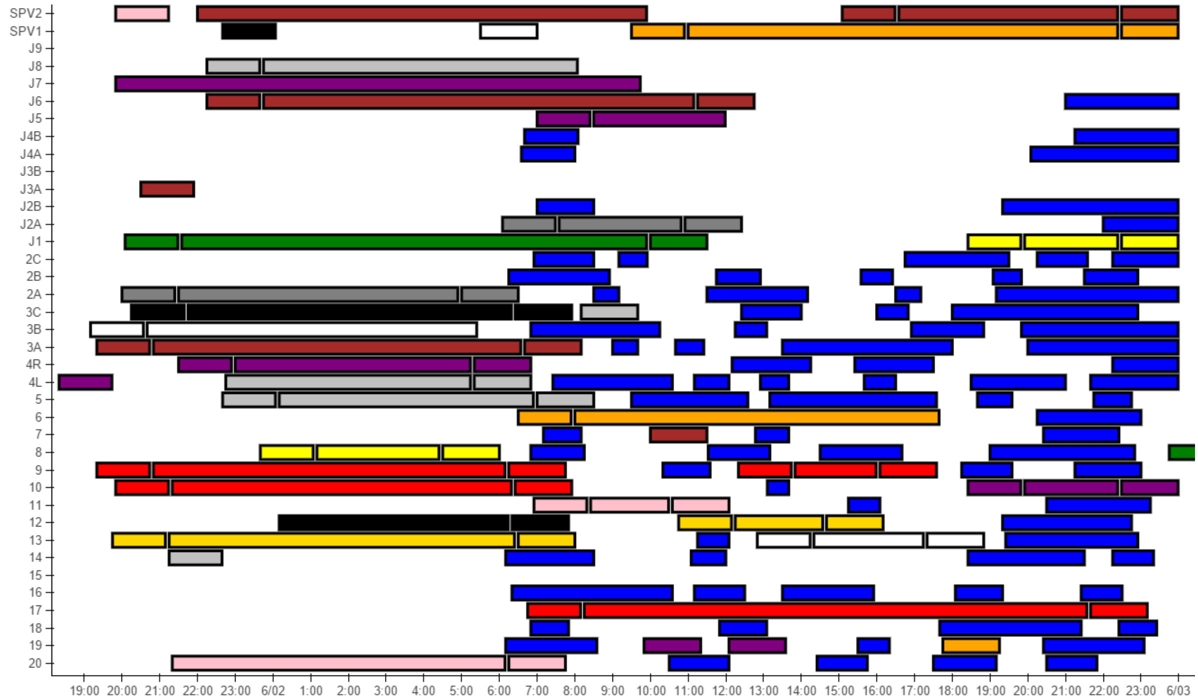


Figure 8.2: Bay Results for 02-06-2015 with the use of spare bays

The results of the use of buffer times were already shown in the previous chapter. From Figure 7.5 you can clearly see that the use of buffer times increases the amount of idle time between flights to a minimum of 30 minutes.

8.1.2. SPARE BAYS

The use of spare bays can reduce the effect of reactionary delays in the bay assignment. The initial model already focusses all flights to favourable bays and the less valuable bays are rarely used as can be seen in Figure 7.5. However, all bays are used and in the morning wave it is impossible to open up bays without additional repositioning. For research purposes the repositioning is allowed to analyse the value of such spare bays. This is done by penalising the use of J3A and J3B. In Figure 8.2, you can see the baseline result where both bays are free on the day of operations.

Since solely the use of spare bays is never sufficient in terms of robustness it is analysed in combination with the use of fixed buffer times of 30 minutes. This allows for a comparison between the two and to see whether spare bays are an added value in terms of robustness.

8.1.3. ROBUST OPTIMIZATION

This method is the novel developed model to introduce robustness in the baseline schedule. It generates additional scenarios based on a random selection from the specific flight delay data. All these developed scenarios are considered while generating the schedule. To avoid unfeasible solutions and the design for unlikely high delays, penalty values are introduced such that some constraints (additional scenarios) can be violated. Meaning that the initial model cannot handle that scenario entirely. The constraints are actually based on flight pairs. When in the new scenario the flight pair becomes conflicting it is added as soft constraint. Resulting in the case that the model can choose per flight pair whether it should be resolved.

The weight of this penalty determines the trade-off between model robustness and the cost of robustness. In this research a value is chosen such that the solution robustness is slightly lower than that of the fixed buffer times. This is done to compare this two methods on their model robustness/stability only.

The number of additional scenarios is chosen based on the results and the computational power available.

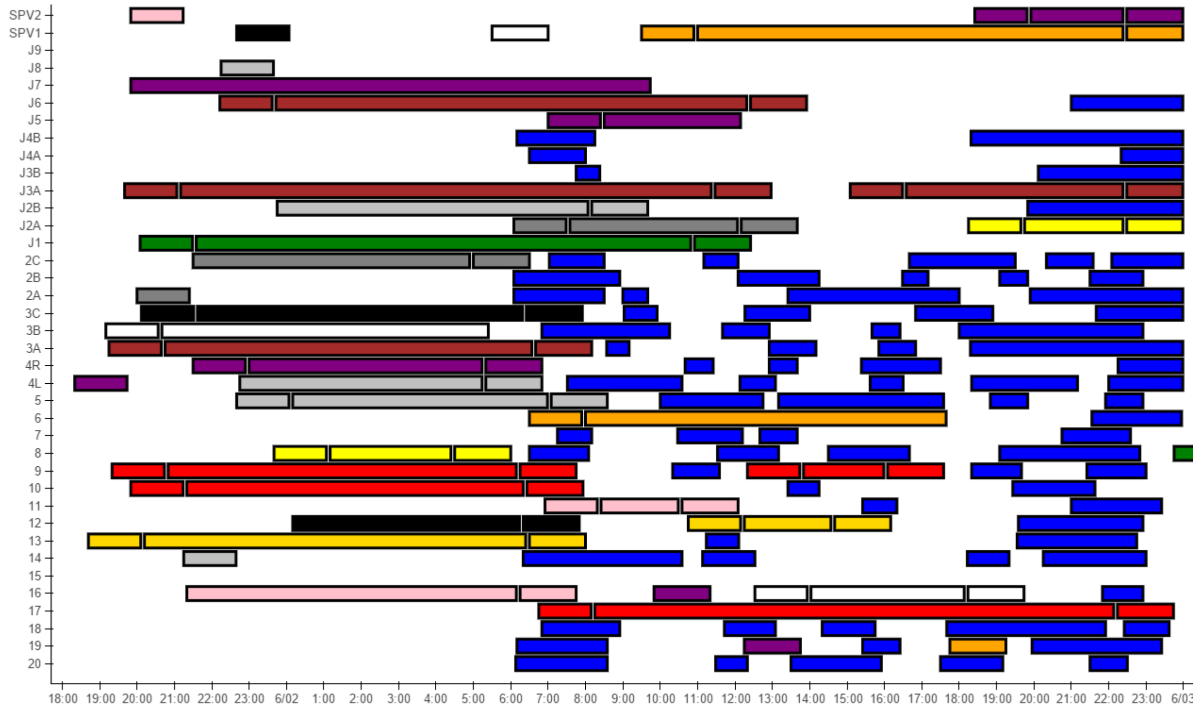


Figure 8.4: Bay Results for 02-06-2015 using robust optimization

Each extra scenario introduces extra constraints and thus also additional decision variables. The higher the number of scenarios the more the results will converge to the optimal solution taking all scenarios into account. However, to take every scenario into account is impossible. When each flight has 40 unique delays available and there are 100 flights in total this will result in 40 to the power of 100 scenarios, which is impossible to take into account. It also must be noted that solving the RO model does not require the most time, this in contrast is generating the model and saving it to a LP file. To see the convergence of the model and select a number of additional scenarios considered a graph is made showing the results for increasing amounts of considered scenarios. This graph is shown in Figure 8.3, where the total number of reassignments for all simulation cases combined is plotted versus the amount of additional considered scenarios. It is clearly converging and the number of 80 scenarios is taken up to 30 minutes for writing of the LP file only. Therefore, an amount of 60 additional scenarios is chosen since it only takes 10 minutes for analysation and gives a proper representation of the possibilities and advantages of Robust Optimization.

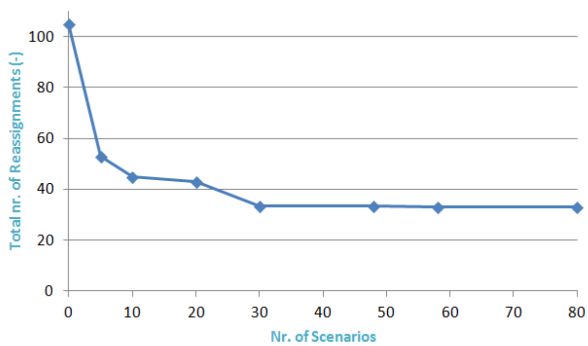


Figure 8.3: Total number of reassignments required versus the amount of additional scenarios considered

One outcome of the use of RO is shown as Gantt Chart in Figure 8.4. You can see that it differs from buffer times since 3 flights violate the minimum amount of idle time of 30 minutes. These are low risk flights which where not delayed much in the months before operations.

8.2. CONSTRUCTING SIMULATION CASES

After developing the baseline models and analysing the results it is now time to draw conclusions on the performance of the robust measures. This will be done by using simulation cases for simulation as described in subsection 8.2.1. After the generation of ten cases all models will be tested on their performance for the different simulations. For each model individually and for all models together conclusions will be drawn on their performance measured by two performance indicators. The first being the number of required reassignments and the second being the costs in terms of the objective value.

8.2.1. DEVELOPING SIMULATION CASES

Generating the simulation cases is a difficult process that in the end will determine the quality of the results. To make the results less dependent on the selected scenario a wide range of cases will be developed ranging from soft delay cases to high delay cases as in the work of Yan and Cheng [26]. This way the cases cover a wide range of possibilities and conclusions can be drawn on the usefulness of the different selected robust scheduling methods for different delay cases. It is important to note that for Kenya Airways the most important case to consider is with delays around 15 minutes.

Now the decision has to be made how to draw these cases, making them useful for KQ as well as for research purposes. To do this a few assumptions are made. The first one is that the maximum delay is 90 minutes, incorporating higher delays will not represent realistic schedules as it will never be thought of while designing the operations a day in advance. The second assumption deals with the usefulness of the scenarios. For the bay assignment delays not only mean late departures, but also early arrivals. It is assumed that departures will never leave early and thus leave on time or are delayed. For arrivals not only the delay affects the schedule but also the early arrivals, when seeing the arrival and the departure independently. Of course when a flight arrives late the probability of a late departure is higher than normal and this aspect have to be covered while generating the simulation cases.

To make the cases specific for KQ delay data of JKIA is used. For each inbound or outbound number relevant delay data (location, time, flight number) is searched and based on the mean of this delay data it is divided in a low delay category or a high delay category. This is done to be able to develop the test scenarios for certain delay categories. In total 10 simulation cases are developed, where for each test cases the probability of selecting a delay from the high category is increased by 10%. It must be noted that the calculation and the division of the delay are different for arrival flights and departure flights. Both will be individually elaborated based on an example case in the following subsections.

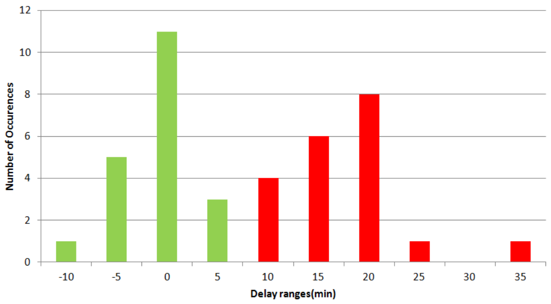
DEPARTURE FLIGHT

As already mentioned, available delay data is used to construct valuable cases both for KQ as well as for research purposes. In Figure 8.5, the histogram and cumulative plot of the delay data for flight KQ116 to Amsterdam is shown. You can see that the amount and value of early departures is negligible and will not affect the bay assignment. This supports the assumption to deal only with late departures. All departures leaving early are replaced with a delay of zero minutes in the delay data.

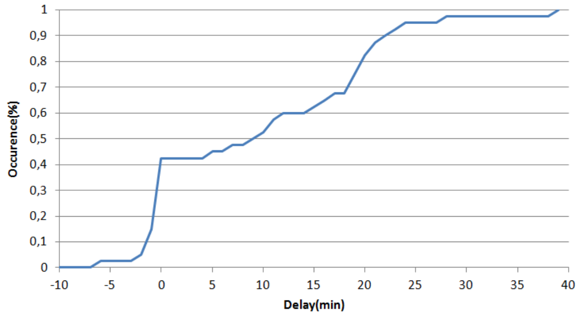
To be able to generate test cases with a certain delay level, the data is divided into two categories. The result of this is shown Figure 8.5a, where the histogram represents the original delay data and the colours shows the data used in the model. Delays of the high delay category are indicated with a red colour and soft delays with a green colour. The results are straightforward and will be used when constructing the test cases, this will be explained in detail after the analysation of all data.

ARRIVAL FLIGHT

The use of arrival data requires additional methods to generate usable results. The main difference lies in the fact that arriving flights can both arrive early as well as late with the same probability. Where for departing flights the probability and impact of early departures is small. For arrival flights the impact of an early arrival as well as for a late arrival can be catastrophic for the bay assignment. To give an example, Figure 8.6 shows the raw delay data of flight KQ117 arriving from Amsterdam. With at the left the histogram of the delays and on the right the cumulative plot.

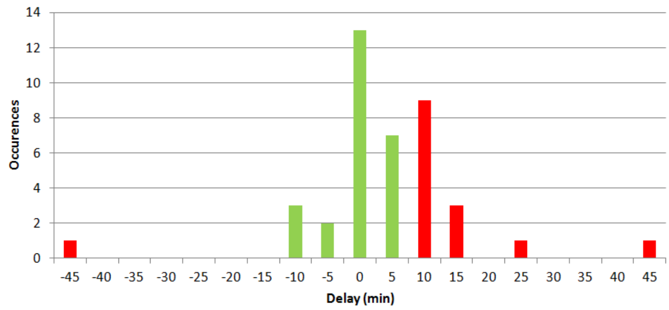


(a) Histogram of raw delay data

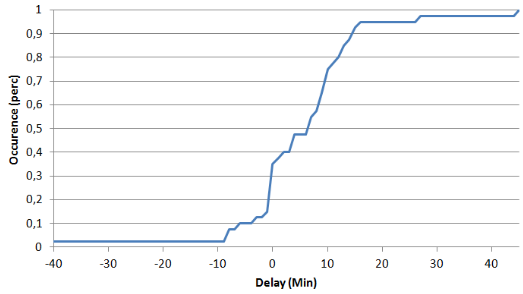


(b) Cumulative plot of the delay data

Figure 8.5: Overview of the raw delay data for flight KQ116



(a) Histogram raw delay data



(b) Cumulative plot of the delay data

Figure 8.6: Overview of the raw delay data for flight KQ117

To divide this data first the impact of the delays should be known to classify them accordingly to the high class or the low class. In other words: what is the impact of an early arrival and what is the impact of a late arrival on the bay assignment?

Late Arrival When seeing the arrival flight and departing flight independently, you can say that a late arrival is beneficial for the bay assignment since it increases the total amount of available idle time. However, a late arrival often results in a late departure affecting the bay assignment. Therefore, a late arrival can be allocated to both classes based on the value. To model this the average value is computed for the late arrivals and this is used as the barrier for the classification of the late arrival delays.

Early Arrival An early arrival can affect the bay assignment rather fast. When an idle time of 10 minutes is used between two flights allocated to the same bay and one flights arrive 8 minutes early and the other 2 minutes late there is already a conflict. Therefore, the value of the number determines the impact of the delay on the bay assignment. To model this the same rule is used as for late arrivals, which used the average of the early arrivals as barrier for the early arrival delay classification.

An overview of the classification is shown in Figure 8.6a, where the again the green colour represents the low delay data and the red colour the high delay data.

NO DELAY DATA

When for a certain flight no delay data can be found additional data is required. This is actually necessary for all non-KQ handled flights since there is no available data for those. For these flights the standard deviation and mean are computed of the entire delay data. To be able to do this again the assumption is made to only consider delays within 90 minutes which immediately removes the outliers.

For the arrival data this results in a mean of 2.2 minutes and a standard deviation of 11 minutes. And for the departure data this implies a mean of 1 minute and a standard deviation of 4.5 minutes. Based on this information 40 data points are constructed complying to the overall data. These 40 data points are then used as explained by the previous two subsections.

8.2.2. CONSTRUCTING THE SIMULATION CASES

Now that all data is pre-processed, the simulation cases are generated. To generate these cases all flights are allocated with an arrival delay and a departure delay. To correctly construct the 10 simulation cases ranging from soft to high a random number generator is used to select the data from the pre-processed data.

For the low simulation cases more delays are wanted from the soft delay pools and for the high test case more data is wanted from the high delay pools. To make this division smoothly the probability of selecting a high delay increases by 10 % for every case starting with 10 %. Meaning that for the first test case 90 % of the delays are selected from the soft delay pools and for case 10 all delays are selected from the high delay pools.

As can be noted the delays are still treated independently. To model the dependency of the delays a post-processor will be used that takes into account the feasibility of the test cases. For example, when one arrival is delayed with 40 minutes and has a minimum ground time of 30 minutes it cannot depart earlier than 70 minutes after arrival. To model this the assumption is made that for narrow body flights the minimum ground time is 45 minutes and for wide body flights 90 minutes. When conflicts are detected the departure time is altered to the earliest available time to depart, again based on the minimum ground time, the delay and the arrival time.

CONCLUSION SIMULATION CASES

The final results of the simulation cases are given in Table 8.1, and are displayed with the mean and the standard deviation. In Appendix D all simulation cases are tabulated. You can clearly see from the mean and standard deviation that the used approach is working correctly developing cases that are slowly becoming more severe.

Table 8.1: Overview of the test scenarios by means of the mean and the standard deviation (SD)

Simulation Cases	1	2	3	4	5	6	7	8	9	10
Arrival										
Mean(min)	-0,91	-0,68	-0,07	-3,73	0,08	-4,29	0,24	-7,61	-0,35	-3,19
SD(min)	5,91	5,84	11,50	13,28	13,92	18,51	20,18	23,78	24,79	24,24
Departure										
Mean(min)	2,45	4,39	6,63	8,81	13,79	15,75	16,22	19,02	21,75	24,36
SD(min)	3,90	6,14	10,00	11,59	14,72	16,59	17,44	19,00	19,32	19,74

8.3. RESULTS SIMULATION CASES

With the generated simulation cases the simulations can be run for the different baseline schedule. The simulation is based on a new model that takes the new departure and arrival times into account in combination with the baseline bay assignment results. This way the model develops a new schedule for the updated arrival and departure times. To minimize the amount of reassignment this model needs a penalty value when a flight is assigned to another bay. This is achieved by introducing a new soft constraint with a high penalty value to assure that the model is optimized for minimum number of reassignments. In this section the results for each individual baseline schedule will be elaborated. The first model tested is with fixed buffer times.

8.3.1. RESULTS USING FIXED BUFFER TIMES

With the simulation cases given the initial baseline models can be tested. In Table 8.2, the results can be obtained with the use of buffer times. You can clearly see that it performs rather well for the first soft cases and starts to require more reassignments for the high delay cases. The second row with results represents the increment of objective value compared to the optimal baseline model without any robust measures. This way you can see how the solution robustness is behaving for the different models with a similar performance indicator.

When comparing the two cases with flight preferences and without flight preferences you see that the results of the latter one is slightly improved. This is as expected since it allows for more flexibility and thus more possibilities to generate a robust schedule. Note that the increments of objective value cannot be compared. Since both are based on the optimal results of the two different baseline schedules.

Table 8.2: Model robustness of fixed buffer times

Simulation Cases	1	2	3	4	5	6	7	8	9	10
Preferences										
Reassignments	0	0	2	3	4	2	4	7	9	9
Obj. value (%)	7,87	7,87	8,31	10,43	15,42	8,27	18,62	27,13	28,24	34,93
Non-Preferences										
Reassignments	0	0	2	3	2	3	4	7	8	7
Obj. value (%)	21,84	21,84	25,38	25,44	24,32	23,61	26,60	45,05	32,98	71,80

8.3.2. RESULTS USING SPARE BAYS

The second model tested with the different test cases is the one using spare bays. From Table 8.3, you can see that is performing worse compared to the one with buffer times in terms of both reassignments and objective value. The latter is logical since it is a combination of buffer times with spare bays making this model more costly. And the former can be attributed to the working of the simulation model. The simulation model minimizes the amount of reassignments and does not calculate the possible amount or reassignments when the order of information is retrieved on bad timings. It just looks at the entire day which can include some reactionary delays, but are less likely to be modelled. Therefore, with the current used simulation model the value of the spare bays cannot be measured correctly.

Again you can see that the number of reassignments for the non preference case is slightly lower. This difference is minimal which has to do with the fact that the obtainment of spare bays limits the flexibility in de schedule and thus the solution space. Note that again the objective value is significantly higher compared to the model with preferences. This has to do with the fact that also the baseline model without any robust measures has more flexibility allowing for a better solution found. Where initially the cost of the model where around 24% it is now increased to 54%.

Table 8.3: Model robustness of spare bays

Simulation Cases	1	2	3	4	5	6	7	8	9	10
Preferences										
Reassignments	0	0	4	3	5	3	4	9	8	10
Obj value	24,12	24,12	14,90	26,67	32,10	24,78	35,52	33,12	55,69	68,22
Non-Preferences										
Reassignments	0	0	5	3	4	3	4	8	9	9
Obj value	54,56	54,56	38,66	56,18	58,38	56,33	59,28	64,36	66,43	83,16

8.3.3. RESULTS USING ROBUST OPTIMIZATION

The last method to be analysed is the use of the novel model RO for the bay assignment. Since the model is based on random selections of delays results can differ from one run to another. Therefore, the model is ran 50 times and the average values and standard deviations are showed in the table. The results in Table 8.4 show an expected trend. Where the model is becoming more unstable for the more severe delay cases. The stability is measured with the standard deviation, indicating the possible deviation of the mean. For the worst case this implies a deviation of 6.9 which can affect the results significantly.

Compared to the other two models the RO method shows the largest difference between the two models with preferences. It can therefore be concluded that the RO method requires a certain amount of flexibility in the solution space to find a robust solution based on delay data. When looking to the standard deviations the solution is really stable compared to the model with less flexibility meaning that the model finds more similar results.

Table 8.4: Model robustness of RO

Simulation Cases	1	2	3	4	5	6	7	8	9	10
Preferences										
Reassignments	1	0	0	1.67	2.75	2.08	3.75	6.75	5.17	10
SD Reassignments	0	0	0	0.27	0.77	0.69	1.38	3.09	2.10	6.93
Obj. value	20,46	10,07	10,07	16,30	28,14	33,35	36,76	45,90	40,66	69.30
SD Obj. Value	1.30	1.29	1.29	4.32	2.62	1.16	1.56	3.39	5.08	2.52
Non-Preferences										
Reassignments	1.09	0.09	0.09	0.91	1.73	2.09	2.55	3.64	2.55	4.82
SD Reassignments	0.16	0.16	0.16	0.50	0.53	0.17	0.68	0.88	0.68	0.78
Obj value	27.10	26.99	26.99	27.23	28.50	50.19	37.71	39.34	41.58	53.92
SD Obj. Value	2.57	2.58	2.58	2.74	2.10	6.07	1.74	4.21	2.48	6.49

8.4. COMPARISON

Now that the models are elaborated individually it is now time to see the differences between the three. This will be done in two parts. The first being the model including flight preferences and the second being the model without flight preferences.

8.4.1. INCLUDING FLIGHT PREFERENCES

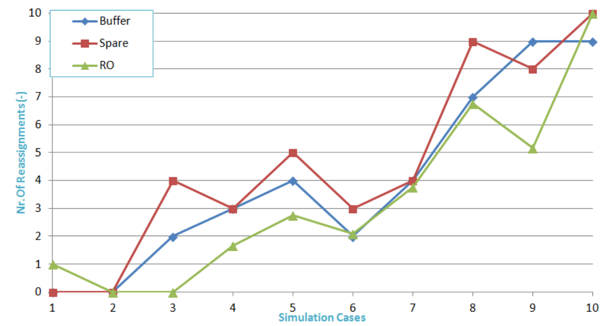
The results from the previous section are now used to draw graphs indicating the performance of the different models. First the amount of required reassignments will be compared and discussed. Secondly, the costs of the solutions will be compared and lastly the product of the former two will be compared representing the total value of performance. Figure 8.7, shows the three graphs individually.

Starting with the amount of reassignments in Figure 8.7a, you can see that overall the averaged values of RO outperforms the other two methods. For the first case, however, the RO method requires one reassignment for every simulation ran (SD equals zero). This is the result of the domestic flight KQ8651 which is arriving 17 minutes early in simulation case 1. Since this early arrival requires a domestic flight to be positioned at a non-domestic bay, the RO method does not design for this situation since the penalty value is lower then the additional cost of placing a domestic flight on a non-domestic bay. Increasing the penalty value would results in a change, however this would also increase the initial cost of the solution. Which is now slightly lower then the initial cost of the buffer times. The objective function of the baseline schedule for buffer times is 355301 where the of RO is 353202.

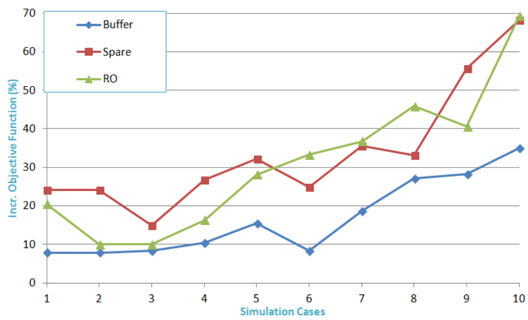
Based on the average values of RO it can be concluded that RO is preferred above the use of buffer times. However, looking to the stability you see that for the three worst case simulation cases the model results are unstable. With a maximum value of the standard deviation (SD) of 6.93, implying that the amount of reassignments can be 16 but it also could be 4. Therefore, the use of buffer times can be preferred.

From the second graph you can conclude that the cost of the actual day of operations using spare bays and RO is significantly higher than the use of buffer times. This is the fact for both low delay cases and high delay cases. At cases 2 and 3 you can see that the cost of RO with the same amount of reassignments is slightly higher than that of buffer times (1%). The value of buffer times is lower for all ten cases which has to do with the fact that they both require different reassignments. Note that this value is hard to compare since it strongly depends on the flights that are reassigned. For this case with preferences there is one flight constantly allocated to an additional hotel bay which looking to the schedule is not needed if the splitted flights are arranged differently, this results in a 8% reduction in objective value. This will make the RO objective value lower for 3 cases.

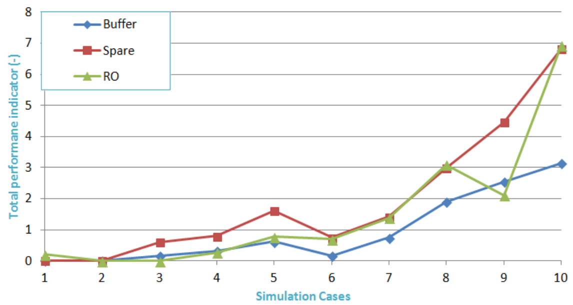
Since no model outperforms for both performance indicators the performance of both indicators is constructed. This is done by multiplying both results and is shown in Figure 8.7c. Here you can see that for the low delay cases the three models are performing quite similar, but for the high delay cases the use of buffer times is preferred. Note the one exception for case 9 where there is a dip in the amount of reassignments. This value of the total performance indicator is assuming that both indicators have the same value. How-



(a) Results reassignments



(b) Results objective function



(c) Results total performance

Figure 8.7: Results of comparison between the three models including flight preferences

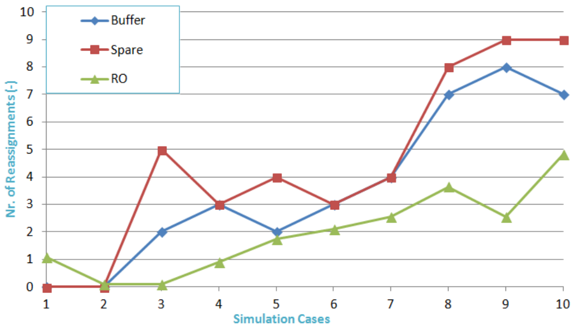
ever, the change of objective function for each test case is not a reliable measure since it is fluctuating a lot. Therefore, the actual performance indicator is the amount of reassignments times the cost of the baseline schedule. Since the cost of the RO model is slightly lower in terms of the baselines schedule and the amount of reassignments is seen as most important performance indicator, the RO method is preferred over the use of buffer times. However, this depends per case severity and on the required stability.

8.4.2. EXCLUDING FLIGHT PREFERENCES

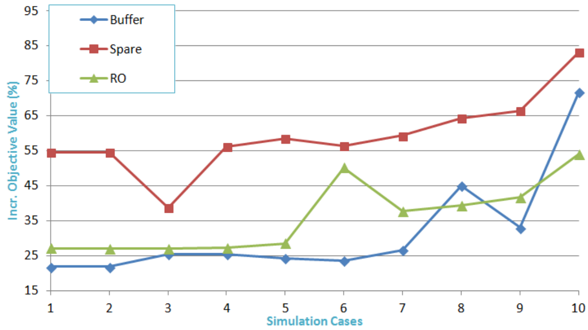
The results from the previous section focussed on the baseline model including flight preferences. This section will focus on the results without the use of flight preferences in the objective function. First the amount of required reassignments will be compared and discussed. Secondly, the costs of the solutions will be compared and lastly the product of the former two will be compared indicating the total value of performance. Figure 8.7, shows the three graphs individually. Note that the total performance indicator is just an indication of the total behaviour. In the end the initial costs and the amount of reassignments are most important to consider for comparison.

Starting with the amount of reassignments in Figure 8.8a, you can see that overall the averaged values of RO outperforms the other two methods except for case 1. For this first case the RO method requires one reassignment for every simulation ran (see standard deviation of 0). This has the identical reason as in the case including preferences. It holds flight KQ8651 at domestic bays instead of reallocating due to the cost of trade-off. Again the weight of the penalty value is chosen such that the objective function of the baseline schedule is slightly lower than the one using buffer times. Meaning that RO is outperforming the other two methods significantly. Looking to the stability it can be concluded that the RO method is stable for all simulation cases and is therefore preferred above the use of buffer times.

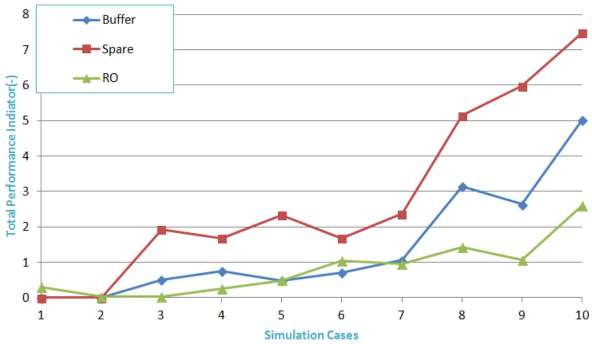
From the second graph you can conclude that the cost of the actual operational schedule of using spare bays and RO is higher than the use of buffer times with two exceptions. These two exceptions are in case 8 and 10 where the cost of buffer times is higher than that of RO. The peaks in the schedule can only be clarified by the repositioning of domestic flights to non-domestic bays or by a repositioning to a hotel bay. In this case it is a combination of both, where a domestic flight is reassigned to a hotel bay.



(a) Results reassignments



(b) Results objective function



(c) Results total performance

Figure 8.8: Results comparison between the three selected models excluding flight preferences

Since no model outperforms for both performance indicators the performance of both indicators is constructed. This is done by multiplying both results and is shown in Figure 8.7c. Here you can see that for the low delay cases the three models are performing quite similar, but for the high delay cases the use of RO is preferred. Again the assumption is made that both performance indicators are equally important. However, the amount of reassignments and the initial cost in the baseline schedule are the two most import trade-off criteria. It can therefore be concluded that again the RO method is preferred above the use of buffer times. However, in this case the RO model is stable.

8.5. CONCLUSION

From the comparison it can be concluded that the use of spare bays with this simulation model is not valuable. The added value of the spare bays should be the ability to absorb reactionary delays. However the simulation model does not cover this measure entirely. It results in high cost in terms of the objective value and makes the model more sensitive to flight delays when comparing with the use of buffer times. This has to do with the fact that the other bays become higher utilized. In contrast to the comparison of the use of spare bays the comparison between the use of buffer and RO is difficult since both models are performing well.

For the baseline schedule including flight preferences the use of buffer times can be preferred over the use of RO. The average performance of RO is slightly better but the results are not stable. For the three worst case test simulations it has one SD of 6,93. This implies that the amount of repositioning can be 6 higher or 6 lower. However, for the other simulation cases the model is running stable. So it really depends for which scenario you would like to design your model.

For the case without flight preferences the RO method outperforms the buffer times in terms of the amount of required reassignments and has a lower initial cost. This can be altered by using a different penalty value. However, since the initial cost of the two solution are almost identical (RO slightly lower) it is a good basis for comparison. You can conclude that the RO model is now stable for all simulation cases and that its total performance is significantly better than the use of buffer times.

Summarizing, there is not one best solution. It depends on what type of stability you require and for what severity of delays you want to design. In general, the idea behind robust optimization should be outperforming the use of buffer times due to its ability to look further then 30 minutes delay and design for lower cost solutions (less idle time for low likely delays). However, it needs some attention to make the results more stable in the case of over-constrained schedules. In addition, the use of buffer times in a model differs from the use of buffer times manually. Manually the Duty Ramp Controller has the ability to use his knowledge and experience to insert historical delay data. In a model this is impossible and is therefore a static method. This is in contrast to robust optimization which does use historical data and is therefore more dynamic. This advantage allows automated models to behave more similar to the manual assignment. This does not only hold for the bay and gate assignment but also for other general allocation processes.

9

Model Verification and Validation

Now that the bay and gate assignment model produces results, the last step is to verify and validate these results. The verification and validation is the crucial test to see whether the developed model provides feasible and valuable results both from a research perspective as well as from an industrial perspective. Therefore, the results of this last step will determine the applicability and the relevance both for research as well as for an industry perspective.

The verification and validation test used is almost similar to the predecessor of this work of Van Goethem [2]. The method is based on the method as proposed by Sargent [55]. The chapter is therefore structured according to their validation and verification process for simulation models. This starts in section 9.1 by setting the the strategy followed by section 9.2 which performs the model verification. Then section 9.4 takes you through the concept validation process. Lastly, the operational validation of the model will be given in section 9.5.

9.1. Model Verification and Validation Strategy

The developed model in this thesis is an assignment commissioned by Kenya Airways. Therefore, the model results should be driven by the assignment procedures used at Kenya Airways hub airport JKIA. However, since the assignment is part of a research graduation it should also contribute to the academic knowledge. This implies that the verification and validation process should be seen from two points of view, one being the academic scope and second being the actual industrial problem. This section section sets out the strategy to comply to both industrial and academic requirements.

Before the development of the verification and validation strategy, it is good to known or restate the definitions of verification and validation. There exist different definitions on the two terms, a common used definition in simulation analyses and in this thesis is given by Schlesinger [56].

- **Model verification:** ensuring that the computer program of the computerized model and its implementation are correct.

- **Model validation:** substantiation that a computerized model within its domain of application possesses a satisfactory range of accuracy consistent with the intended applications of the model.

To be more specific the model verification focuses on the computational correctness of the programming code written. It does not focus on the value of the results but rather if their are no mistakes in the code. In contrast, model validation does put focus on the value of the results. It investigates the fit between the model and the real life solutions. With these two definitions in mind the verification and validation process is set out. As already mentioned, the approach of Sargent [55] is followed which can be divided in four categories:

1. **Dataset verification**
   The input data is evaluated and verificated during the dataset verification

2. **Computational model verification**
   The model verification involves the testing and verification of the software code to provide correct results

3. **Computational validation**
   The computational validation deals with validating the primary assumptions used to construct the model

4. **Operational model validation**
   The operation validation involves validating the value and the feasibility of the results.

Since this is the last written chapter with new information it may seem that it is carried out on the end of the project. However, nothing can be last true. When you start verification and validating on the end of your project you have know idea if all the primary assumptions and codes are correct. Therefore, the verification and validation process was an integral part of the development of the model itself. This was done by validating expert advise on the assumptions and verification results after each iterative step in the software development process. Expert advise is used for the verification and validation process. It is part of the face validity check where experts are questioned whether the results are logic and reasonable. In addition, it is used for the turing test where experts are asked to differentiate between the model results and results in reality.

The other method used is tracing. Tracing is actually used to verify the model. Where one or more flights are followed throughout the process and the information available on the beginning of the trace and on the ending of the trace is compared which should remain the same.

It must be noted that in the software model use is made of optimization software such as Cplex and LPsolve. These models are not verified and validated in this thesis since they are already considered validated in the field of operations research.

9.2. MODEL INPUT DATA VERIFICATION

The only input data used in the bay assignment application is the historical data obtained from Saba. This data sheet forms the basis of the model and it is therefore of utmost importance to be verified.

This data sheet already contains all the registrations numbers for each inbound and outbound flight. However, to run the model on the day of operations the turn schedule report is required to obtain the tail assignment for all flights. The model is constructed such that it can easily be integrated with the turn schedule report and the historical data. The former one is not yet used in the thesis and therefore does not have to verified. But from industrial perspective it is good to known the limitations of this data sheet.

The turn schedule reports used by the DRC's to develop the bay assignment does not contain any information on the actual location of the aircraft. In the historical data this is available for the arrival flight but when the arrival flight is repositioned during arrival and midnight the location of the aircraft is unknown in the data sheets. This is also the primary reason why all DRC's start their shift by making a round to link all tail numbers to their current bay position. In this thesis it is assumed that the aircraft are allocated on the bays of arrival, but for implementation this should be manually entered each night.

Since the used historical data already contains all the registration number it is good to verify the data sheets on feasibility. In general the only aspect that should be verified is the correctness of the tail assignment and the correctness of the delay data. Unfortunately these were not entirely flawless. The delay data contained some outliers which were removed by the assumption that only delays ranging between -90 minutes and 90 minutes are used for the model.

While linking the inbound flights with the outbound flights based on registration number, some errors were found as well. Registration numbers suddenly disappeared on other airports and some flights on JKIA itself. On JKIA itself can easily be contributed to required maintenance time. But other flights took of from JKIA while from data it was still considered to be allocated on an other airport. These all considered the small regional flights where probably not all registrations number were correctly entered. All these errors were

Table 9.1: Raw data from traced flights

iflight	fdate	ireg	iorig	ista	itype	ibay	oflight	oreg	oto	ostd	otype	obay
KL565	2-6-2015		AMS	20:25	747	7	KL566		AMS	22:25	747	7
KQ101	2-6-2015	KZC	LHR	06:30	788	11	KQ310	KZC	DXB	19:15	788	19
SA180	2-6-2015		JNB	20:30	320		SA181		JNB	08:30	320	
KQ205	2-6-2015	CYB	BOM	10:30	738	16	KQ704	CYB	LUN	12:05	738	16

Table 9.2: Data python from traced flights

iflight	fdate	reg	iorig	type	ibay	oflight	oreg	oto	ostd	obay
KL565	2-06-15 20:25		AMS	747	7	KL566		AMS	2-06-15 22:25	7
KQ101	2-06-15 6:30	KZC	LHR	788	11	KQ310	KZC	DXB	2-06-15 19:15	19
SA180	1-06-15 20:30		JNB	320		SA181		JNB	2-06-15 8:30	
KQ205	2-06-15 10:30	CYB	BOM	738	16	KQ704	CYB	LUN	2-06-15 12:05	16

manually solved by logically looking to the flights without an inbound flight or outbound flight. Using the online link to the Sabra environment to obtain the turn schedule report should solve these errors.

9.3. MODEL COMPONENTS VERIFICATION

Now that the input data is verified all the separate models using this input data should be verified as well. The method used to do this is called tracing, where you trace certain flights and look to the outcome of these flights for each separate model. The raw data of these traced flights is shown in Table 9.1. This data is then used for the various components such as: loading flight schedule, classification of flight characteristics, generating time matrix, developing bay compliance matrix, obtaining flight preference and finally the obtainment of delay data. All these separate models will be verified in this section based on the method called tracing.

9.3.1. LOADING FLIGHT SCHEDULE

The first step of the model is to load the flight data to python. Table 9.2, shows all the information loaded into python from the raw data. The arrival and departure times are loaded in datetime format and are displayed using the output DD:MM:YY - HH:MM. Looking back to the raw data this process is executed correctly. The other data loaded is all identical to the information seen in the raw data.

9.3.2. CLASSIFICATION FLIGHT CHARACTERISTICS

The next step of the model is to classify certain characteristics for each flight. These are the flight index, the airline code, the airline group, long stay flight , aircraft group, domestic, passenger and whether it is an arrival parking or departure activity. First the loaded flights are given an index based on the position in the raw data. This index can then be used to obtain all information from all the arrays. When a certain flight is classified as long stay two new flight/indices are generated representing the parking and departure activity. You can see the working of this in Table 9.3. Note that in this table you can see all the other properties which are generated correctly. The passenger number is not obtained from the raw data but is linked to the maximum capacity of the aircraft type. All flights are non-domestic what can be traced back from the airport code in the raw data.

Table 9.3: Classification of flight data

iflight	arl	arlgr	lstay	nstay	acgr	dom	pass	a/d
15	KL	0	False	False	G	False	370	Full
16	KQ	0	True	False	E	False	210	Arr
17	KQ	0	True	False	E	False	210	Park
18	KQ	0	True	False	E	False	210	Dep
173	KQ	0	True	False	E	False		Arr
174	SA	1	True	True	C	False	150	Park
175	SA	1	True	True	C	False	150	Dep
20	KQ	0	False	False	C	False	150	Full

Table 9.4: Time Matrix for traced flights

index	15	16	17	18	173	174	175	20
15	0	0	0	0	0	0	0	0
16	0	0	0	0	0	1	1	0
17	0	0	0	0	0	0	1	1
18	0	0	0	0	0	0	0	0
173	0	0	0	0	0	0	0	0
174	0	1	0	0	0	0	0	0
175	0	1	1	0	0	0	0	0
20	0	0	1	0	0	0	0	0

Table 9.5: Verification of bay compliance matrix

ind/bay	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4L	4R
15	0	1	1	0	0	0	0	0	0	1	1	1	1	1	1	1	0	0
16,17,18	0	1	1	1	0	0	0	0	0	1	1	1	1	1	1	1	0	0
173,174,175	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	0
20	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	0
ind/bay	3C	3B	3A	2C	2B	2A	J1	J2A	J2B	J3A	J3B	J4A	J4B	J5	J6	J7	J8	J9
15	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0
16,17,18	0	0	0	0	0	0	1	0	0	0	0	0	0	1	1	0	0	0
173,174,175	1	0	0	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1
20	1	0	0	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1

9.3.3. TIME CONSTRAINTS

The generation of the time constraints is an essential part of both the bay assignment model and the robust model. It is therefore of utmost importance to be verified. The model generates a time matrix based on the arrival and departure times of each index which is then used for the time constraints. This matrix shows whether a flight pair is conflicting (1) or can be assigned to the same bay (0). Table 9.4, shows part of the matrix containing the traced flight indices. As can be seen the matrix is symmetrical which is as expected. If flight i is conflicting with flight j it automatically means that flight j is also conflicting with flight i. From the matrix you can also see that flight indices 15, 18 and 173 are not conflicting with any other traced flights. Looking to the raw data this is true. It also shows some conflicting flights which are all valid looking to the raw data.

9.3.4. BAY COMPLIANCE

Another very important constraint to assure feasible and valuable solutions is the bay compliance constraint. Again this constraint make use of a pre-processed matrix called the bay compliance matrix. The matrix shows for each bay which AC group is compatible. This matrix can be found in the appendices. For the traced flights this matrix is used to see the value of the matrix for each flight. So first the flights are assigned to a flight group as was done in the previous component called the classification of flight characteristics and then this flight group is checked for every bay. The results are shown in Table 9.5. You can see that no flights are regional jets since no flights are compatible with bay 4R, 2A and 3A which is true. You can also clearly see that wide body aircraft are limited compatible which is also true. Due to the importance the results are extensively validated during the process and all flights are only assigned to feasible bays due to the correct working of the bay compliance matrix and the classification of the aircraft groups.

9.3.5. AIRLINE PREFERENCES

The verfication of the airline preferences function is already extensively elaborated in Chapter 7 for both the analysed days. The results show that the function is working properly and all preferred flights are allocated to their preferences. This can also be seen from the fact that traced flight 15,16,17 is repositioned to bay 19 for preferences of the international flight, see Table 9.6.

9.3.6. CPLEX RESULTS

While the bay model is written based on the information from python, Cplex now uses this information to creates its own output. This output determines the solution and therefore has to be interpreted correctly.

Table 9.6: Time matrix for traced flights

index	Assigned Bay Cplex	Assigned Bay Bokeh	Assigned Gate Cplex	Assigned Gate Bokeh
15	7	7	7	7
16	6	6	6	6
17	6	6	6	6
18	19	19	19	19
173	5	5	5	5
174	5	5	5	5
175	5	5	5	5
20	16	16	16	16

Since Cplex uses another chronological order of decision variables a separate function is required to trace back the solution. To do this first all the solution values are gone through and when the rounded value is equal to one the index is stored[1]. Then another loop is made through all the decision variables only using the indices found from the previous loop. The decision variables are strings which are splitted in pieces. First the first index of the string is checked which has to be equal to x. This can also be a U,V,W representing the penalty values. When the value is x the rest of the string is mapped and the found integers are stored. The first found integer represents the flight index from python and the second found index represents the bay/gate.

You can see why it is important to verify this process since there are many steps required to translate the Cplex output back to the python interface. Table 9.6, shows the results for the traced flights and as can be seen the Cplex output is loaded correctly.

9.4. MODEL CONCEPTUAL VALIDATION

The conceptual validation of the model is valuable for the research in two ways. First, it questions whether the theories and assumptions on which the model and this research are based are correct. Secondly, it validates the conceptual model results versus the real life results to see whether it is a proper representation. The following theories and assumptions are validated in this section:

1. Maximizing robustness increases the on-time performance and improves the passenger service.
2. Decreasing the number of aircraft repositioning decreases the execution complexity of the bay assignment plan and reduces the direct operational costs.
3. An automated bay and gate assignment tool enhances the allocation consistency and the bay assignment quality
4. Objective function hierarchy considered

9.4.1. MAXIMIZING ROBUSTNESS

The entire thesis is based on the concept of schedule robustness and its advantages. As you might know by now it is the concept of designing a schedule in advance that in a way is insensitive for variations in the considered flight schedule. It is therefore of utmost importance to validate the assumption that schedule robustness has a positive effect on the on-time performance of the airport.

The results of this thesis shows that the the assumption is correct, since the amount of required repositioning is reduced significantly. However, this is based on a simulation and not the true order of events on the day of operations. Fortunately, in literature much attention is given to the use of robust scheduling methods and many articles are implemented in real cases. One of these articles, written by Hassounah and Steuart [25], shows the value of using fixed buffer times for the on-time performance during real operations.

9.4.2. AIRCRAFT REPOSITIONING

The assumption used in this thesis states that the amount of repositioning influences the airport complexity, reduces the direct operational cost, improves the on-time performance and increases safety.

[1]The value have to be rounded due to the fact that Cplex can find non-integer solution which are very close to one.

The fact that minimizing the amount of repositioning influences the on-time performance is a results of the reduction of operation complexity. If a repositioning task is delayed it influences the on-time performance for example. This in combination with other examples and expert opinions show that the amount of repositioning does influence the operational complexity and when minimized, the complexity will also be reduced. Improving the on-time performance and reducing the amount of towings does also indeed result in a reduction of direct operational costs.

Lastly the experts indicated that less aircraft repositioning is beneficial for ramp handling safety and reduces the risks, costs and delays associated with aircraft damage. Since all additional movements of aircraft increases the risk of incidents and accidents, it indeed enhances safety during operations.

9.4.3. AUTOMATED DECISION TOOL

Another main assumption in this thesis holds that an automated tool for the bay and gate assignment can be developed that increases the quality of the overall schedule as it can lowers the work load, design for the transition of shifts and use historical data. Part of this claim is validated by the fact that the current manual bay assignment process is very strongly influenced by the experience of the duty ramp controller. When the less experienced DRC's have to develop the schedule they have less knowledge of the delay patterns and the interference with the gate assignment.

In addition, the tool can help standardizing the results of different bay planners. Each duty ramp controller has a slightly different approach on allocating the flights to the bays. Therefore, the bay and gate assignment tool can help enhance the consistency.

9.4.4. OBJECTIVE FUNCTION HIERARCHY

During the development of the objective function certain assumptions were made. These assumptions all have to do with the fact that there exist a certain hierarchy between the objectives. For the bay assignment the objectives used where the airline preferences, aircraft repositioning and the passenger transport distance. As already mentioned in the weight determination the airline preferences is the highest objective and the passenger transport the lowest.

These assumptions are all validated with the iterative validation process with Gordon Anyimu. He is the head of the Hub Control Center and partly responsible for the performance of the bay and gate assignment. He knows all the in and outs and all the preferences of the stakeholders.

9.5. MODEL OPERATIONAL VALIDATION

The above mentioned assumptions support the conceptual logic that the on-time performance can be enhanced by using an efficient bay and gate assignment. The next step in the process is the operational validity. The operational validity determines in which degree the model results are executable and useful for the daily operations. The operational validity is checked based on the constraints and the practical usefulness of the results.

9.5.1. CONSTRAINT COMPLIANCE

The constraint compliance is an important criteria for the bay and gate assignment process. However, the nature of the hard constraints already ensures feasible solutions. In this chapter the constraints were already verified and checked to be written correctly. Therefore, this already ensures the constraint compliance for the assignment process. When the model gives an infeasible solution it immediately states which constraint gives the error, indicating the constraints type and the number where the model becomes unfeasible.

While analysing the results in Chapter 7 already some validations were given for the soft constraints such as the adjacency constraints. It can be concluded that the soft constraints are implemented correctly and are producing valuable results.

9.5.2. USEFULNESS OF RESULTS

In order to validate the usefulness of the results, a comparison test is executed for the operations on 02-06-2015. This comparison compares the results of the automated tool with the results of the manual bay assignment in terms of robustness. It must be noted that the actual comparison between the manual bay assignment and the automated bay assignment is of no value. This because the model is already validated and is not there to improve the current technique but rather to automatize it and make it more robust. In addition, the value of this model above the manual model is that it designs for the entire day instead of two shifts.

In terms of this transition the automated model requires less repositioning to prepare for the evening wave. Where the automated model requires nine repositions the manual assignment requires twelve repositions. The three additional repositions consist of one for the morning wave and two for the evening wave. This validates the usefulness of the proposed model, since it will reduce the cost and complexity of the current operations.

As experienced during operations and seen in the validation of van Goethem each DRC solves the problem on his own unique way. This makes it hard to draw conclusions on the differences. In general the supervisors of the DRC has the same objective as used in this thesis. Where the airline preferences are leading and the number of repositioning is the second important point to consider. Therefore, an additional value of this thesis is to provide a standard and consistent solution not dependent on the experience and quality of DRC's.

The last point to consider is the difference in robustness between the use of buffer times and the use or robust optimization. To compare these two for validation a real day with all actual available delays is used and simulated on the same way as in Chapter 8. The results show that the evening wave has more severe delays compared to the morning wave and is the only part where the model requires reassignments for both the use of buffer times and robust optimization. However, the use of buffer times requires three reassignments where the use of robust optimization only requires one. This shows and validates the value of the novel developed model for operations.

10

Conclusion and Discussion

With the bay and gate assignment tool being developed and analysed this chapter will discuss the major details of the project. These details include the starting of the project being the research scope, the main conclusions on the available literature, the applicability of the model, the results of the model and the recommendations for future research. Therefore this chapter is structured in the following 4 topics:

1. Research Scope
2. Academic Novelty
3. Conclusions
4. Recommendations for future research

10.1. Research Scope

The bay and gate assignment model developed in this project is driven by the specific need for an advanced bay and gate assignment planning taking into account the objectives of various stakeholders. The most important objective considered in this thesis is the objective to minimize the operational costs. To do this the bay and gate assignment has to be robust. This will enhance the on-time performance and thus the operational costs. This objective will be referred to as robust scheduling. The other two objectives that are considered are the minimization of passenger transport distance and the minimization of airport operational complexity, both important for the minimization of operational costs and a satisfying on-time performance.

Robust Scheduling

The main objective of this thesis is the development and the analysation of robust scheduling methods and making the developed model and results applicable for airports suffering from delays due to conflicts in the bay assignment.

The objective to obtain robustness is becoming more important in a wide area of fields. The literature on the bay assignment already took some measures to introduce or design for robustness, most of the results where however not applicable for real size problems such as the work of Bolat [29]. The use of buffer times is an easy straightforward measure which is commonly used. However, the comparison of buffer times with other methods is not yet researched. Therefore, this thesis developed a new and a existing method and compared it to the most common measure of buffer times to be able to draw conclusions on the different performances.

In addition, the novel developed method can be applicable for other fields. In general all scheduling and assignment problems dealing with uncertainty can use this method to obtain robust solutions. This makes the model applicable for a wide range of applications and widens the scope of the research.

PASSENGER TRANSPORT DISTANCE

The other considered objective concerns the passenger. As one of the most important stakeholder the passenger want to have a satisfactory experience. Therefore, Kenya Airways focusses amongst others on the walking distance of the passenger and the on-time performance. The walking distance is used as on of the objectives in the model and is applicable for many airports. The connectivity of passengers is unfortunately not taken into account. This has to do with the required quadratic objective function that makes the problem considered NP-hard. Implying that it is less likely to find the optimal solution within a certain time bound.

For JKIA the most important aspect to minimize the passenger transport distance is the combination of the bay and gate assignment. Usually, bays have dedicated gates but in the situation of JKIA there are more bays than gates. This makes it of utmost importance to consider the connection between the bay and gate assignment. In this thesis this connection between the two assignments is modelled by the use of adjacency constraint. This way the amount of additional bussing can be minimized and the experience of the passenger can be improved.

AIRPORT OPERATIONAL COMPLEXITY

The complexity of the airport operations strongly depends on the airport specific constraints. Jomo Kenyatta International Airport has two very specific constraints where one is the availability of serviceable fuelling bays and the second is the connection of the bay assignment with the gate assignment to minimize bussing as discussed in the previous section. At Jomo Kenyatta International Airport the amount of non-serviceable bays and the unavailability of fuelling trucks leads to an increased need for aircraft repositioning. These additional aircraft movements puts a considerable strain on the airport operational complexity and the on-time performance.

The developed model is able to take this situation into account and minimize the amount of movements required. The second specific constraint is also considered in the model to avoid unnecessary bussing and to stimulate a efficient boarding process. This is achieved with the use of adjacency constraints and preferences for non-bussing bays.

10.2. ACADEMIC NOVELTY

This thesis is driven by the need to develop a robust bay and gate assignment schedule while taking into account the high-end objectives of the various stakeholders. The project plan and the literature study preceding this thesis indicated that the bay assignment is a well researched topic in which multiple formulations and solution methods are considered and developed.

Although the on-time performance and thus the robustness of the bay assignment is considered as an important objective in literature, only limited effort is spent on the investigation of existing methods and the development of new methods. In contrast to other areas, such as control, a lot of effort is spent on improving robust measures and the development of new robust methods. One of this new methods called Robust Optimization is recently getting more attention due to its results and its applicability. The idea behind it is used in this thesis and is translated into the bay assignment problem, resulting in a novel model to provide robustness for the bay assignment problem. To contribute more to research the use of buffer times will be compared with the functioning of the novel method and the method using spare resources.

In addition, the combination of the bay assignment with the gate assignment is considered in this thesis. Since Jomo Kenyatta International Airport has more bays than gates a distinction have to be made between the two assignments to optimize for passenger convenience and operational complexity.

Lastly, during this thesis the use of different time constraints is investigated. This important constraint primary determines the size of the optimization model. In literature different methods are used but non are explained in detail. This report shows the pros and cons of the different notations to make the decision of the type of constraint easier in future research.

10.3. CONCLUSIONS

The main contribution of this thesis does not only have a clear industrial value but also a clear research value. The current airline industry is benchmarking its operations to improve the use of scarce resources. For Jomo Kenyatta International Airport two of these scarce resources are the bays and gates which are affecting the quality of the on-time performance and the passenger satisfaction. Therefore, this thesis investigates the bay and gate assignment at JKIA and tries to minimize the impact on the on-time performance and maximize the passenger convenience. After a thorough stakeholder analysis at KQ the following hypothesis was formed:

Hypothesis: ”A robust bay and gate assignment model can be developed which optimizes for minimum aircraft repositioning as well as for minimum passenger transport distance.

Where for the on-time performance, the two main points are the robustness and the amount of required aircraft repositioning to generate feasible solutions. The additional objective is the minimization of passenger transport distance which can be traced back to the higher end objectives of passenger convenience, operational complexity and the costs of operations. Since the passenger transport distance includes bussing, where high use of bussing complicates the current operations on tarmac and are expensive in use. Other clear industrial benefits for KQ are the automation of the process, the possibility to optimize while considering transitions of shifts and the combination of the bay and gate assignment simultaneously.

The other objective stated in the hypothesis is the combination of the bay and gate assignment. This is modelled by using adjacency constraints in the bay assignment taking into account the constraints of the gate assignment. It can be concluded that the use of adjacency constraints results in the wanted outcome in terms of the gate assignment, where no gates are double scheduled and no additional bussing is required for the bays 6 and 11.

Besides these industrial considered objectives this thesis focused on the maximization of robustness. But what is robustness and how is it measured? In this thesis the robustness is measured with the use of two performance indicators: one being the amount of required reassignments and two being the cost of the objective function. To determine these indicators a simulation is used of the actual day of operations. Because the results strongly depend on the delays on the day of operations, the simulation tool analyses 10 different simulation cases. These cases are constructed such that it ranges from soft delay cases to high delay cases. On this way you can draw separate conclusions on the performance of the robust measures for low delay cases, intermediate delays cases and high delay cases. It can be concluded that the developed simulation cases are representing the intended purpose.

The simulation tool is used to compare different robust methods. The first robust method considered is the of buffer times which is very common in operations and is therefore a good basis to compare the working of other methods. The second method is the use of buffer times in combination with the use of spare bays. The cost for this solution is logically higher but it should generate the possibility to absorb reactionary delays. Lastly, a novel method for the bay assignment is designed called robust optimization.

Robust optimization is currently used for control algorithms and is becoming more common in use. The underlying principle is that the model tries to generate a solution based on multiple plausible scenarios. In this thesis the main flight schedule is used as basis (hard constraints) and in addition soft constraints are added representing additional flight schedules including delays. These applied delays are based on historical data and therefore have some advantages over the use of buffer times. Buffer times are mostly fixed to 30 minutes, where robust optimization is more dynamic and can look beyond this point. Therefore, modelling buffer times is very fixed compared to the current use of buffer times in the manual process. In the manual process the bay planner can use historical data when developing the schedule depending on his quality and experience. For automated processes it is therefore valuable to be able to use historical data.

The model is validated with the use of buffer times. Results are drawn for two typical days. The first being Tuesday 02-06-2015 and the second being Sunday 05-07-2015. The first day is chosen due to the fact that it is an average day. The lower amount of movements increases the possibilities/flexibility for robust scheduling which is required. The second day being a peak day with high amount movements which is chosen to analyse and validate the applicability for peak days. Validation results shown the similarity between the manual bay assignment and the automated bay assignment with the use of 30 minutes fixed buffer times. In addition, the output is analysed to check whether all objectives are represented correctly in the results.

From these two days it can be concluded that the model behaves as intended. Where the entire day can be analysed within minutes to an optimal solution taking into account the transition of shifts and the short time span to generate the results. The model minimizes the amount of repositioning correctly with the known exception cases and pushes all the flights to their preferred bays and gates. These are not only the flights with flight preferences, but also all the other flights. For these flights it depends on the aircraft size and the terminal used which solution is preferred most. In Chapter 7 you have a clear Gantt chart displaying the various flight types with their location. It can be seen that all flights are centred around the wanted terminal if possible. Note that the allocation of night flights is still a point to look into. Since they do not have a destination it is hard to determine the preferred position. This now requires the nights shift to reallocate most of these flights while early tail information can foresee this problem.

The previous conclusion is used for the validation of the model with the real situation using buffer times. Unfortunately, the use of buffer times in automated models does not allow for the same rules bay planners use considering historical data. To cope with this effect a novel method is developed called robust optimization. This model is compared to the working of fixed buffer times and it can be concluded that the use of historical data has benefits in terms of the amount of reassignments. It has nearly the same cost for the baseline schedule and requires less reassignment for 9 out of the 10 simulation cases. However, it must be noted that these results are based on the average values of robust optimization. Since for each run it uses random scenarios the results can differ.

Two cases are considered in this thesis for comparison. These are simulations including flight preferences and simulations excluding flight preferences. The reason for these two cases is to see the affects of the flexibility in the schedule. From results it can be concluded that the model excluding flight preferences requires less reassignments both for the use of buffer times and the use of robust optimization. Again the robust optimization is performing better for 9 out of the 10 simulation cases and has stable results. For the simulation including flight preferences the same results are found except for the stability. The robust optimization has a hard time finding possible solutions to cope with the additional scenarios and is therefore fluctuating significantly for the two most severe simulation cases.

In addition, the use of spare bays is investigated. The main advantage of spare bays should be the fact that it is able to absorb reactionary delays. However, the way the simulation model is constructed it only computes the minimum amount of reassignments required over the entire and does model all possible reactionary delays. From the use of this simulation model it can be concluded that the obtainment of spare bays in this over constrained schedule does come with an additional cost in the objective function of around 10% and that the other resources are higher utilized requiring a slightly increase of reassignments.

The developed bay assignment model is verified and validated with the test case Jomo Kenyatta International Airport. From the results it can be concluded that the hypothesis is achieved. Furthermore, the developed bay and gate assignment model provides the airline with an automate decision support system which helps the airline and airport to operate in the heavily constraint environment. In addition, this automated tool will enhance consistency and make the bay assignment independent of the experience and quality of Duty Ramp Controllers. Lastly, the use of robust optimization can be used to minimize the amount of reassignments and to mode the current manual process more precisely using historical data.

10.4. RECOMMENDATIONS FOR FUTURE RESEARCH

This thesis contributed to both research and industrial perspective. Unfortunately, research is never done and there are always new points to consider. In addition to this, the model is not yet implemented which allows for some recommendations for future research and future use. These include recommendations for the bay assignment itself, the tail assignment, the real-time bay assignment and lastly the robust scheduling. All these will be elaborated in the respective order.

BAY ASSIGNMENT MODEL

The bay assignment model is based on some assumptions. Two important assumptions that need to be further analysed are both dealing with the split flight function, where the arrival and departure activity are fixed to last 90 minutes and non-domestic flights can only be fuelled during the departure activity.

The assumption to fix the activities to 90 minutes were made to simplify the model, resulting in the case where for each planning the schedule should be revised by looking to the activities. When it is set as control variable in the model it will put a significant limit on the complexity. This control variable should then also be constrained per flight type to the minimum required turn around time. Doing this will not only increase the complexity of the model but also the complexity of the operations. When all activities are set to the minimum amount of ground time this will put a significant pressure on the ground handling increasing the risks of delays. However, these static times of 90 minutes are not ideal and further research would be recommended to analyse the possibilities to overcome this short coming of the current model.

In addition, it was assumed that only the departure activity can be fuelled for non-domestic flights. In real operations this is not the actual case and change on flight by flight basis. In addition, it also depends on weather. When there is an uniform consistent rule it would make the results of the model more valuable.

TAIL ASSIGNMENT

Where the bay assignment is a predecessor of the gate assignment the tail assignment is the predecessor of the bay assignment. This makes it an important aspect to consider since it limits the possibilities. Mainly due the late publishing of results and the amount of tail swaps. When information of the tail assignment is known earlier night flights can be allocated to the correct bays for the following day minimizing the required reposition during. It will therefore of large value if the tail assignment can take certain preferences of the bay assignment in account. This makes the tail assignment a interesting area for future research.

REAL-TIME BAY ASSIGNMENT

The previous done by Van Goethem considered the seasonal schedule of the bay assignment. This thesis focussed on the baseline schedule of the bay assignment and the logical next step will be to consider the operational schedule. As already mentioned in this thesis the model is able to produce results quickly and already uses constraints considering flights standing on ground. To implement this developed model Kenya Airways already requires multiple time instances to run the model to cope with delays. The step towards real time allocation will then be to use certain small time intervals to run the model. This will be valuable for Kenya Airways and maximize the robustness of the schedule. Therefore further research to this topic can prove to be an interesting area of research.

ROBUST OPTIMIZATION

The novel developed method is still standing on the beginning of its time. It is therefore that the developed model can still be improved in future research. One of this points is to improve its stability in providing results and to analyse the reasons for the instability. In this research it was already shown that a less constrained schedule allows for more flexibility for robust scheduling and therefore increases the stability significantly. However, in which cases is it then applicable? In addition, the stability can be increased by using it in combination with buffer times or other robust methods. This are all interesting topics for further research.

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Appendices

A

Constructing the Model

A.1. Bay Compliance Matrix

For the bay compliance matrix, see Table A.1 on the following page.

A.2. Bay-terminal distances

Table A.2: Distances from from terminal to bay

Terminal				
Bay	A	B	C	D
20	2	16	17	22
19	3	17	18	23
18	4	18	19	24
17	3	18	19	24
16	0	17	18	20
14	5	9	10	12
13	6	8	9	11
12	7	7	8	10
11	8	6	7	9
10	9	5	6	8
9	10	4	5	7
8	11	3	4	6
7	12	2	3	5
6	13	1	2	4
5	14	0	1	3
4	15	2	0	2
3C	18	4	3	2
3B	18	4	2	1
3A	18	4	1	0
2C	19	5	3	3
2B	19	5	2	2
2A	19	5	1	1
J1	25	19	20	25
J2	24	19	21	26
J3	23	19	22	28
J4	22	20	23	29
J5	21	21	24	30
J6	22	22	25	31
J7	23	23	26	32
J8	24	24	27	33
J9	24	25	28	33
H1	200	200	200	200
H2	200	200	200	200
H3	200	200	200	200
H4	200	200	200	200
H5	200	200	200	200
H6	200	200	200	200

A.3. LP FILE EXAMPLES

A.3.1. BAY COMPLIANCE CONSTRAINT & FLIGHT MUST BE ASSIGNED CONSTRAINT

```
BC1: x_1_1 + x_1_10 + x_1_11 + x_1_12 + x_1_13 + x_1_14 + x_1_15 + x_1_2
 + x_1_24 + x_1_3 + x_1_31 + x_1_9 = 1
BC10: x_10_0 + x_10_1 + x_10_10 + x_10_11 + x_10_12 + x_10_13 + x_10_14
 + x_10_15 + x_10_16 + x_10_2 + x_10_20 + x_10_23 + x_10_24 + x_10_25
 + x_10_26 + x_10_27 + x_10_28 + x_10_29 + x_10_3 + x_10_30 + x_10_31
 + x_10_32 + x_10_33 + x_10_34 + x_10_35 + x_10_36 + x_10_37 + x_10_38
 + x_10_39 + x_10_4 + x_10_40 + x_10_41 + x_10_42 + x_10_43 + x_10_6 + x_10_7
 + x_10_8 + x_10_9 = 1
```

Figure A.1: Bay Compliance Constraint and Flight must be Assigned Constraint for flight 1 and 10

A.3.2. NIGHT STAYS

```
AB107: x_107_37 = 1
AB111: x_111_27 = 1
AB119: x_119_7 = 1
AB127: x_127_34 = 1
```

Figure A.2: Already Assigned Night Stays Constraint for flight 107, 111, 119 and 127.

A.3.3. TIME CONSTRAINT

```
TCI100O112B30: x_100_30 + x_112_30 <= 1
TCI100O112B31: x_100_31 + x_112_31 <= 1
TCI100O112B32: x_100_32 + x_112_32 <= 1
TCI100O112B33: x_100_33 + x_112_33 <= 1
TCI100O112B34: x_100_34 + x_112_34 <= 1
TCI100O112B35: x_100_35 + x_112_35 <= 1
```

Figure A.3: Time constraints for the flight pair 100,112 at bay 30 till 35

A.3.4. FUELLING CONSTRAINT SPLITTED FLIGHTS

```
F97: x_96_0 + x_96_1 + x_96_10 + x_96_11 + x_96_12 + x_96_13 + x_96_14
 + x_96_15 + x_96_16 + x_96_17 + x_96_19 + x_96_2 + x_96_20 + x_96_22
 + x_96_23 + x_96_24 + x_96_25 + x_96_26 + x_96_27 + x_96_28 + x_96_29
 + x_96_3 + x_96_30 + x_96_31 + x_96_32 + x_96_38 + x_96_39 + x_96_4 + x_96_40
 + x_96_41 + x_96_42 + x_96_43 + x_96_6 + x_96_7 + x_96_8 + x_96_9 + x_97_0
 + x_97_1 + x_97_10 + x_97_11 + x_97_12 + x_97_13 + x_97_14 + x_97_15
 + x_97_16 + x_97_17 + x_97_19 + x_97_2 + x_97_20 + x_97_22 + x_97_23
 + x_97_24 + x_97_25 + x_97_26 + x_97_27 + x_97_28 + x_97_29 + x_97_3
 + x_97_30 + x_97_31 + x_97_32 + x_97_38 + x_97_39 + x_97_4 + x_97_40
 + x_97_41 + x_97_42 + x_97_43 + x_97_6 + x_97_7 + x_97_8 + x_97_9 >= 1
```

Figure A.4: Fueling constraint for splitted flight 97

A.3.5. AJACENCY CONSTRAINTS

```
AJB6C32C67: x_32_15 + x_67_14 <= 1
AJB6C32C69: x_32_15 + x_69_14 <= 1
AJB6C32C77: x_32_15 + x_77_14 <= 1
```

Figure A.5: Adjacency constraints for flight 32 paired with 67,69 and 77 at Bay 6

Table A.1: Bay compliance matrix

A/C Group	H	G	F	E	D	C	B	A
A/C Type	B747	B772 B773	B787 B788 A330 B767	B73J	B737 B738 A320	E90	B733 E70	AT4 AT7 Q400
2A	0	0	0	0	0	0	1	1
2B	0	0	0	0	0	1	1	1
2C	0	0	0	1	1	1	1	1
3A	0	0	0	0	0	0	1	1
3B	0	0	0	0	0	1	1	1
3C	0	0	0	1	1	1	1	1
4L	0	1	1	1	1	1	1	0
4R	0	0	0	1	1	1	1	0
5	1	1	1	1	1	1	1	0
6	1	1	1	1	1	1	1	0
7	1	1	1	1	1	1	1	0
8	1	1	1	1	1	1	1	0
9	1	1	1	1	1	1	1	0
10	1	1	1	1	1	1	1	0
11	1	1	1	1	1	1	1	0
12				1	1	1	1	0
13	0	0	0	1	1	1	1	0
14	0	0	0	1	1	1	1	0
15	0	0	0	1	1	1	1	0
16	0	0	0	1	1	1	1	0
17	0	1	1	1	1	1	1	0
18	1	1	1	1	1	1	1	0
19	1	1	1	1	1	1	1	0
20	0	0	0	1	1	1	1	0
J1	1	1	1	1	1	1	1	1
J2A	0	0	0	1	1	1	1	1
J2B	0	0	0	1	1	1	1	1
J3A	0	0	0	1	1	1	1	1
J3B	0	0	0	1	1	1	1	1
J4A	0	0	0	1	1	1	1	1
J4B	0	0	0	1	1	1	1	1
J5	1	1	1	1	1	1	1	1
J6	0	0	0	1	1	1	1	1
J7	0	0	0	1	1	1	1	1
J8	0	0	0	1	1	1	1	1
J9	0	0	0	1	1	1	1	1
H1	0	0	0	1	1	1	1	1
H2	0	0	0	1	1	1	1	1
H3	0	0	0	1	1	1	1	1
H4	0	0	0	1	1	1	1	1
H5	0	0	0	1	1	1	1	1
H6	0	0	0	1	1	1	1	1
H7	0	0	0	1	1	1	1	1
H8	0	0	0	1	1	1	1	1
H9	0	0	0	1	1	1	1	1
H10	0	0	0	1	1	1	1	1

B

Bay Assignment Results 02-06-2015

Table B.1: Bay and gate assignment results 02-06-2015 using buffer times

Inbound				Outbound						
Flight Type	Fl No.	Origin	ETA	Bay	Gate	Reg. No.	Fl No.	Dest	ETD	AC Type
Full	BA065	LHR	20:30	11	10		BA064	LHR	23:15	772
Full	EK719	DXB	14:30	8	8		EK720	DUB	16:40	773
Full	ET302	ADD	10:20	9	9	AOB	ET303	ADD	11:35	738
Arr	ET304	ADD	12:20	9				ADD	13:44	738
Park		ADD	13:50	9				ADD	15:59	738
Dep		ADD	16:05	9	9		ET305	ADD	17:35	738
Full	ET306	ADD	18:15	9	9	ALM	ET307	ADD	19:35	B73
Arr	ET308	ADD	23:40	8		ALM		ADD	1:04	737
Park		ADD	1:10	8		ALM		ADD	4:24	737
Dep		ADD	4:30	8	8	ALM	ET309	ADD	6:00	737
Arr	ET308	ADD	23:45	8				ADD	1:09	738
Park		ADD	1:15	8				ADD	4:24	738
Dep		ADD	4:30	8	8		ET309	ADD	6:00	738
Full	EY641	AUH	12:47	7	7		EY642	AUH	13:40	320
Full	G9734	SHJ	13:06	10	10		G9735	SHJ	13:40	320
Full	KL565	AMS	20:25	7	7		KL566	AMS	22:25	747
Arr	KQ101	LHR	6:30	6		KZC		DXB	7:54	788
Park		LHR	8:00	6		KZC		DXB	17:39	788
Dep		LHR	17:45	19	19	KZC	KQ310	DXB	19:15	788
Full	KQ117	AMS	6:10	19	19	KZY	KQ116	AMS	8:35	773
Full	KQ205	BOM	10:30	20	20	CYB	KQ704	LUN	12:05	738
Full	KQ251	SEZ	18:25	14	14	FFA	KQ330	JED	21:30	E90
Arr	KQ252	HAH	18:25	J2A		KQH			19:49	737
Park		HAH	19:55	J2A		KQH			22:23	737
Dep		HAH	22:29	J2A	None	KQH			23:59	737
Arr	KQ257	TNR	20:15	3C		FFC		ABV	21:39	E90
Park		TNR	21:45	3C		FFC		ABV	6:19	E90
Dep		TNR	6:25	3C	4	FFC	KQ536	ABV	7:55	E90
Full	KQ257	TNR	20:15	13	13	FFB	KQ708	HRE	23:00	E90
Arr	KQ311	DXB	6:55	11		KZB		FIH	8:19	788
Park		DXB	8:25	11		KZB		FIH	10:29	788
Dep		DXB	10:35	11	10	KZB	KQ554	FIH	12:05	788
Full	KQ349	KRT	6:35	8	8	FFJ	KQ402	JIB	8:15	E90
Full	KQ351	JUB	12:10	3B	1	FFH	KQ608	MBA	14:15	E90
Full	KQ353	JUB	18:00	3C	1	KYR	KQ624	MBA	22:55	E90
Full	KQ403	ADD	17:30	20	20	FFJ	KQ416	EBB	19:10	E90
Full	KQ411	EBB	11:05	14	14	KQG	KQ412	EBB	12:00	737
Arr	KQ413	EBB	15:05	SPV1		KQG			16:29	737
Park		EBB	16:35	SPV1		KQG			22:23	737
Dep		EBB	22:29	SPV1	None	KQG			23:59	737
Full	KQ415	EBB	19:25	12	12	KYQ	KQ488	DAR	22:55	E90
Full	KQ417	EBB	22:15	14	14	FFJ	KQ466	KGL	23:20	E90
Full	KQ419	EBB	6:35	J4A	21	FFF	KQ432	JRO	8:00	E90
Arr	KQ433	JRO	10:45	12		FFF		BJM	12:09	E90
Park		JRO	12:15	12		FFF		BJM	14:34	E90
Dep		JRO	14:40	12	12	FFF	KQ444	BJM	16:10	E90
Full	KQ437	JRO	22:00	2C	None	KYT			23:59	E90
Arr	KQ444	BJM	21:15	14		KYP		KIS	22:39	E90
Park		BJM	22:45	4L		KYP		KIS	5:14	E90
Dep		BJM	5:20	4L	2	KYP	KQ650	KIS	6:50	E90
Full	KQ444	BJM	21:15	9	24	FFF	KQ498	ZNZ	23:00	E90
Arr	KQ447	KGL	6:05	J2A		KYT		APL	7:29	E90
Park		KGL	7:35	J2A		KYT		APL	10:49	E90
Dep		KGL	10:55	J2A	15	KYT	KQ748	APL	12:25	E90
Arr	KQ448	BJM	12:50	13		KYS		DAR	14:14	E90
Park		BJM	14:20	13		KYS		DAR	17:14	E90
Dep		BJM	17:20	13	13	KYS	KQ486	DAR	18:50	E90
Full	KQ481	DAR	11:10	16	16	KYD	KQ586	NLA	12:30	738
Full	KQ483	DAR	15:30	16	16	KYQ	KQ414	EBB	16:20	E90
Arr	KQ485	DAR	19:20	9		KYS		BJM	20:44	E90
Park		DAR	20:50	9		KYS		BJM	6:09	E90
Dep		DAR	6:15	9	9	KYS	KQ448	BJM	7:45	E90
Full	KQ485	DAR	19:20	10	12	FFG	KQ734	LUN	22:45	E90
Arr	KQ487	DAR	22:15	J6		FFB		TNR	23:39	E90
Park		DAR	23:45	J6		FFB		TNR	11:09	E90
Dep		DAR	11:15	J6	21	FFB	KQ256	TNR	12:45	E90
Full	KQ487	DAR	22:15	6	None	KYS			23:59	E90
Full	KQ489	DAR	6:40	J3B	15	KYQ	KQ494	ZNZ	8:05	E90
Full	KQ495	ZNZ	11:15	13	13	KYQ	KQ482	DAR	12:05	E90

Inbound				Outbound						
Flight Type	Fl No.	Origin	ETA	Bay	Gate	Reg. No.	Fl No.	Dest	ETD	AC Type
Full	KQ509	ACC	6:10	14	14	CYA	KQ760	JNB	8:30	738
Full	KQ521	ABJ	6:20	16	16	KYE	KQ504	FNA	10:35	738
Full	KQ522	NSI	21:40	J6	None	KYF			23:59	738
Arr	KQ524	DLA	18:20	4L		KYF		NSI	19:44	738
Park		DLA	19:50	J7		KYF		NSI	9:44	738
Dep		DLA	9:50	19	19	KYF	KQ522	NSI	11:20	738
Arr	KQ533	LOS	19:50	10		CYD		COO	21:14	738
Park		LOS	21:20	10		CYD		COO	6:19	738
Dep		LOS	6:25	10	10	CYD	KQ542	COO	7:55	738
Arr	KQ537	ABV	18:25	J2B		FFC			19:49	E90
Park		ABV	19:55	J2B		FFC			22:23	E90
Dep		ABV	22:29	J2B	None	FFC			23:59	E90
Full	KQ542	LOS	21:00	J4B	None	CYD			23:59	738
Full	KQ555	FIH	20:25	19	19	KZB	KQ112	CDG	23:05	788
Arr	KQ584	FBM	20:05	J1		KQH		HAH	21:29	737
Park		FBM	21:35	J1		KQH		HAH	9:54	737
Dep		FBM	10:00	J1	15	KQH	KQ252	HAH	11:30	737
Full	KQ586	NLA	20:05	J3B	None	KYD			23:59	738
Arr	KQ601	MBA	9:30	SPV2		FFK			10:54	E90
Park		MBA	11:00	SPV2		FFK			22:23	E90
Dep		MBA	22:29	SPV2	None	FFK			23:59	E90
Full	KQ603	MBA	11:10	4L	4	CYC	KQ762	JNB	12:05	738
Full	KQ605	MBA	12:55	2B	4	KYR	KQ352	JUB	13:40	E90
Full	KQ607	MBA	15:35	4R	1	FFE	KQ610	MBA	16:25	E90
Full	KQ609	MBA	16:55	2B	1	FFH	KQ616	MBA	18:50	E90
Full	KQ611	MBA	19:05	3B	1	FFE	KQ618	MBA	19:50	E90
Arr	KQ617	MBA	21:30	4R		FFK		MBA	22:54	E90
Park		MBA	23:00	4R		FFK		MBA	5:14	E90
Dep		MBA	5:20	4R	2	FFK	KQ600	MBA	6:50	E90
Full	KQ617	MBA	21:30	3B	21	FFH	KQ418	EBB	22:55	E90
Arr	KQ619	MBA	22:40	SPV1		FFH		JUB	0:04	E90
Park		MBA	0:10	12		FFH		JUB	6:14	E90
Dep		MBA	6:20	12	12	FFH	KQ350	JUB	7:50	E90
Full	KQ625	MBA	6:15	2B	2	FFE	KQ640	MYD	8:55	E90
Full	KQ641	MYD	11:45	4R	1	FFE	KQ606	MBA	12:55	E90
Full	KQ651	KIS	9:10	2C	1	KYP	KQ654	KIS	9:55	E90
Full	KQ655	KIS	12:15	2C	2	KYP	KQ656	KIS	13:05	E90
Full	KQ657	KIS	15:25	3B	1	KYP	KQ670	KIS	17:30	E90
Arr	KQ671	KIS	19:50	SPV2		KYD		DAR	21:14	738
Park		KIS	21:20	20		KYD		DAR	6:09	738
Dep		KIS	6:15	20	20	KYD	KQ480	DAR	7:45	738
Full	KQ671	KIS	19:50	2B	None	KYP			23:59	E90
Arr	KQ704	LUN	20:30	J3A		FFA		SEZ	21:54	E90
Park		LUN	22:00	J3A		FFA		SEZ	9:54	E90
Dep		LUN	10:00	J3A	23	FFA	KQ250	SEZ	11:30	E90
Full	KQ704	LUN	20:30	20	20	CYB	KQ764	JNB	21:50	738
Full	KQ717	GBE	6:50	J4B	23	FFG	KQ730	LLW	8:15	E90
Full	KQ720	HRE	6:50	3B	2	KYR	KQ604	MBA	10:15	E90
Full	KQ731	LLW	13:30	20	20	FFG	KQ484	DAR	15:55	E90
Full	KQ749	APL	18:05	16	16	KYT	KQ436	JRO	19:20	E90
Arr	KQ752	BLZ	19:45	13		KQG		EBB	21:09	737
Park		BLZ	21:15	13		KQG		EBB	6:24	737
Dep		BLZ	6:30	13	13	KQG	KQ410	EBB	8:00	737
Full	KQ761	JNB	17:40	18	18	CYA	KQ204	BOM	21:25	738
Full	KQ763	JNB	21:25	16	16	CYC	KQ304	DXB	22:30	738
Full	KQ765	JNB	6:55	2C	1	CYC	KQ602	MBA	8:30	738
Full	KQ8603	MBA	12:25	3C	1	KQB	KQ8606	MBA	14:00	73J
Full	KQ8607	MBA	16:45	2C	2	KQB	KQ8608	MBA	19:30	737
Arr	KQ8609	MBA	22:15	J8		KQB		MBA	23:39	737
Park		MBA	23:45	SPV2		KQB		MBA	8:04	737
Dep		MBA	8:10	3C	2	KQB	KQ8602	MBA	9:40	737
Full	KQ8609	MBA	22:15	4L	None	KQB			23:59	737
Full	KQ8651	KIS	8:30	2A	1	QUE	KQ8690	UKU	9:10	AT7
Arr	KQ8655	KIS	20:00	2A		QUE		KIS	21:24	AT7
Park		KIS	21:30	2A		QUE		KIS	4:54	AT7
Dep		KIS	5:00	2A	1	QUE	KQ8650	KIS	6:30	AT7
Full	KQ8655	KIS	20:00	3A	None	QHW			23:59	AT7
Full	KQ8661	EDL	9:00	3A	1	QHW	KQ8680	LAU	9:40	AT7
Arr	KQ8665	EDL	19:10	3B		QHW		EDL	20:34	AT7
Park		EDL	20:40	3B		QHW		EDL	5:24	AT7
Dep		EDL	5:30	SPV1	1	QHW	KQ8660	EDL	7:00	AT7
Full	KQ8665	EDL	19:10	2A	None	QUE			23:59	AT7
Full	KQ8681	MYD	13:30	3A	2	QHW	KQ8654	KIS	18:00	AT7
Full	KQ8691	UKU	11:30	2A	2	QUE	KQ8692	UKU	14:10	AT7
Full	KQ8693	UKU	16:30	2A	2	QUE	KQ8664	EDL	17:10	AT7
Arr	KQ887	BKK	6:45	17		KZE		BKK	8:09	788
Park		BKK	8:15	17		KZE		BKK	21:34	788
Dep		BKK	21:40	17	25	KZE	KQ886	BKK	23:10	788
Full	LX294	ZRH	18:40	5	5		LX295	DAR	19:35	330
Full	MK534	MRU	11:50	18	18		MK535	MRU	13:05	332
Full	MS849	CAI	7:10	7	7		MS850	CAI	8:10	320
Full	PW715	ZNZ	21:15	J3A	None	PWG			23:59	AT7
Full	PW723	JRO	7:00	J2B	21	PWB	PW722	JRO	8:30	AT7
Arr	PW725	JRO	19:20	3A		PWG		ZNZ	20:44	AT7
Park		JRO	20:50	3A		PWG		ZNZ	6:34	AT7
Dep		JRO	6:40	3A	22	PWG	PW710	ZNZ	8:10	AT7
Full	PW725	JRO	19:20	J4A	None	PWB			23:59	AT7
Full	PW727	JRO	16:00	3C	22	PWB	PW726	JRO	16:50	AT7
Full	QR1337	DOH	9:30	5	5		QR1338	DOH	12:35	320
Full	QR1339	DOH	13:10	5	5		QR1340	DOH	17:35	320
Full	SA184	JNB	15:15	11	10		SA185	JNB	16:05	320
Full	SN463	BRU	21:45	5	5		SN463	BRU	22:45	332
Full	SV431	JED	11:32	8	8		SV430	JED	13:10	320
Full	TK6510	FIH	18:30	4L	4		TK6492	IST	21:00	330
Full	TM4462	MPM	14:25	19	19		TM4463	MPM	15:45	E90
Full	WB402	KGL	15:40	4L	4	9XRWH	WB403	KGL	16:30	CRJ
Full	WB450	EBB	10:40	3A	4	9XRWI	WB450	KGL	11:25	CRJ
Full	WB460	KGL	20:15	6	5	9XRWH	WB460	EBB	21:35	CRJ
Full			6:50	18	18		KQ210	BOM	7:50	788
Full			22:25	18	18		KQ102	LHR	23:25	788
Arr	CZ633	CAN	7:00	J5				CAN	8:24	330
Park		CAN	8:30	J5				CAN	11:59	330
Dep		CAN	12:05	19	19		CZ634	CAN	13:35	330
Full	EK721	DXB	19:00	8	8		EK722	DUB	22:50	773
Arr	SA180	JNB	22:40	5				JNB	0:04	320
Park		JNB	0:10	5				JNB	6:54	320
Dep		JNB	7:00	5	5		SA181	JNB	8:30	320
Full	TK607	IST	7:25	4L	4		TK608	IST	10:35	330

C

Bay Assignment Results 05-07-2015

Table C.1: Bay and gate assignment results 05-07-2015 using buffer times

Inbound				Outbound						
Flight Type	Fl No.	Origin	ETA	Bay	Gate	Reg. No.	Fl No.	Dest	ETD	AC Type
Full	ET302	ADD	10:20	9	9	ETALK	ET303	ADD	11:35	738
Arr	ET304	ADD	12:20	9		ETAQO		ADD	13:44	738
Park		ADD	13:50	9		ETAQO		ADD	15:59	738
Dep		ADD	16:05	9	9	ETAQO	ET305	ADD	17:35	738
Full	ET306	ADD	18:15	9	9	ETARD	ET307	ADD	19:35	738
Arr	ET308	ADD	23:40	8				ADD	1:04	738
Park		ADD	1:10	8				ADD	4:24	738
Dep		ADD	4:30	8	8		ET309	ADD	6:00	738
Full	KL565	AMS	20:25	7	7		KL566	AMS	22:25	747
Full	KQ101	LHR	6:30	19	19	KZZ	KQ116	AMS	8:15	773
Full	KQ113	CDG	20:00	19	19	KZB	KQ112	CDG	23:05	788
Full	KQ117	AMS	6:20	17	17	KZX	KQ116	AMS	8:35	773
Full	KQ205	BOM	11:00	17	25	CYC	KQ586	NLA	12:30	738
Full	KQ211	BOM	20:55	18	18	KZC	KQ102	LHR	23:25	788
Arr	KQ251	SEZ	18:55	SPV1		KQH			20:19	737
Park		SEZ	20:25	SPV1		KQH			22:23	737
Dep		SEZ	22:29	SPV1	None	KQH			23:59	737
Full	KQ257	TNR	20:15	16	16	KYF	KQ204	BOM	21:55	738
Full	KQ263	TNR	6:50	13	13	KQG	KQ512	DKR	8:10	737
Arr	KQ265	HAH	17:40	J1		KYT			19:04	E90
Park		HAH	19:10	J1		KYT			22:23	E90
Dep		HAH	22:29	J1	None	KYT			23:59	E90
Full	KQ305	DXB	10:15	20	20	CYD	KQ762	JNB	12:00	738
Arr	KQ311	DXB	6:55	J1		KZA		DXB	8:19	788
Park		DXB	8:25	J1		KZA		DXB	17:39	788
Dep		DXB	17:45	19	19	KZA	KQ310	DXB	19:15	788
Arr	KQ331	JED	6:55	J9		FFE		LUN	8:19	E90
Park		JED	8:25	12		FFE		LUN	10:49	E90
Dep		JED	10:55	12	12	FFE	KQ726	LUN	12:25	E90
Arr	KQ349	KRT	6:35	J4A		KYT		HAH	7:59	E90
Park		KRT	8:05	J4A		KYT		HAH	10:24	E90
Dep		KRT	10:30	J4A	15	KYT	KQ264	HAH	12:00	E90
Full	KQ351	JUB	12:10	2B	1	FFG	KQ656	KIS	13:05	E90
Full	KQ353	JUB	18:10	3B	1	FFF	KQ616	MBA	18:55	E90
Full	KQ411	EBB	11:10	14	14	KQF	KQ770	LAD	12:10	737
Full	KQ413	EBB	15:05	16	16	KYP	KQ444	KGL	16:10	E90
Full	KQ415	EBB	19:45	J6	15	FFK	KQ348	KRT	22:50	E90
Full	KQ417	EBB	22:15	H6	None	KYR			23:59	E90
Full	KQ419	EBB	6:35	8	8	FFC	KQ706	HRE	8:10	E90
Full	KQ433	JRO	10:50	11	10	KYQ	KQ780	HRE	13:00	E90
Full	KQ444	KGL	21:15	J2A	None	KYP			23:59	E90
Full	KQ448	BJM	13:00	20	20	FFF	KQ352	JUB	13:50	E90
Full	KQ467	KGL	6:05	H4	15	FFA	KQ760	JNB	8:30	E90
Full	KQ481	DAR	11:10	7	7	KYS	KQ482	DAR	12:15	E90
Full	KQ483	DAR	15:40	4L	2	KYS	KQ610	MBA	16:30	E90
Full	KQ485	DAR	19:20	12	12	FFJ	KQ488	DAR	22:50	E90
Full	KQ487	DAR	22:15	9	25	FFA	KQ262	TNR	22:40	E90
Full	KQ489	DAR	6:40	3B	2	FFK	KQ654	KIS	9:45	E90
Full	KQ495	ZNZ	11:10	13	13	KYP	KQ412	EBB	12:00	E90
Full	KQ499	ZNZ	7:00	J4B	15	KYR	KQ494	ZNZ	8:00	E90
Full	KQ505	ACC	6:15	14	14	KYE	KQ522	NSI	9:50	738
Arr	KQ521	ABJ	6:20	J7		KYD		EBB	7:44	738
Park		ABJ	7:50	J7		KYD		EBB	21:19	738
Dep		ABJ	21:25	13	13	KYD	KQ418	EBB	22:55	738
Full	KQ522	NSI	20:30	J2B	None	KYE			23:59	738
Full	KQ533	LOS	19:55	20	20	CYA	KQ764	JNB	21:45	738
Full	KQ537	ABV	19:20	10	12	FFB	KQ720	LUN	22:10	E90
Full	KQ555	FIH	20:25	17	22	KZG	KQ886	CAN	23:15	788
Full	KQ586	NLA	20:05	J4A	None	CYC			23:59	738
Full	KQ603	MBA	11:10	2C	4	KQH	KQ250	SEZ	11:50	737
Full	KQ607	MBA	15:45	4R	4	FFK	KQ414	EBB	16:40	E90
Full	KQ609	MBA	17:15	2B	22	KYR	KQ416	EBB	19:10	E90
Full	KQ611	MBA	19:10	3C	1	KYS	KQ618	MBA	19:55	E90
Full	KQ617	MBA	21:35	4R	None	FFF			23:59	E90
Full	KQ619	MBA	22:45	4L	None	KYS			23:59	E90
Full	KQ625	MBA	6:15	3C	4	KQF	KQ410	EBB	8:00	737
Full	KQ640D.	MBA	13:45	3B	4	FFJ	KQ484	DAR	15:55	E90
Full	KQ643	MYD	19:20	2C	21	FFG	KQ498	ZNZ	23:00	E90
Full	KQ655	KIS	12:05	3B	2	FFK	KQ606	MBA	13:05	E90

Inbound				Outbound						
Flight Type	Fl No.	Origin	ETA	Bay	Gate	Reg. No.	Fl No.	Dest	ETD	AC Type
Full	KQ657	KIS	15:25	2B	1	FFG	KQ642	MYD	16:30	E90
Full	KQ671	KIS	19:50	2B	24	FFC	KQ466	KGL	23:20	E90
Full	KQ706	HRE	16:45	3B	1	FFC	KQ670	KIS	17:30	E90
Full	KQ709	HRE	6:20	H6	24	FFG	KQ350	JUB	7:55	E90
Full	KQ726	LUN	20:25	6	25	FFE	KQ406	ADD	23:10	E90
Full	KQ731	LLW	13:45	4R	1	KYR	KQ608	MBA	14:35	E90
Full	KQ734	LLW	6:15	2C	1	FFJ	KQ640	MYD	10:00	E90
Full	KQ741	MPM	21:05	J3A	None	FFD			23:59	E90
Full	KQ761	JNB	17:40	20	20	FFA	KQ486	DAR	18:50	E90
Full	KQ763	JNB	21:25	14	14	CYD	KQ304	DXB	22:30	738
Full	KQ765	JNB	6:55	20	20	CYB	KQ502	ACC	9:00	738
Full	KQ771	LAD	21:15	3C	2	KQF	KQ624	MBA	22:55	737
Full	KQ780	HRE	22:00	J4B	None	KYQ			23:59	E90
Full	KQ8603	MBA	11:20	3A	2	BWG	KQ8680	LAU	12:30	AT7
Full	KQ8605	MBA	14:05	3C	1	KQB	KQ8606	MBA	14:55	73J
Arr	KQ8607	MBA	17:40	SPV2		KQB			19:04	73J
Park		MBA	19:10	SPV2		KQB			22:23	73J
Dep		MBA	22:29	SPV2	None	KQB			23:59	73J
Arr	KQ861	BKK	6:45	10		KZG		FIH	8:09	788
Park		BKK	8:15	10		KZG		FIH	10:29	788
Dep		BKK	10:35	10	10	KZG	KQ554	FIH	12:05	788
Full	KQ8611	MBA	22:40	2A	None	BWG			23:59	AT7
Full	KQ8613	MBA	22:50	3A	None	QUE			23:59	AT7
Full	KQ8653	KIS	14:00	3A	2	QUE	KQ8692	UKU	14:40	AT7
Full	KQ8655	KIS	19:40	3B	None	BWG			23:59	AT7
Full	KQ8655.	KIS	7:50	3A	1	BWG	KQ8602	MBA	8:50	AT7
Full	KQ8665	EDL	19:10	3A	2	QUE	KQ8612	MBA	20:20	AT7
Full	KQ8681	MYD	16:20	3A	2	BWG	KQ8654	KIS	17:40	AT7
Full	KQ8691	UKU	11:30	2A	2	QHW	KQ8652	KIS	12:00	AT7
Full	KQ8693	UKU	16:30	2A	2	BWG	KQ8610	MBA	19:50	AT7
Full	KQ871	HAN	6:45	18	21	KZC	KQ210	BOM	7:50	788
Full	MS849	CAI	7:10	7	7		MS850	CAI	8:10	320
Full	PW713	ZNZ	18:35	J5	23	PWA	PW712	ZNZ	19:05	AT7
Full	PW715	ZNZ	21:15	J5	21	PWB	PW728	JRO	22:20	AT7
Full	PW723	JRO	7:00	J2B	24	PWC	PW722	JRO	8:30	AT7
Full	PW725	JRO	19:20	J3B	None	PWC			23:59	AT7
Full	PW727	JRO	15:15	2C	22	PWC	PW726	JRO	16:50	AT7
Full	TM4460	APL	15:00	20	20		TM4461	APL	16:15	E90
Full	WB450	EBB	10:40	6	7	9XRWJ	WB450	KGL	11:25	737
Full	WB452	EBB	14:10	2A	4	9XRWL	WB453	EBB	14:50	Q40
Full	WB460	KGL	20:55	3A	4	9XRWI	WB460	EBB	21:35	CRJ
Arr	KQ417	EBB	22:15	J2A		KYS		DAR	23:39	E90
Park		EBB	23:45	J2A		KYS		DAR	6:09	E90
Dep		EBB	6:15	J2A	22	KYS	KQ480	DAR	7:45	E90
Arr	KQ444	KGL	21:15	J6		FFF		BJM	22:39	E90
Park		KGL	22:45	J6		FFF		BJM	6:14	E90
Dep		KGL	6:20	J6	23	FFF	KQ448	BJM	7:50	E90
Arr	KQ619	MBA	22:45	2C		FFB		ABV	0:09	E90
Park		MBA	0:15	6		FFB		ABV	6:29	E90
Dep		MBA	6:35	6	25	FFB	KQ536	ABV	8:05	E90
Arr	KQ487	DAR	22:15	2B		KYQ		JRO	23:39	E90
Park		DAR	23:45	2B		KYQ		JRO	6:29	E90
Dep		DAR	6:35	2B	20	KYQ	KQ432	JRO	8:05	E90
Arr	PW725	JRO	19:20	3A		PWA		ZNZ	20:44	AT7
Park		JRO	20:50	J3B		PWA		ZNZ	6:34	AT7
Dep		JRO	6:40	J3B	21	PWA	PW710	ZNZ	8:10	AT7
Arr	KQ257	TNR	20:15	9		FFC		HRE	21:39	E90
Park		TNR	21:45	9		FFC		HRE	6:34	E90
Dep		TNR	6:40	9	9	FFC	KQ706	HRE	8:10	E90
Arr	KQ542	COO	20:55	12		CYA		LOS	22:19	738
Park		COO	22:25	12		CYA		LOS	6:39	738
Dep		COO	6:45	12	12	CYA	KQ532	LOS	8:15	738
Arr	KQ485	DAR	19:20	4L		KYR		LLW	20:44	E90
Park		DAR	20:50	11		KYR		LLW	6:44	E90
Dep		DAR	6:50	11	10	KYR	KQ730	LLW	8:20	E90
Arr	KQ251	SEZ	18:55	SPV1		KQH		MBA	20:19	737
Park		SEZ	20:25	J2B		KQH		MBA	6:54	737
Dep		SEZ	7:00	SPV1	2	KQH	KQ602	MBA	8:30	737
Arr	ET308	ADD	23:40	8		ETAPF		ADD	1:04	738
Park		ADD	1:10	8		ETAPF		ADD	4:24	738
Dep		ADD	4:30	8	8	ETAPF	ET309	ADD	6:00	738
Arr	KQ8665	EDL	19:10	H5		QUE		UKU	20:34	AT7
Park		EDL	20:40	2A		QUE		UKU	7:54	AT7
Dep		EDL	8:00	2A	1	QUE	KQ8690	UKU	9:30	AT7
Arr	KQ8603	MBA	12:25	SPV2		KQB		MBA	13:49	73J
Park		MBA	13:55	SPV2		KQB		MBA	9:44	73J
Dep		MBA	9:50	3C	1	KQB	KQ8604	MBA	11:20	73J
Arr	KQ704	LUN	20:40	3C		FFD		MPM	22:04	E90
Park		LUN	22:10	J3A		FFD		MPM	10:34	E90
Dep		LUN	10:40	J3A	21	FFD	KQ740	MPM	12:10	E90
Arr	KQ503	ACC	22:00	16		KYF		TNR	23:24	738
Park		ACC	23:30	16		KYF		TNR	11:09	738
Dep		ACC	11:15	16	16	KYF	KQ256	TNR	12:45	738
Full	BA065	LHR	20:30	11	10		BA064	LHR	23:15	772
Full	EK719	DXB	14:30	8	8		EK720	DUB	16:40	773
Full	EY641	AUH	12:47	7	7		EY642	AUH	13:40	320
Full	G9734	SHJ	13:06	10	10		G9735	SHJ	13:40	320
Full	LX294	ZRH	18:40	5	5		LX295	DAR	19:35	330
Full	MK534	MRU	11:50	18	18		MK535	MRU	13:05	332
Full	QR1337	DOH	9:30	5	5		QR1338	DOH	12:35	320
Full	QR1339	DOH	13:10	5	5		QR1340	DOH	17:35	320
Full	SA184	JNB	15:15	11	10		SA185	JNB	16:05	320
Full	SN463	BRU	21:45	5	5		SN463	BRU	22:45	332
Full	SV431	JED	11:32	8	8		SV430	JED	13:10	320
Full	TK607	IST	7:25	4L	4		TK608	IST	10:35	330
Arr	CZ633	CAN	7:00	J5				CAN	8:24	330
Park		CAN	8:30	19				CAN	11:59	330
Dep		CAN	12:05	19	19		CZ634	CAN	13:35	330
Full	EK721	DXB	19:00	8	8		EK722	DUB	22:50	773
Arr	SA180	JNB	22:40	5				JNB	0:04	320
Park		JNB	0:10	5				JNB	6:54	320
Dep		JNB	7:00	5	5		SA181	JNB	8:30	320
Full	TK6510	FIH	18:30	4L	4		TK6492	IST	21:00	330

D

Simulation Cases

Table D.1: Simulation case 1

Inbound					Outbound			
Flight Type	Fl No.	Origin	ETA	ATA	Fl No.	Dest	ETD	ATD
Full	BA065	LHR	20:30	20:30	BA064	LHR	23:15	23:20
Full	EK719	DXB	14:30	14:35	EK720	DUB	16:40	16:40
Full	ET302	ADD	10:20	10:25	ET303	ADD	11:35	11:35
Arr	ET304	ADD	12:20	12:20	ET305	ADD	13:44	13:44
Park	ET304	ADD	13:50	13:50	ET305	ADD	15:59	15:59
Dep	ET304	ADD	16:05	16:05	ET305	ADD	17:35	17:35
Full	ET306	ADD	18:15	18:15	ET307	ADD	19:35	19:40
Arr	ET308	ADD	23:40	23:40	ET309	ADD	1:04	1:04
Park	ET308	ADD	1:10	1:10	ET309	ADD	4:24	4:29
Dep	ET308	ADD	4:30	4:35	ET309	ADD	6:00	6:05
Arr	ET308	ADD	23:45	23:45	ET309	ADD	1:09	1:09
Park	ET308	ADD	1:15	1:15	ET309	ADD	4:24	4:29
Dep	ET308	ADD	4:30	4:35	ET309	ADD	6:00	6:05
Full	EY641	AUH	12:47	12:45	EY642	AUH	13:40	13:40
Full	G9734	SHJ	13:06	13:19	G9735	SHJ	13:40	14:10
Full	KL565	AMS	20:25	20:25	KL566	AMS	22:25	22:25
Arr	KQ101	LHR	6:30	6:30	KQ310	DXB	7:54	7:54
Park	KQ101	LHR	8:00	8:00	KQ310	DXB	17:39	17:39
Dep	KQ101	LHR	17:45	17:45	KQ310	DXB	19:15	19:15
Full	KQ117	AMS	6:10	6:10	KQ116	AMS	8:35	8:35
Full	KQ205	BOM	10:30	10:28	KQ704	LUN	12:05	12:05
Full	KQ251	SEZ	18:25	18:23	KQ330	JED	21:30	21:30
Arr	KQ252	HAH	18:25	18:15			19:49	19:39
Park	KQ252	HAH	19:55	19:45			22:23	22:23
Dep	KQ252	HAH	22:29	22:29			23:59	23:59
Arr	KQ257	TNR	20:15	20:08	KQ536	ABV	21:39	21:32
Park	KQ257	TNR	21:45	21:38	KQ536	ABV	6:19	6:19
Dep	KQ257	TNR	6:25	6:25	KQ536	ABV	7:55	7:55
Full	KQ257	TNR	20:15	20:24	KQ708	HRE	23:00	23:00
Arr	KQ311	DXB	6:55	6:55	KQ554	FIH	8:19	8:19
Park	KQ311	DXB	8:25	8:25	KQ554	FIH	10:29	10:54
Dep	KQ311	DXB	10:35	11:00	KQ554	FIH	12:05	12:30
Full	KQ349	KRT	6:35	6:25	KQ402	JIB	8:15	8:15
Full	KQ351	JUB	12:10	11:58	KQ608	MBA	14:15	14:15
Full	KQ353	JUB	18:00	17:53	KQ624	MBA	22:55	22:55
Full	KQ403	ADD	17:30	17:27	KQ416	EBB	19:10	19:10
Full	KQ411	EBB	11:05	11:05	KQ412	EBB	12:00	12:10
Arr	KQ413	EBB	15:05	14:55			16:29	16:19
Park	KQ413	EBB	16:35	16:25			22:23	22:23
Dep	KQ413	EBB	22:29	22:29			23:59	23:59
Full	KQ415	EBB	19:25	19:20	KQ488	DAR	22:55	22:55
Full	KQ417	EBB	22:15	22:15	KQ466	KGL	23:20	23:20
Full	KQ419	EBB	6:35	6:22	KQ432	JRO	8:00	8:00
Arr	KQ433	JRO	10:45	10:45	KQ444	BJM	12:09	12:09
Park	KQ433	JRO	12:15	12:15	KQ444	BJM	14:34	14:34
Dep	KQ433	JRO	14:40	14:40	KQ444	BJM	16:10	16:10
Full	KQ437	JRO	22:00	22:03			23:59	23:59
Arr	KQ444	BJM	21:15	21:13	KQ650	KIS	22:39	22:37
Park	KQ444	BJM	22:45	22:43	KQ650	KIS	5:14	5:14
Dep	KQ444	BJM	5:20	5:20	KQ650	KIS	6:50	6:50
Full	KQ444	BJM	21:15	21:25	KQ498	ZNZ	23:00	23:00
Arr	KQ447	KGL	6:05	6:05	KQ748	APL	7:29	7:29
Park	KQ447	KGL	7:35	7:35	KQ748	APL	10:49	10:49
Dep	KQ447	KGL	10:55	10:55	KQ748	APL	12:25	12:25
Arr	KQ448	BJM	12:50	12:50	KQ486	DAR	14:14	14:14
Park	KQ448	BJM	14:20	14:20	KQ486	DAR	17:14	17:14
Dep	KQ448	BJM	17:20	17:20	KQ486	DAR	18:50	18:50
Full	KQ481	DAR	11:10	11:10	KQ586	NLA	12:30	12:30
Full	KQ483	DAR	15:30	15:25	KQ414	EBB	16:20	16:20
Arr	KQ485	DAR	19:20	19:20	KQ448	BJM	20:44	20:44
Park	KQ485	DAR	20:50	20:50	KQ448	BJM	6:09	6:09
Dep	KQ485	DAR	6:15	6:15	KQ448	BJM	7:45	7:45
Full	KQ485	DAR	19:20	19:13	KQ734	LUN	22:45	22:45
Arr	KQ487	DAR	22:15	22:15	KQ256	TNR	23:39	23:39
Park	KQ487	DAR	23:45	23:45	KQ256	TNR	11:09	11:09
Dep	KQ487	DAR	11:15	11:15	KQ256	TNR	12:45	12:45
Full	KQ487	DAR	22:15	22:13			23:59	23:59
Full	KQ489	DAR	6:40	6:46	KQ494	ZNZ	8:05	8:05
Full	KQ495	ZNZ	11:15	11:15	KQ482	DAR	12:05	12:05
Full	KQ509	ACC	6:10	6:08	KQ760	JNB	8:30	8:30
Full	KQ521	ABJ	6:20	7:39	KQ504	FNA	10:35	10:43
Full	KQ522	NSI	21:40	21:40			23:59	23:59
Arr	KQ524	DLA	18:20	18:20	KQ522	NSI	19:44	19:44

Inbound					Outbound			
Flight Type	Fl No.	Origin	ETA	ATA	Fl No.	Dest	ETD	ATD
Park	KQ524	DLA	19:50	19:50	KQ522	NSI	9:44	9:44
Dep	KQ524	DLA	9:50	9:50	KQ522	NSI	11:20	11:20
Arr	KQ533	LOS	19:50	19:50	KQ542	COO	21:14	21:14
Park	KQ533	LOS	21:20	21:20	KQ542	COO	6:19	7:08
Dep	KQ533	LOS	6:25	7:14	KQ542	COO	7:55	8:44
Arr	KQ537	ABV	18:25	18:18			19:49	19:42
Park	KQ537	ABV	19:55	19:48			22:23	22:23
Dep	KQ537	ABV	22:29	22:29			23:59	23:59
Full	KQ542	LOS	21:00	20:06			23:59	23:59
Full	KQ555	FIH	20:25	20:18	KQ112	CDG	23:05	23:05
Arr	KQ584	FBM	20:05	19:52	KQ252	HAH	21:29	21:16
Park	KQ584	FBM	21:35	21:22	KQ252	HAH	9:54	9:59
Dep	KQ584	FBM	10:00	10:05	KQ252	HAH	11:30	11:35
Full	KQ586	NLA	20:05	20:19			23:59	23:59
Arr	KQ601	MBA	9:30	9:30			10:54	10:54
Park	KQ601	MBA	11:00	11:00			22:23	22:23
Dep	KQ601	MBA	22:29	22:29			23:59	23:59
Full	KQ603	MBA	11:10	11:10	KQ762	JNB	12:05	12:18
Full	KQ605	MBA	12:55	12:50	KQ352	JUB	13:40	13:40
Full	KQ607	MBA	15:35	15:35	KQ610	MBA	16:25	16:25
Full	KQ609	MBA	16:55	17:00	KQ616	MBA	18:50	18:50
Full	KQ611	MBA	19:05	19:10	KQ618	MBA	19:50	19:50
Arr	KQ617	MBA	21:30	21:30	KQ600	MBA	22:54	22:54
Park	KQ617	MBA	23:00	23:00	KQ600	MBA	5:14	5:14
Dep	KQ617	MBA	5:20	5:20	KQ600	MBA	6:50	6:50
Full	KQ617	MBA	21:30	21:30	KQ418	EBB	22:55	22:55
Arr	KQ619	MBA	22:40	22:38	KQ350	JUB	0:04	0:02
Park	KQ619	MBA	0:10	0:08	KQ350	JUB	6:14	6:20
Dep	KQ619	MBA	6:20	6:26	KQ350	JUB	7:50	7:56
Full	KQ625	MBA	6:15	6:15	KQ640	MYD	8:55	8:55
Full	KQ641	MYD	11:45	11:35	KQ606	MBA	12:55	12:55
Full	KQ651	KIS	9:10	9:05	KQ654	KIS	9:55	9:55
Full	KQ655	KIS	12:15	12:10	KQ656	KIS	13:05	13:05
Full	KQ657	KIS	15:25	15:23	KQ670	KIS	17:30	17:30
Arr	KQ671	KIS	19:50	19:50	KQ480	DAR	21:14	21:14
Park	KQ671	KIS	21:20	21:20	KQ480	DAR	6:09	6:09
Dep	KQ671	KIS	6:15	6:15	KQ480	DAR	7:45	7:45
Full	KQ671	KIS	19:50	19:58			23:59	23:59
Arr	KQ704	LUN	20:30	20:27	KQ250	SEZ	21:54	21:51
Park	KQ704	LUN	22:00	21:57	KQ250	SEZ	9:54	9:54
Dep	KQ704	LUN	10:00	10:00	KQ250	SEZ	11:30	11:30
Full	KQ704	LUN	20:30	20:30	KQ764	JNB	21:50	22:04
Full	KQ717	GBE	6:50	6:58	KQ730	LLW	8:15	8:15
Full	KQ720	HRE	6:50	7:40	KQ604	MBA	10:15	10:23
Full	KQ731	LLW	13:30	13:30	KQ484	DAR	15:55	16:07
Full	KQ749	APL	18:05	18:05	KQ436	JRO	19:20	19:20
Arr	KQ752	BLZ	19:45	19:43	KQ410	EBB	21:09	21:07
Park	KQ752	BLZ	21:15	21:13	KQ410	EBB	6:24	6:24
Dep	KQ752	BLZ	6:30	6:30	KQ410	EBB	8:00	8:00
Full	KQ761	JNB	17:40	17:49	KQ204	BOM	21:25	21:50
Full	KQ763	JNB	21:25	21:16	KQ304	DXB	22:30	22:46
Full	KQ765	JNB	6:55	6:55	KQ602	MBA	8:30	8:30
Full	KQ8603	MBA	12:25	12:30	KQ8606	MBA	14:00	14:00
Full	KQ8607	MBA	16:45	16:53	KQ8608	MBA	19:30	19:30
Arr	KQ8609	MBA	22:15	22:15	KQ8602	MBA	23:39	23:39
Park	KQ8609	MBA	23:45	23:45	KQ8602	MBA	8:04	8:04
Dep	KQ8609	MBA	8:10	8:10	KQ8602	MBA	9:40	9:40
Full	KQ8609	MBA	22:15	22:20			23:59	23:59
Full	KQ8651	KIS	8:30	8:12	KQ8690	UKU	9:10	9:20
Arr	KQ8655	KIS	20:00	19:58	KQ8650	KIS	21:24	21:22
Park	KQ8655	KIS	21:30	21:28	KQ8650	KIS	4:54	4:54
Dep	KQ8655	KIS	5:00	5:00	KQ8650	KIS	6:30	6:30
Full	KQ8655	KIS	20:00	19:57			23:59	23:59
Full	KQ8661	EDL	9:00	9:00	KQ8680	LAU	9:40	9:40
Arr	KQ8665	EDL	19:10	19:10	KQ8660	EDL	20:34	20:34
Park	KQ8665	EDL	20:40	20:40	KQ8660	EDL	5:24	5:24
Dep	KQ8665	EDL	5:30	5:30	KQ8660	EDL	7:00	7:00
Full	KQ8665	EDL	19:10	19:10			23:59	23:59
Full	KQ8681	MYD	13:30	13:40	KQ8654	KIS	18:00	18:00
Full	KQ8691	UKU	11:30	11:14	KQ8692	UKU	14:10	14:16
Full	KQ8693	UKU	16:30	16:21	KQ8664	EDL	17:10	17:10
Arr	KQ887	BKK	6:45	6:37	KQ886	BKK	8:09	8:01
Park	KQ887	BKK	8:15	8:07	KQ886	BKK	21:34	21:34
Dep	KQ887	BKK	21:40	21:40	KQ886	BKK	23:10	23:10
Full	LX294	ZRH	18:40	18:45	LX295	DAR	19:35	19:35
Full	MK534	MRU	11:50	11:47	MK535	MRU	13:05	13:05
Full	MS849	CAI	7:10	7:10	MS850	CAI	8:10	8:10
Full	PW715	ZNZ	21:15	21:05			23:59	23:59
Full	PW723	JRO	7:00	6:15	PW722	JRO	8:30	8:30
Arr	PW725	JRO	19:20	19:10	PW710	ZNZ	20:44	20:34
Park	PW725	JRO	20:50	20:40	PW710	ZNZ	6:34	6:34
Dep	PW725	JRO	6:40	6:40	PW710	ZNZ	8:10	8:10
Full	PW725	JRO	19:20	19:20			23:59	23:59
Full	PW727	JRO	16:00	15:45	PW726	JRO	16:50	16:50
Full	QR1337	DOH	9:30	9:30	QR1338	DOH	12:35	12:35
Full	QR1339	DOH	13:10	13:10	QR1340	DOH	17:35	17:35
Full	SA184	JNB	15:15	15:20	SA185	JNB	16:05	16:10
Full	SN463	BRU	21:45	21:50	SN463	BRU	22:45	22:45
Full	SV431	JED	11:32	11:32	SV430	JED	13:10	13:10
Full	TK6510	FIH	18:30	18:23	TK6492	IST	21:00	21:00
Full	TM4462	MPM	14:25	14:20	TM4463	MPM	15:45	15:45
Full	WB402	KGL	15:40	15:40	WB403	KGL	16:30	16:30
Full	WB450	EBB	10:40	10:40	WB450	KGL	11:25	11:30
Full	WB460	KGL	20:15	20:15	WB460	EBB	21:35	21:40
Full			6:50	6:50	KQ210	BOM	7:50	7:50
Full			22:25	22:25	KQ102	LHR	23:25	23:25
Arr	CZ633	CAN	7:00	7:00	CZ634	CAN	8:24	8:24
Park	CZ633	CAN	8:30	8:30	CZ634	CAN	11:59	12:04
Dep	CZ633	CAN	12:05	12:10	CZ634	CAN	13:35	13:40
Full	EK721	DXB	19:00	19:00	EK722	DUB	22:50	22:50
Arr	SA180	JNB	22:40	22:40	SA181	JNB	0:04	0:04
Park	SA180	JNB	0:10	0:10	SA181	JNB	6:54	6:54
Dep	SA180	JNB	7:00	7:00	SA181	JNB	8:30	8:30
Full	TK607	IST	7:25	7:15	TK608	IST	10:35	10:42

Table D.2: Simulation case 2

Inbound					Outbound			
Flight Type	Fl No.	Origin	ETA	ATA	Fl No.	Dest	ETD	ATD
Full	BA065	LHR	20:30	20:30	BA064	LHR	23:15	23:20
Full	EK719	DXB	14:30	14:40	EK720	DUB	16:40	17:02
Full	ET302	ADD	10:20	10:20	ET303	ADD	11:35	11:40
Arr	ET304	ADD	12:20	12:20	ET305	ADD	13:44	13:44
Park	ET304	ADD	13:50	13:50	ET305	ADD	15:59	15:59
Dep	ET304	ADD	16:05	16:05	ET305	ADD	17:35	17:35
Full	ET306	ADD	18:15	18:25	ET307	ADD	19:35	19:50
Arr	ET308	ADD	23:40	23:40	ET309	ADD	1:04	1:04
Park	ET308	ADD	1:10	1:10	ET309	ADD	4:24	4:24
Dep	ET308	ADD	4:30	4:30	ET309	ADD	6:00	6:00
Arr	ET308	ADD	23:45	23:45	ET309	ADD	1:09	1:09
Park	ET308	ADD	1:15	1:15	ET309	ADD	4:24	4:24
Dep	ET308	ADD	4:30	4:30	ET309	ADD	6:00	6:00
Full	EY641	AUH	12:47	13:22	EY642	AUH	13:40	13:53
Full	G9734	SHJ	13:06	12:56	G9735	SHJ	13:40	13:45
Full	KL565	AMS	20:25	20:45	KL566	AMS	22:25	22:40
Arr	KQ101	LHR	6:30	6:30	KQ310	DXB	7:54	7:54
Park	KQ101	LHR	8:00	8:00	KQ310	DXB	17:39	17:39
Dep	KQ101	LHR	17:45	17:45	KQ310	DXB	19:15	19:15
Full	KQ117	AMS	6:10	6:10	KQ116	AMS	8:35	8:35
Full	KQ205	BOM	10:30	10:53	KQ704	LUN	12:05	12:05
Full	KQ251	SEZ	18:25	18:33	KQ330	JED	21:30	21:30
Arr	KQ252	HAH	18:25	18:25			19:49	19:49
Park	KQ252	HAH	19:55	19:55			22:23	22:23
Dep	KQ252	HAH	22:29	22:29			23:59	23:59
Arr	KQ257	TNR	20:15	20:10	KQ536	ABV	21:39	21:34
Park	KQ257	TNR	21:45	21:40	KQ536	ABV	6:19	6:19
Dep	KQ257	TNR	6:25	6:25	KQ536	ABV	7:55	7:55
Full	KQ257	TNR	20:15	19:57	KQ708	HRE	23:00	23:00
Arr	KQ311	DXB	6:55	6:55	KQ554	FIH	8:19	8:19
Park	KQ311	DXB	8:25	8:25	KQ554	FIH	10:29	10:36
Dep	KQ311	DXB	10:35	10:42	KQ554	FIH	12:05	12:12
Full	KQ349	KRT	6:35	6:30	KQ402	JIB	8:15	8:15
Full	KQ351	JUB	12:10	11:58	KQ608	MBA	14:15	14:15
Full	KQ353	JUB	18:00	18:10	KQ624	MBA	22:55	22:55
Full	KQ403	ADD	17:30	17:27	KQ416	EBB	19:10	19:10
Full	KQ411	EBB	11:05	11:05	KQ412	EBB	12:00	12:00
Arr	KQ413	EBB	15:05	15:05			16:29	16:29
Park	KQ413	EBB	16:35	16:35			22:23	22:23
Dep	KQ413	EBB	22:29	22:29			23:59	23:59
Full	KQ415	EBB	19:25	19:25	KQ488	DAR	22:55	22:55
Full	KQ417	EBB	22:15	22:09	KQ466	KGL	23:20	23:20
Full	KQ419	EBB	6:35	6:22	KQ432	JRO	8:00	8:00
Arr	KQ433	JRO	10:45	10:45	KQ444	BJM	12:09	12:09
Park	KQ433	JRO	12:15	12:15	KQ444	BJM	14:34	14:34
Dep	KQ433	JRO	14:40	14:40	KQ444	BJM	16:10	16:10
Full	KQ437	JRO	22:00	21:59			23:59	23:59
Arr	KQ444	BJM	21:15	21:15	KQ650	KIS	22:39	22:39
Park	KQ444	BJM	22:45	22:45	KQ650	KIS	5:14	5:14
Dep	KQ444	BJM	5:20	5:20	KQ650	KIS	6:50	6:50
Full	KQ444	BJM	21:15	21:10	KQ498	ZNZ	23:00	23:00
Arr	KQ447	KGL	6:05	6:05	KQ748	APL	7:29	7:29
Park	KQ447	KGL	7:35	7:35	KQ748	APL	10:49	11:01
Dep	KQ447	KGL	10:55	11:07	KQ748	APL	12:25	12:37
Arr	KQ448	BJM	12:50	12:50	KQ486	DAR	14:14	14:14
Park	KQ448	BJM	14:20	14:20	KQ486	DAR	17:14	17:14
Dep	KQ448	BJM	17:20	17:20	KQ486	DAR	18:50	18:50
Full	KQ481	DAR	11:10	11:15	KQ586	NLA	12:30	12:30
Full	KQ483	DAR	15:30	15:30	KQ414	EBB	16:20	16:26
Arr	KQ485	DAR	19:20	19:20	KQ448	BJM	20:44	20:44
Park	KQ485	DAR	20:50	20:50	KQ448	BJM	6:09	7:11
Dep	KQ485	DAR	6:15	7:17	KQ448	BJM	7:45	8:47
Full	KQ485	DAR	19:20	19:21	KQ734	LUN	22:45	22:45
Arr	KQ487	DAR	22:15	22:15	KQ256	TNR	23:39	23:39
Park	KQ487	DAR	23:45	23:45	KQ256	TNR	11:09	11:09
Dep	KQ487	DAR	11:15	11:15	KQ256	TNR	12:45	12:45
Full	KQ487	DAR	22:15	22:15			23:59	23:59
Full	KQ489	DAR	6:40	6:33	KQ494	ZNZ	8:05	8:05
Full	KQ495	ZNZ	11:15	11:15	KQ482	DAR	12:05	12:05
Full	KQ509	ACC	6:10	6:08	KQ760	JNB	8:30	8:30
Full	KQ521	ABJ	6:20	6:20	KQ504	FNA	10:35	10:35
Full	KQ522	NSI	21:40	21:38			23:59	23:59
Arr	KQ524	DLA	18:20	18:20	KQ522	NSI	19:44	19:44
Park	KQ524	DLA	19:50	19:50	KQ522	NSI	9:44	9:44
Dep	KQ524	DLA	9:50	9:50	KQ522	NSI	11:20	11:20
Arr	KQ533	LOS	19:50	19:50	KQ542	COO	21:14	21:14
Park	KQ533	LOS	21:20	21:20	KQ542	COO	6:19	6:19
Dep	KQ533	LOS	6:25	6:25	KQ542	COO	7:55	7:55
Arr	KQ537	ABV	18:25	18:17			19:49	19:41
Park	KQ537	ABV	19:55	19:47			22:23	22:23
Dep	KQ537	ABV	22:29	22:29			23:59	23:59
Full	KQ542	LOS	21:00	21:00			23:59	23:59
Full	KQ555	FIH	20:25	20:24	KQ112	CDG	23:05	23:05
Arr	KQ584	FBM	20:05	20:05	KQ252	HAH	21:29	21:29
Park	KQ584	FBM	21:35	21:35	KQ252	HAH	9:54	10:22
Dep	KQ584	FBM	10:00	10:28	KQ252	HAH	11:30	11:58
Full	KQ586	NLA	20:05	19:54			23:59	23:59
Arr	KQ601	MBA	9:30	9:25			10:54	10:49
Park	KQ601	MBA	11:00	10:55			22:23	22:23
Dep	KQ601	MBA	22:29	22:29			23:59	23:59
Full	KQ603	MBA	11:10	11:10	KQ762	JNB	12:05	12:15
Full	KQ605	MBA	12:55	12:55	KQ352	JUB	13:40	13:40
Full	KQ607	MBA	15:35	15:30	KQ610	MBA	16:25	16:25
Full	KQ609	MBA	16:55	17:05	KQ616	MBA	18:50	18:50
Full	KQ611	MBA	19:05	19:00	KQ618	MBA	19:50	20:03
Arr	KQ617	MBA	21:30	21:30	KQ600	MBA	22:54	22:54
Park	KQ617	MBA	23:00	23:00	KQ600	MBA	5:14	5:14
Dep	KQ617	MBA	5:20	5:20	KQ600	MBA	6:50	6:50
Full	KQ617	MBA	21:30	21:30	KQ418	EBB	22:55	22:55
Arr	KQ619	MBA	22:40	22:05	KQ350	JUB	0:04	23:29
Park	KQ619	MBA	0:10	23:35	KQ350	JUB	6:14	6:14
Dep	KQ619	MBA	6:20	6:20	KQ350	JUB	7:50	7:50
Full	KQ625	MBA	6:15	6:20	KQ640	MYD	8:55	8:55
Full	KQ641	MYD	11:45	11:45	KQ606	MBA	12:55	12:55
Full	KQ651	KIS	9:10	9:03	KQ654	KIS	9:55	9:55
Full	KQ655	KIS	12:15	12:19	KQ656	KIS	13:05	13:05

Inbound					Outbound			
Flight Type	Fl No.	Origin	ETA	ATA	Fl No.	Dest	ETD	ATD
Full	KQ657	KIS	15:25	15:10	KQ670	KIS	17:30	17:45
Arr	KQ671	KIS	19:50	19:50	KQ480	DAR	21:14	21:14
Park	KQ671	KIS	21:20	21:20	KQ480	DAR	6:09	6:09
Dep	KQ671	KIS	6:15	6:15	KQ480	DAR	7:45	7:45
Full	KQ671	KIS	19:50	19:30			23:59	23:59
Arr	KQ704	LUN	20:30	20:30	KQ250	SEZ	21:54	21:54
Park	KQ704	LUN	22:00	22:00	KQ250	SEZ	9:54	9:54
Dep	KQ704	LUN	10:00	10:00	KQ250	SEZ	11:30	11:30
Full	KQ704	LUN	20:30	20:22	KQ764	JNB	21:50	21:58
Full	KQ717	GBE	6:50	6:50	KQ730	LLW	8:15	8:15
Full	KQ720	HRE	6:50	6:40	KQ604	MBA	10:15	10:15
Full	KQ731	LLW	13:30	13:20	KQ484	DAR	15:55	16:10
Full	KQ749	APL	18:05	17:59	KQ436	JRO	19:20	19:20
Arr	KQ752	BLZ	19:45	19:45	KQ410	EBB	21:09	21:09
Park	KQ752	BLZ	21:15	21:15	KQ410	EBB	6:24	7:00
Dep	KQ752	BLZ	6:30	7:06	KQ410	EBB	8:00	8:36
Full	KQ761	JNB	17:40	17:53	KQ204	BOM	21:25	21:42
Full	KQ763	JNB	21:25	21:40	KQ304	DXB	22:30	22:56
Full	KQ765	JNB	6:55	6:55	KQ602	MBA	8:30	8:30
Full	KQ8603	MBA	12:25	12:39	KQ8606	MBA	14:00	14:10
Full	KQ8607	MBA	16:45	16:45	KQ8608	MBA	19:30	19:30
Arr	KQ8609	MBA	22:15	22:15	KQ8602	MBA	23:39	23:39
Park	KQ8609	MBA	23:45	23:45	KQ8602	MBA	8:04	8:04
Dep	KQ8609	MBA	8:10	8:10	KQ8602	MBA	9:40	9:40
Full	KQ8609	MBA	22:15	22:15			23:59	23:59
Full	KQ8651	KIS	8:30	8:40	KQ8690	UKU	9:10	9:10
Arr	KQ8655	KIS	20:00	19:59	KQ8650	KIS	21:24	21:23
Park	KQ8655	KIS	21:30	21:29	KQ8650	KIS	4:54	4:54
Dep	KQ8655	KIS	5:00	5:00	KQ8650	KIS	6:30	6:30
Full	KQ8655	KIS	20:00	19:50			23:59	23:59
Full	KQ8661	EDL	9:00	9:05	KQ8680	LAU	9:40	9:40
Arr	KQ8665	EDL	19:10	19:10	KQ8660	EDL	20:34	20:34
Park	KQ8665	EDL	20:40	20:40	KQ8660	EDL	5:24	5:24
Dep	KQ8665	EDL	5:30	5:30	KQ8660	EDL	7:00	7:00
Full	KQ8665	EDL	19:10	19:18			23:59	23:59
Full	KQ8681	MYD	13:30	13:37	KQ8654	KIS	18:00	18:00
Full	KQ8691	UKU	11:30	11:24	KQ8692	UKU	14:10	14:10
Full	KQ8693	UKU	16:30	16:32	KQ8664	EDL	17:10	17:10
Arr	KQ887	BKK	6:45	6:45	KQ886	BKK	8:09	8:09
Park	KQ887	BKK	8:15	8:15	KQ886	BKK	21:34	21:53
Dep	KQ887	BKK	21:40	21:59	KQ886	BKK	23:10	23:29
Full	LX294	ZRH	18:40	18:45	LX295	DAR	19:35	19:40
Full	MK534	MRU	11:50	12:20	MK535	MRU	13:05	13:31
Full	MS849	CAI	7:10	7:20	MS850	CAI	8:10	8:20
Full	PW715	ZNZ	21:15	21:00			23:59	23:59
Full	PW723	JRO	7:00	6:09	PW722	JRO	8:30	8:40
Arr	PW725	JRO	19:20	19:20	PW710	ZNZ	20:44	20:44
Park	PW725	JRO	20:50	20:50	PW710	ZNZ	6:34	6:34
Dep	PW725	JRO	6:40	6:40	PW710	ZNZ	8:10	8:10
Full	PW725	JRO	19:20	19:15			23:59	23:59
Full	PW727	JRO	16:00	15:50	PW726	JRO	16:50	16:50
Full	QR1337	DOH	9:30	9:35	QR1338	DOH	12:35	12:40
Full	QR1339	DOH	13:10	13:10	QR1340	DOH	17:35	17:40
Full	SA184	JNB	15:15	15:15	SA185	JNB	16:05	16:10
Full	SN463	BRU	21:45	21:45	SN463	BRU	22:45	22:45
Full	SV431	JED	11:32	11:42	SV430	JED	13:10	13:40
Full	TK6510	FIH	18:30	18:11	TK6492	IST	21:00	21:10
Full	TM4462	MPM	14:25	14:20	TM4463	MPM	15:45	15:45
Full	WB402	KGL	15:40	15:39	WB403	KGL	16:30	16:30
Full	WB450	EBB	10:40	10:40	WB450	KGL	11:25	11:30
Full	WB460	KGL	20:15	20:20	WB460	EBB	21:35	21:40
Full			6:50	6:50	KQ210	BOM	7:50	8:06
Full			22:25	22:25	KQ102	LHR	23:25	23:25
Arr	CZ633	CAN	7:00	7:00	CZ634	CAN	8:24	8:24
Park	CZ633	CAN	8:30	8:30	CZ634	CAN	11:59	11:59
Dep	CZ633	CAN	12:05	12:05	CZ634	CAN	13:35	13:35
Full	EK721	DXB	19:00	19:00	EK722	DUB	22:50	22:50
Arr	SA180	JNB	22:40	22:40	SA181	JNB	0:04	0:04
Park	SA180	JNB	0:10	0:10	SA181	JNB	6:54	6:54
Dep	SA180	JNB	7:00	7:00	SA181	JNB	8:30	8:30
Full	TK607	IST	7:25	7:25	TK608	IST	10:35	10:35

Table D.3: Simulation case 3

Inbound					Outbound			
Flight Type	Fl No.	Origin	ETA	ATA	Fl No.	Dest	ETD	ATD
Full	BA065	LHR	20:30	21:00	BA064	LHR	23:15	23:25
Full	EK719	DXB	14:30	14:30	EK720	DUB	16:40	16:40
Full	ET302	ADD	10:20	10:20	ET303	ADD	11:35	11:35
Arr	ET304	ADD	12:20	12:20	ET305	ADD	13:44	13:44
Park	ET304	ADD	13:50	13:50	ET305	ADD	15:59	15:59
Dep	ET304	ADD	16:05	16:05	ET305	ADD	17:35	17:35
Full	ET306	ADD	18:15	18:20	ET307	ADD	19:35	19:40
Arr	ET308	ADD	23:40	23:40	ET309	ADD	1:04	1:04
Park	ET308	ADD	1:10	1:10	ET309	ADD	4:24	4:24
Dep	ET308	ADD	4:30	4:30	ET309	ADD	6:00	6:00
Arr	ET308	ADD	23:45	23:45	ET309	ADD	1:09	1:09
Park	ET308	ADD	1:15	1:15	ET309	ADD	4:24	4:24
Dep	ET308	ADD	4:30	4:30	ET309	ADD	6:00	6:00
Full	EY641	AUH	12:47	12:40	EY642	AUH	13:40	13:40
Full	G9734	SHJ	13:06	13:25	G9735	SHJ	13:40	14:15
Full	KL565	AMS	20:25	20:45	KL566	AMS	22:25	22:35
Arr	KQ101	LHR	6:30	6:30	KQ310	DXB	7:54	7:54
Park	KQ101	LHR	8:00	8:00	KQ310	DXB	17:39	17:39
Dep	KQ101	LHR	17:45	17:45	KQ310	DXB	19:15	19:15
Full	KQ117	AMS	6:10	6:10	KQ116	AMS	8:35	8:35
Full	KQ205	BOM	10:30	11:29	KQ704	LUN	12:05	12:20
Full	KQ251	SEZ	18:25	19:26	KQ330	JED	21:30	21:38
Arr	KQ252	HAH	18:25	18:25			19:49	19:49
Park	KQ252	HAH	19:55	19:55			22:23	22:23
Dep	KQ252	HAH	22:29	22:29			23:59	23:59
Arr	KQ257	TNR	20:15	20:07	KQ536	ABV	21:39	21:31
Park	KQ257	TNR	21:45	21:37	KQ536	ABV	6:19	6:19
Dep	KQ257	TNR	6:25	6:25	KQ536	ABV	7:55	7:55
Full	KQ257	TNR	20:15	20:15	KQ708	HRE	23:00	23:00
Arr	KQ311	DXB	6:55	6:55	KQ554	FIH	8:19	8:19
Park	KQ311	DXB	8:25	8:25	KQ554	FIH	10:29	10:29
Dep	KQ311	DXB	10:35	10:35	KQ554	FIH	12:05	12:05
Full	KQ349	KRT	6:35	6:10	KQ402	JIB	8:15	8:15
Full	KQ351	JUB	12:10	12:05	KQ608	MBA	14:15	14:15
Full	KQ353	JUB	18:00	18:00	KQ624	MBA	22:55	22:55
Full	KQ403	ADD	17:30	17:30	KQ416	EBB	19:10	19:10
Full	KQ411	EBB	11:05	11:14	KQ412	EBB	12:00	12:06
Arr	KQ413	EBB	15:05	15:05			16:29	16:29
Park	KQ413	EBB	16:35	16:35			22:23	22:23
Dep	KQ413	EBB	22:29	22:29			23:59	23:59
Full	KQ415	EBB	19:25	19:35	KQ488	DAR	22:55	22:55
Full	KQ417	EBB	22:15	21:33	KQ466	KGL	23:20	23:57
Full	KQ419	EBB	6:35	6:30	KQ432	JRO	8:00	8:00
Arr	KQ433	JRO	10:45	10:45	KQ444	BJM	12:09	12:09
Park	KQ433	JRO	12:15	12:15	KQ444	BJM	14:34	14:34
Dep	KQ433	JRO	14:40	14:40	KQ444	BJM	16:10	16:10
Full	KQ437	JRO	22:00	22:00			23:59	23:59
Arr	KQ444	BJM	21:15	21:15	KQ650	KIS	22:39	22:39
Park	KQ444	BJM	22:45	22:45	KQ650	KIS	5:14	5:14
Dep	KQ444	BJM	5:20	5:20	KQ650	KIS	6:50	6:50
Full	KQ444	BJM	21:15	21:25	KQ498	ZNZ	23:00	23:00
Arr	KQ447	KGL	6:05	6:05	KQ748	APL	7:29	7:29
Park	KQ447	KGL	7:35	7:35	KQ748	APL	10:49	12:04
Dep	KQ447	KGL	10:55	12:10	KQ748	APL	12:25	13:40
Arr	KQ448	BJM	12:50	12:32	KQ486	DAR	14:14	13:56
Park	KQ448	BJM	14:20	14:02	KQ486	DAR	17:14	18:08
Dep	KQ448	BJM	17:20	18:14	KQ486	DAR	18:50	19:44
Full	KQ481	DAR	11:10	11:08	KQ586	NLA	12:30	12:32
Full	KQ483	DAR	15:30	15:25	KQ414	EBB	16:20	16:25
Arr	KQ485	DAR	19:20	19:20	KQ448	BJM	20:44	20:44
Park	KQ485	DAR	20:50	20:50	KQ448	BJM	6:09	6:09
Dep	KQ485	DAR	6:15	6:15	KQ448	BJM	7:45	7:45
Full	KQ485	DAR	19:20	19:33	KQ734	LUN	22:45	22:45
Arr	KQ487	DAR	22:15	22:13	KQ256	TNR	23:39	23:37
Park	KQ487	DAR	23:45	23:43	KQ256	TNR	11:09	12:19
Dep	KQ487	DAR	11:15	12:25	KQ256	TNR	12:45	13:55
Full	KQ487	DAR	22:15	22:15			23:59	23:59
Full	KQ489	DAR	6:40	6:30	KQ494	ZNZ	8:05	8:05
Full	KQ495	ZNZ	11:15	10:28	KQ482	DAR	12:05	12:12
Full	KQ509	ACC	6:10	6:08	KQ760	JNB	8:30	8:35
Full	KQ521	ABJ	6:20	6:20	KQ504	FNA	10:35	10:35
Full	KQ522	NSI	21:40	21:40			23:59	23:59
Arr	KQ524	DLA	18:20	18:20	KQ522	NSI	19:44	19:44
Park	KQ524	DLA	19:50	19:50	KQ522	NSI	9:44	9:44
Dep	KQ524	DLA	9:50	9:50	KQ522	NSI	11:20	11:20
Arr	KQ533	LOS	19:50	19:50	KQ542	COO	21:14	21:14
Park	KQ533	LOS	21:20	21:20	KQ542	COO	6:19	6:20
Dep	KQ533	LOS	6:25	6:26	KQ542	COO	7:55	7:56
Arr	KQ537	ABV	18:25	18:15			19:49	19:39
Park	KQ537	ABV	19:55	19:45			22:23	22:23
Dep	KQ537	ABV	22:29	22:29			23:59	23:59
Full	KQ542	LOS	21:00	21:00			23:59	23:59
Full	KQ555	FIH	20:25	19:57	KQ112	CDG	23:05	23:25
Arr	KQ584	FBM	20:05	20:05	KQ252	HAH	21:29	21:29
Park	KQ584	FBM	21:35	21:35	KQ252	HAH	9:54	10:49
Dep	KQ584	FBM	10:00	10:55	KQ252	HAH	11:30	12:25
Full	KQ586	NLA	20:05	20:07			23:59	23:59
Arr	KQ601	MBA	9:30	9:30			10:54	10:54
Park	KQ601	MBA	11:00	11:00			22:23	22:23
Dep	KQ601	MBA	22:29	22:29			23:59	23:59
Full	KQ603	MBA	11:10	11:10	KQ762	JNB	12:05	12:05
Full	KQ605	MBA	12:55	12:55	KQ352	JUB	13:40	13:40
Full	KQ607	MBA	15:35	15:40	KQ610	MBA	16:25	16:25
Full	KQ609	MBA	16:55	16:50	KQ616	MBA	18:50	18:54
Full	KQ611	MBA	19:05	19:05	KQ618	MBA	19:50	19:50
Arr	KQ617	MBA	21:30	21:30	KQ600	MBA	22:54	22:54
Park	KQ617	MBA	23:00	23:00	KQ600	MBA	5:14	5:14
Dep	KQ617	MBA	5:20	5:20	KQ600	MBA	6:50	6:50
Full	KQ617	MBA	21:30	21:30	KQ418	EBB	22:55	22:55
Arr	KQ619	MBA	22:40	22:40	KQ350	JUB	0:04	0:04
Park	KQ619	MBA	0:10	0:10	KQ350	JUB	6:14	6:14
Dep	KQ619	MBA	6:20	6:20	KQ350	JUB	7:50	7:50
Full	KQ625	MBA	6:15	6:05	KQ640	MYD	8:55	8:55
Full	KQ641	MYD	11:45	11:40	KQ606	MBA	12:55	12:55
Full	KQ651	KIS	9:10	9:02	KQ654	KIS	9:55	9:55
Full	KQ655	KIS	12:15	12:08	KQ656	KIS	13:05	13:05

Inbound					Outbound			
Flight Type	Fl No.	Origin	ETA	ATA	Fl No.	Dest	ETD	ATD
Full	KQ657	KIS	15:25	15:23	KQ670	KIS	17:30	17:30
Arr	KQ671	KIS	19:50	19:50	KQ480	DAR	21:14	21:14
Park	KQ671	KIS	21:20	21:20	KQ480	DAR	6:09	6:09
Dep	KQ671	KIS	6:15	6:15	KQ480	DAR	7:45	7:45
Full	KQ671	KIS	19:50	19:50			23:59	23:59
Arr	KQ704	LUN	20:30	19:40	KQ250	SEZ	21:54	21:04
Park	KQ704	LUN	22:00	21:10	KQ250	SEZ	9:54	11:22
Dep	KQ704	LUN	10:00	11:28	KQ250	SEZ	11:30	12:58
Full	KQ704	LUN	20:30	21:50	KQ764	JNB	21:50	22:55
Full	KQ717	GBE	6:50	7:45	KQ730	LLW	8:15	8:23
Full	KQ720	HRE	6:50	6:50	KQ604	MBA	10:15	10:15
Full	KQ731	LLW	13:30	13:30	KQ484	DAR	15:55	15:55
Full	KQ749	APL	18:05	18:13	KQ436	JRO	19:20	19:20
Arr	KQ752	BLZ	19:45	18:42	KQ410	EBB	21:09	20:06
Park	KQ752	BLZ	21:15	20:12	KQ410	EBB	6:24	6:24
Dep	KQ752	BLZ	6:30	6:30	KQ410	EBB	8:00	8:00
Full	KQ761	JNB	17:40	17:40	KQ204	BOM	21:25	21:55
Full	KQ763	JNB	21:25	21:30	KQ304	DXB	22:30	22:30
Full	KQ765	JNB	6:55	7:02	KQ602	MBA	8:30	8:30
Full	KQ8603	MBA	12:25	12:16	KQ8606	MBA	14:00	14:00
Full	KQ8607	MBA	16:45	16:40	KQ8608	MBA	19:30	19:30
Arr	KQ8609	MBA	22:15	22:15	KQ8602	MBA	23:39	23:39
Park	KQ8609	MBA	23:45	23:45	KQ8602	MBA	8:04	8:04
Dep	KQ8609	MBA	8:10	8:10	KQ8602	MBA	9:40	9:40
Full	KQ8609	MBA	22:15	22:05			23:59	23:59
Full	KQ8651	KIS	8:30	8:34	KQ8690	UKU	9:10	9:10
Arr	KQ8655	KIS	20:00	20:00	KQ8650	KIS	21:24	21:24
Park	KQ8655	KIS	21:30	21:30	KQ8650	KIS	4:54	4:54
Dep	KQ8655	KIS	5:00	5:00	KQ8650	KIS	6:30	6:30
Full	KQ8655	KIS	20:00	19:54			23:59	23:59
Full	KQ8661	EDL	9:00	9:00	KQ8680	LAU	9:40	9:40
Arr	KQ8665	EDL	19:10	19:10	KQ8660	EDL	20:34	20:34
Park	KQ8665	EDL	20:40	20:40	KQ8660	EDL	5:24	5:24
Dep	KQ8665	EDL	5:30	5:30	KQ8660	EDL	7:00	7:00
Full	KQ8665	EDL	19:10	18:18			23:59	23:59
Full	KQ8681	MYD	13:30	13:25	KQ8654	KIS	18:00	18:00
Full	KQ8691	UKU	11:30	12:55	KQ8692	UKU	14:10	14:10
Full	KQ8693	UKU	16:30	16:29	KQ8664	EDL	17:10	17:10
Arr	KQ887	BKK	6:45	6:45	KQ886	BKK	8:09	8:09
Park	KQ887	BKK	8:15	8:15	KQ886	BKK	21:34	22:08
Dep	KQ887	BKK	21:40	22:14	KQ886	BKK	23:10	23:44
Full	LX294	ZRH	18:40	18:50	LX295	DAR	19:35	19:50
Full	MK534	MRU	11:50	11:43	MK535	MRU	13:05	13:05
Full	MS849	CAI	7:10	7:15	MS850	CAI	8:10	8:10
Full	PW715	ZNZ	21:15	22:20			23:59	23:59
Full	PW723	JRO	7:00	6:05	PW722	JRO	8:30	8:30
Arr	PW725	JRO	19:20	19:15	PW710	ZNZ	20:44	20:39
Park	PW725	JRO	20:50	20:45	PW710	ZNZ	6:34	6:34
Dep	PW725	JRO	6:40	6:40	PW710	ZNZ	8:10	8:10
Full	PW725	JRO	19:20	18:19			23:59	23:59
Full	PW727	JRO	16:00	15:51	PW726	JRO	16:50	16:50
Full	QR1337	DOH	9:30	10:00	QR1338	DOH	12:35	12:45
Full	QR1339	DOH	13:10	13:10	QR1340	DOH	17:35	17:35
Full	SA184	JNB	15:15	15:25	SA185	JNB	16:05	16:20
Full	SN463	BRU	21:45	21:55	SN463	BRU	22:45	22:55
Full	SV431	JED	11:32	11:32	SV430	JED	13:10	13:10
Full	TK6510	FIH	18:30	18:20	TK6492	IST	21:00	21:10
Full	TM4462	MPM	14:25	14:20	TM4463	MPM	15:45	15:45
Full	WB402	KGL	15:40	15:37	WB403	KGL	16:30	16:30
Full	WB450	EBB	10:40	10:40	WB450	KGL	11:25	11:25
Full	WB460	KGL	20:15	20:20	WB460	EBB	21:35	21:35
Full			6:50	6:50	KQ210	BOM	7:50	8:55
Full			22:25	22:25	KQ102	LHR	23:25	23:37
Arr	CZ633	CAN	7:00	7:00	CZ634	CAN	8:24	8:24
Park	CZ633	CAN	8:30	8:30	CZ634	CAN	11:59	12:09
Dep	CZ633	CAN	12:05	12:15	CZ634	CAN	13:35	13:45
Full	EK721	DXB	19:00	19:05	EK722	DUB	22:50	22:50
Arr	SA180	JNB	22:40	22:40	SA181	JNB	0:04	0:04
Park	SA180	JNB	0:10	0:10	SA181	JNB	6:54	6:59
Dep	SA180	JNB	7:00	7:05	SA181	JNB	8:30	8:35
Full	TK607	IST	7:25	7:31	TK608	IST	10:35	10:35

Table D.4: Simulation case 4

Inbound					Outbound			
Flight Type	Fl No.	Origin	ETA	ATA	Fl No.	Dest	ETD	ATD
Full	BA065	LHR	20:30	20:45	BA064	LHR	23:15	23:25
Full	EK719	DXB	14:30	14:40	EK720	DUB	16:40	17:40
Full	ET302	ADD	10:20	10:20	ET303	ADD	11:35	11:40
Arr	ET304	ADD	12:20	12:20	ET305	ADD	13:44	13:44
Park	ET304	ADD	13:50	13:50	ET305	ADD	15:59	16:00
Dep	ET304	ADD	16:05	16:06	ET305	ADD	17:35	17:36
Full	ET306	ADD	18:15	18:20	ET307	ADD	19:35	19:40
Arr	ET308	ADD	23:40	23:40	ET309	ADD	1:04	1:04
Park	ET308	ADD	1:10	1:10	ET309	ADD	4:24	4:29
Dep	ET308	ADD	4:30	4:35	ET309	ADD	6:00	6:05
Arr	ET308	ADD	23:45	23:45	ET309	ADD	1:09	1:09
Park	ET308	ADD	1:15	1:15	ET309	ADD	4:24	4:39
Dep	ET308	ADD	4:30	4:45	ET309	ADD	6:00	6:15
Full	EY641	AUH	12:47	12:37	EY642	AUH	13:40	13:40
Full	G9734	SHJ	13:06	12:16	G9735	SHJ	13:40	13:50
Full	KL565	AMS	20:25	20:55	KL566	AMS	22:25	22:55
Arr	KQ101	LHR	6:30	6:30	KQ310	DXB	7:54	7:54
Park	KQ101	LHR	8:00	8:00	KQ310	DXB	17:39	17:39
Dep	KQ101	LHR	17:45	17:45	KQ310	DXB	19:15	19:15
Full	KQ117	AMS	6:10	6:10	KQ116	AMS	8:35	8:42
Full	KQ205	BOM	10:30	10:29	KQ704	LUN	12:05	12:05
Full	KQ251	SEZ	18:25	18:25	KQ330	JED	21:30	21:30
Arr	KQ252	HAH	18:25	18:25			19:49	19:49
Park	KQ252	HAH	19:55	19:55			22:23	22:23
Dep	KQ252	HAH	22:29	22:29			23:59	23:59
Arr	KQ257	TNR	20:15	19:59	KQ536	ABV	21:39	21:23
Park	KQ257	TNR	21:45	21:29	KQ536	ABV	6:19	6:19
Dep	KQ257	TNR	6:25	6:25	KQ536	ABV	7:55	7:55
Full	KQ257	TNR	20:15	20:07	KQ708	HRE	23:00	23:00
Arr	KQ311	DXB	6:55	6:42	KQ554	FIH	8:19	8:06
Park	KQ311	DXB	8:25	8:12	KQ554	FIH	10:29	11:46
Dep	KQ311	DXB	10:35	11:52	KQ554	FIH	12:05	13:22
Full	KQ349	KRT	6:35	6:35	KQ402	JIB	8:15	8:15
Full	KQ351	JUB	12:10	12:03	KQ608	MBA	14:15	14:15
Full	KQ353	JUB	18:00	17:56	KQ624	MBA	22:55	22:55
Full	KQ403	ADD	17:30	17:25	KQ416	EBB	19:10	19:10
Full	KQ411	EBB	11:05	12:02	KQ412	EBB	12:00	12:48
Arr	KQ413	EBB	15:05	15:05			16:29	16:29
Park	KQ413	EBB	16:35	16:35			22:23	22:23
Dep	KQ413	EBB	22:29	22:29			23:59	23:59
Full	KQ415	EBB	19:25	19:17	KQ488	DAR	22:55	22:55
Full	KQ417	EBB	22:15	21:25	KQ466	KGL	23:20	23:30
Full	KQ419	EBB	6:35	5:29	KQ432	JRO	8:00	8:00
Arr	KQ433	JRO	10:45	10:42	KQ444	BJM	12:09	12:06
Park	KQ433	JRO	12:15	12:12	KQ444	BJM	14:34	14:34
Dep	KQ433	JRO	14:40	14:40	KQ444	BJM	16:10	16:10
Full	KQ437	JRO	22:00	21:04			23:59	23:59
Arr	KQ444	BJM	21:15	21:02	KQ650	KIS	22:39	22:26
Park	KQ444	BJM	22:45	22:32	KQ650	KIS	5:14	5:14
Dep	KQ444	BJM	5:20	5:20	KQ650	KIS	6:50	6:50
Full	KQ444	BJM	21:15	21:10	KQ498	ZNZ	23:00	23:00
Arr	KQ447	KGL	6:05	6:05	KQ748	APL	7:29	7:29
Park	KQ447	KGL	7:35	7:35	KQ748	APL	10:49	10:59
Dep	KQ447	KGL	10:55	11:05	KQ748	APL	12:25	12:35
Arr	KQ448	BJM	12:50	12:36	KQ486	DAR	14:14	14:00
Park	KQ448	BJM	14:20	14:06	KQ486	DAR	17:14	18:35
Dep	KQ448	BJM	17:20	18:41	KQ486	DAR	18:50	20:11
Full	KQ481	DAR	11:10	11:20	KQ586	NLA	12:30	12:30
Full	KQ483	DAR	15:30	15:23	KQ414	EBB	16:20	16:20
Arr	KQ485	DAR	19:20	19:20	KQ448	BJM	20:44	20:44
Park	KQ485	DAR	20:50	20:50	KQ448	BJM	6:09	6:09
Dep	KQ485	DAR	6:15	6:15	KQ448	BJM	7:45	7:45
Full	KQ485	DAR	19:20	19:20	KQ734	LUN	22:45	22:45
Arr	KQ487	DAR	22:15	22:10	KQ256	TNR	23:39	23:34
Park	KQ487	DAR	23:45	23:40	KQ256	TNR	11:09	11:35
Dep	KQ487	DAR	11:15	11:41	KQ256	TNR	12:45	13:11
Full	KQ487	DAR	22:15	22:18			23:59	23:59
Full	KQ489	DAR	6:40	6:27	KQ494	ZNZ	8:05	8:20
Full	KQ495	ZNZ	11:15	11:15	KQ482	DAR	12:05	12:05
Full	KQ509	ACC	6:10	6:08	KQ760	JNB	8:30	8:38
Full	KQ521	ABJ	6:20	6:39	KQ504	FNA	10:35	10:35
Full	KQ522	NSI	21:40	22:00			23:59	23:59
Arr	KQ524	DLA	18:20	18:20	KQ522	NSI	19:44	19:44
Park	KQ524	DLA	19:50	19:50	KQ522	NSI	9:44	9:44
Dep	KQ524	DLA	9:50	9:50	KQ522	NSI	11:20	11:20
Arr	KQ533	LOS	19:50	19:40	KQ542	COO	21:14	21:04
Park	KQ533	LOS	21:20	21:10	KQ542	COO	6:19	6:34
Dep	KQ533	LOS	6:25	6:40	KQ542	COO	7:55	8:10
Arr	KQ537	ABV	18:25	16:57			19:49	18:21
Park	KQ537	ABV	19:55	18:27			22:23	22:23
Dep	KQ537	ABV	22:29	22:29			23:59	23:59
Full	KQ542	LOS	21:00	21:20			23:59	23:59
Full	KQ555	FIH	20:25	20:24	KQ112	CDG	23:05	23:14
Arr	KQ584	FBM	20:05	20:05	KQ252	HAH	21:29	21:29
Park	KQ584	FBM	21:35	21:35	KQ252	HAH	9:54	11:34
Dep	KQ584	FBM	10:00	11:40	KQ252	HAH	11:30	13:10
Full	KQ586	NLA	20:05	19:35			23:59	23:59
Arr	KQ601	MBA	9:30	9:25			10:54	10:49
Park	KQ601	MBA	11:00	10:55			22:23	22:23
Dep	KQ601	MBA	22:29	22:29			23:59	23:59
Full	KQ603	MBA	11:10	11:05	KQ762	JNB	12:05	12:05
Full	KQ605	MBA	12:55	13:00	KQ352	JUB	13:40	13:40
Full	KQ607	MBA	15:35	15:40	KQ610	MBA	16:25	16:30
Full	KQ609	MBA	16:55	16:42	KQ616	MBA	18:50	20:06
Full	KQ611	MBA	19:05	19:05	KQ618	MBA	19:50	19:50
Arr	KQ617	MBA	21:30	21:30	KQ600	MBA	22:54	22:54
Park	KQ617	MBA	23:00	23:00	KQ600	MBA	5:14	5:20
Dep	KQ617	MBA	5:20	5:26	KQ600	MBA	6:50	6:56
Full	KQ617	MBA	21:30	21:30	KQ418	EBB	22:55	22:55
Arr	KQ619	MBA	22:40	22:30	KQ350	JUB	0:04	23:54
Park	KQ619	MBA	0:10	0:00	KQ350	JUB	6:14	7:04
Dep	KQ619	MBA	6:20	7:10	KQ350	JUB	7:50	8:40
Full	KQ625	MBA	6:15	6:20	KQ640	MYD	8:55	8:55
Full	KQ641	MYD	11:45	11:40	KQ606	MBA	12:55	12:55
Full	KQ651	KIS	9:10	9:10	KQ654	KIS	9:55	9:55
Full	KQ655	KIS	12:15	12:00	KQ656	KIS	13:05	13:38

Inbound					Outbound			
Flight Type	Fl No.	Origin	ETA	ATA	Fl No.	Dest	ETD	ATD
Full	KQ657	KIS	15:25	15:17	KQ670	KIS	17:30	17:30
Arr	KQ671	KIS	19:50	19:50	KQ480	DAR	21:14	21:14
Park	KQ671	KIS	21:20	21:20	KQ480	DAR	6:09	6:09
Dep	KQ671	KIS	6:15	6:15	KQ480	DAR	7:45	7:45
Full	KQ671	KIS	19:50	19:05			23:59	23:59
Arr	KQ704	LUN	20:30	20:30	KQ250	SEZ	21:54	21:54
Park	KQ704	LUN	22:00	22:00	KQ250	SEZ	9:54	9:54
Dep	KQ704	LUN	10:00	10:00	KQ250	SEZ	11:30	11:30
Full	KQ704	LUN	20:30	20:29	KQ764	JNB	21:50	21:50
Full	KQ717	GBE	6:50	8:20	KQ730	LLW	8:15	8:50
Full	KQ720	HRE	6:50	6:41	KQ604	MBA	10:15	10:15
Full	KQ731	LLW	13:30	13:30	KQ484	DAR	15:55	15:55
Full	KQ749	APL	18:05	18:15	KQ436	JRO	19:20	19:20
Arr	KQ752	BLZ	19:45	18:41	KQ410	EBB	21:09	20:05
Park	KQ752	BLZ	21:15	20:11	KQ410	EBB	6:24	6:38
Dep	KQ752	BLZ	6:30	6:44	KQ410	EBB	8:00	8:14
Full	KQ761	JNB	17:40	17:49	KQ204	BOM	21:25	21:25
Full	KQ763	JNB	21:25	21:16	KQ304	DXB	22:30	22:49
Full	KQ765	JNB	6:55	7:02	KQ602	MBA	8:30	8:30
Full	KQ8603	MBA	12:25	12:25	KQ8606	MBA	14:00	14:00
Full	KQ8607	MBA	16:45	16:25	KQ8608	MBA	19:30	19:38
Arr	KQ8609	MBA	22:15	22:10	KQ8602	MBA	23:39	23:34
Park	KQ8609	MBA	23:45	23:40	KQ8602	MBA	8:04	8:04
Dep	KQ8609	MBA	8:10	8:10	KQ8602	MBA	9:40	9:40
Full	KQ8609	MBA	22:15	22:29			23:59	23:59
Full	KQ8651	KIS	8:30	8:45	KQ8690	UKU	9:10	9:34
Arr	KQ8655	KIS	20:00	19:58	KQ8650	KIS	21:24	21:22
Park	KQ8655	KIS	21:30	21:28	KQ8650	KIS	4:54	4:54
Dep	KQ8655	KIS	5:00	5:00	KQ8650	KIS	6:30	6:30
Full	KQ8655	KIS	20:00	20:15			23:59	23:59
Full	KQ8661	EDL	9:00	9:05	KQ8680	LAU	9:40	9:40
Arr	KQ8665	EDL	19:10	18:16	KQ8660	EDL	20:34	19:40
Park	KQ8665	EDL	20:40	19:46	KQ8660	EDL	5:24	5:24
Dep	KQ8665	EDL	5:30	5:30	KQ8660	EDL	7:00	7:00
Full	KQ8665	EDL	19:10	19:08			23:59	23:59
Full	KQ8681	MYD	13:30	13:41	KQ8654	KIS	18:00	18:00
Full	KQ8691	UKU	11:30	11:53	KQ8692	UKU	14:10	14:20
Full	KQ8693	UKU	16:30	16:19	KQ8664	EDL	17:10	17:10
Arr	KQ887	BKK	6:45	6:45	KQ886	BKK	8:09	8:09
Park	KQ887	BKK	8:15	8:15	KQ886	BKK	21:34	21:49
Dep	KQ887	BKK	21:40	21:55	KQ886	BKK	23:10	23:25
Full	LX294	ZRH	18:40	18:50	LX295	DAR	19:35	19:50
Full	MK534	MRU	11:50	11:50	MK535	MRU	13:05	13:13
Full	MS849	CAI	7:10	7:15	MS850	CAI	8:10	8:15
Full	PW715	ZNZ	21:15	20:45			23:59	23:59
Full	PW723	JRO	7:00	6:09	PW722	JRO	8:30	8:38
Arr	PW725	JRO	19:20	19:10	PW710	ZNZ	20:44	20:34
Park	PW725	JRO	20:50	20:40	PW710	ZNZ	6:34	6:34
Dep	PW725	JRO	6:40	6:40	PW710	ZNZ	8:10	8:10
Full	PW725	JRO	19:20	19:15			23:59	23:59
Full	PW727	JRO	16:00	15:50	PW726	JRO	16:50	16:50
Full	QR1337	DOH	9:30	9:45	QR1338	DOH	12:35	12:55
Full	QR1339	DOH	13:10	13:20	QR1340	DOH	17:35	17:45
Full	SA184	JNB	15:15	15:30	SA185	JNB	16:05	16:35
Full	SN463	BRU	21:45	21:50	SN463	BRU	22:45	22:45
Full	SV431	JED	11:32	11:37	SV430	JED	13:10	13:15
Full	TK6510	FIH	18:30	18:28	TK6492	IST	21:00	21:00
Full	TM4462	MPM	14:25	14:20	TM4463	MPM	15:45	15:45
Full	WB402	KGL	15:40	15:54	WB403	KGL	16:30	16:30
Full	WB450	EBB	10:40	10:50	WB450	KGL	11:25	11:55
Full	WB460	KGL	20:15	20:30	WB460	EBB	21:35	21:55
Full			6:50	6:50	KQ210	BOM	7:50	7:50
Full			22:25	22:25	KQ102	LHR	23:25	23:25
Arr	CZ633	CAN	7:00	7:00	CZ634	CAN	8:24	8:24
Park	CZ633	CAN	8:30	8:30	CZ634	CAN	11:59	12:09
Dep	CZ633	CAN	12:05	12:15	CZ634	CAN	13:35	13:45
Full	EK721	DXB	19:00	19:10	EK722	DUB	22:50	23:00
Arr	SA180	JNB	22:40	22:40	SA181	JNB	0:04	0:04
Park	SA180	JNB	0:10	0:10	SA181	JNB	6:54	6:54
Dep	SA180	JNB	7:00	7:00	SA181	JNB	8:30	8:30
Full	TK607	IST	7:25	7:25	TK608	IST	10:35	10:35

Table D.5: Simulation case 5

Inbound				Outbound				
Flight Type	Fl No.	Origin	ETA	ATA	Fl No.	Dest	ETD	ATD
Full	BA065	LHR	20:30	20:30	BA064	LHR	23:15	23:15
Full	EK719	DXB	14:30	14:50	EK720	DUB	16:40	17:02
Full	ET302	ADD	10:20	10:50	ET303	ADD	11:35	11:45
Arr	ET304	ADD	12:20	12:20	ET305	ADD	13:44	13:44
Park	ET304	ADD	13:50	13:50	ET305	ADD	15:59	16:12
Dep	ET304	ADD	16:05	16:18	ET305	ADD	17:35	17:48
Full	ET306	ADD	18:15	18:15	ET307	ADD	19:35	19:40
Arr	ET308	ADD	23:40	23:40	ET309	ADD	1:04	1:04
Park	ET308	ADD	1:10	1:10	ET309	ADD	4:24	4:29
Dep	ET308	ADD	4:30	4:35	ET309	ADD	6:00	6:05
Arr	ET308	ADD	23:45	23:45	ET309	ADD	1:09	1:09
Park	ET308	ADD	1:15	1:15	ET309	ADD	4:24	4:54
Dep	ET308	ADD	4:30	5:00	ET309	ADD	6:00	6:30
Full	EY641	AUH	12:47	13:15	EY642	AUH	13:40	14:10
Full	G9734	SHJ	13:06	13:51	G9735	SHJ	13:40	14:50
Full	KL565	AMS	20:25	20:35	KL566	AMS	22:25	22:35
Arr	KQ101	LHR	6:30	6:30	KQ310	DXB	7:54	7:54
Park	KQ101	LHR	8:00	8:00	KQ310	DXB	17:39	17:50
Dep	KQ101	LHR	17:45	17:56	KQ310	DXB	19:15	19:26
Full	KQ117	AMS	6:10	6:37	KQ116	AMS	8:35	8:46
Full	KQ205	BOM	10:30	10:43	KQ704	LUN	12:05	12:05
Full	KQ251	SEZ	18:25	19:20	KQ330	JED	21:30	21:38
Arr	KQ252	HAH	18:25	18:25			19:49	19:49
Park	KQ252	HAH	19:55	19:55			22:23	22:23
Dep	KQ252	HAH	22:29	22:29			23:59	23:59
Arr	KQ257	TNR	20:15	20:15	KQ536	ABV	21:39	21:39
Park	KQ257	TNR	21:45	21:45	KQ536	ABV	6:19	7:14
Dep	KQ257	TNR	6:25	7:20	KQ536	ABV	7:55	8:50
Full	KQ257	TNR	20:15	21:03	KQ708	HRE	23:00	23:00
Arr	KQ311	DXB	6:55	6:55	KQ554	FIH	8:19	8:19
Park	KQ311	DXB	8:25	8:25	KQ554	FIH	10:29	10:29
Dep	KQ311	DXB	10:35	10:35	KQ554	FIH	12:05	12:05
Full	KQ349	KRT	6:35	6:45	KQ402	JIB	8:15	8:15
Full	KQ351	JUB	12:10	11:50	KQ608	MBA	14:15	14:31
Full	KQ353	JUB	18:00	17:48	KQ624	MBA	22:55	22:55
Full	KQ403	ADD	17:30	17:31	KQ416	EBB	19:10	19:20
Full	KQ411	EBB	11:05	11:05	KQ412	EBB	12:00	12:12
Arr	KQ413	EBB	15:05	15:05			16:29	16:29
Park	KQ413	EBB	16:35	16:35			22:23	22:23
Dep	KQ413	EBB	22:29	22:29			23:59	23:59
Full	KQ415	EBB	19:25	19:45	KQ488	DAR	22:55	23:52
Full	KQ417	EBB	22:15	21:26	KQ466	KGL	23:20	23:30
Full	KQ419	EBB	6:35	6:21	KQ432	JRO	8:00	8:00
Arr	KQ433	JRO	10:45	10:45	KQ444	BJM	12:09	12:09
Park	KQ433	JRO	12:15	12:15	KQ444	BJM	14:34	14:34
Dep	KQ433	JRO	14:40	14:40	KQ444	BJM	16:10	16:10
Full	KQ437	JRO	22:00	22:03			23:59	23:59
Arr	KQ444	BJM	21:15	21:15	KQ650	KIS	22:39	22:39
Park	KQ444	BJM	22:45	22:45	KQ650	KIS	5:14	5:19
Dep	KQ444	BJM	5:20	5:25	KQ650	KIS	6:50	6:55
Full	KQ444	BJM	21:15	21:04	KQ498	ZNZ	23:00	23:00
Arr	KQ447	KGL	6:05	6:01	KQ748	APL	7:29	7:25
Park	KQ447	KGL	7:35	7:31	KQ748	APL	10:49	11:06
Dep	KQ447	KGL	10:55	11:12	KQ748	APL	12:25	12:42
Arr	KQ448	BJM	12:50	12:50	KQ486	DAR	14:14	14:14
Park	KQ448	BJM	14:20	14:20	KQ486	DAR	17:14	18:04
Dep	KQ448	BJM	17:20	18:10	KQ486	DAR	18:50	19:40
Full	KQ481	DAR	11:10	12:05	KQ586	NLA	12:30	13:20
Full	KQ483	DAR	15:30	15:45	KQ414	EBB	16:20	16:58
Arr	KQ485	DAR	19:20	19:20	KQ448	BJM	20:44	20:44
Park	KQ485	DAR	20:50	20:50	KQ448	BJM	6:09	6:09
Dep	KQ485	DAR	6:15	6:15	KQ448	BJM	7:45	7:45
Full	KQ485	DAR	19:20	18:34	KQ734	LUN	22:45	23:50
Arr	KQ487	DAR	22:15	22:15	KQ256	TNR	23:39	23:39
Park	KQ487	DAR	23:45	23:45	KQ256	TNR	11:09	12:22
Dep	KQ487	DAR	11:15	12:28	KQ256	TNR	12:45	13:58
Full	KQ487	DAR	22:15	21:57			23:59	23:59
Full	KQ489	DAR	6:40	6:34	KQ494	ZNZ	8:05	8:05
Full	KQ495	ZNZ	11:15	10:31	KQ482	DAR	12:05	12:17
Full	KQ509	ACC	6:10	6:08	KQ760	JNB	8:30	8:40
Full	KQ521	ABJ	6:20	6:39	KQ504	FNA	10:35	10:47
Full	KQ522	NSI	21:40	22:37			23:59	23:59
Arr	KQ524	DLA	18:20	18:20	KQ522	NSI	19:44	19:44
Park	KQ524	DLA	19:50	19:50	KQ522	NSI	9:44	9:54
Dep	KQ524	DLA	9:50	10:00	KQ522	NSI	11:20	11:30
Arr	KQ533	LOS	19:50	19:45	KQ542	COO	21:14	21:09
Park	KQ533	LOS	21:20	21:15	KQ542	COO	6:19	7:24
Dep	KQ533	LOS	6:25	7:30	KQ542	COO	7:55	9:00
Arr	KQ537	ABV	18:25	17:42			19:49	19:06
Park	KQ537	ABV	19:55	19:12			22:23	22:23
Dep	KQ537	ABV	22:29	22:29			23:59	23:59
Full	KQ542	LOS	21:00	21:22			23:59	23:59
Full	KQ555	FIH	20:25	19:52	KQ112	CDG	23:05	23:22
Arr	KQ584	FBM	20:05	20:05	KQ252	HAH	21:29	21:29
Park	KQ584	FBM	21:35	21:35	KQ252	HAH	9:54	9:54
Dep	KQ584	FBM	10:00	10:00	KQ252	HAH	11:30	11:30
Full	KQ586	NLA	20:05	20:00			23:59	23:59
Arr	KQ601	MBA	9:30	9:20			10:54	10:44
Park	KQ601	MBA	11:00	10:50			22:23	22:23
Dep	KQ601	MBA	22:29	22:29			23:59	23:59
Full	KQ603	MBA	11:10	11:00	KQ762	JNB	12:05	12:22
Full	KQ605	MBA	12:55	12:40	KQ352	JUB	13:40	13:58
Full	KQ607	MBA	15:35	15:35	KQ610	MBA	16:25	16:25
Full	KQ609	MBA	16:55	16:50	KQ616	MBA	18:50	18:50
Full	KQ611	MBA	19:05	19:15	KQ618	MBA	19:50	20:38
Arr	KQ617	MBA	21:30	21:20	KQ600	MBA	22:54	22:44
Park	KQ617	MBA	23:00	22:50	KQ600	MBA	5:14	5:24
Dep	KQ617	MBA	5:20	5:30	KQ600	MBA	6:50	7:00
Full	KQ617	MBA	21:30	21:40	KQ418	EBB	22:55	23:44
Arr	KQ619	MBA	22:40	22:40	KQ350	JUB	0:04	0:04
Park	KQ619	MBA	0:10	0:10	KQ350	JUB	6:14	6:14
Dep	KQ619	MBA	6:20	6:20	KQ350	JUB	7:50	7:50
Full	KQ625	MBA	6:15	6:10	KQ640	MYD	8:55	8:55
Full	KQ641	MYD	11:45	11:25	KQ606	MBA	12:55	13:25
Full	KQ651	KIS	9:10	8:58	KQ654	KIS	9:55	10:32
Full	KQ655	KIS	12:15	12:07	KQ656	KIS	13:05	13:05

Inbound					Outbound			
Flight Type	Fl No.	Origin	ETA	ATA	Fl No.	Dest	ETD	ATD
Full	KQ657	KIS	15:25	15:13	KQ670	KIS	17:30	17:39
Arr	KQ671	KIS	19:50	19:08	KQ480	DAR	21:14	20:32
Park	KQ671	KIS	21:20	20:38	KQ480	DAR	6:09	6:09
Dep	KQ671	KIS	6:15	6:15	KQ480	DAR	7:45	7:45
Full	KQ671	KIS	19:50	19:01			23:59	23:59
Arr	KQ704	LUN	20:30	20:29	KQ250	SEZ	21:54	21:53
Park	KQ704	LUN	22:00	21:59	KQ250	SEZ	9:54	11:24
Dep	KQ704	LUN	10:00	11:30	KQ250	SEZ	11:30	13:00
Full	KQ704	LUN	20:30	20:48	KQ764	JNB	21:50	21:50
Full	KQ717	GBE	6:50	6:50	KQ730	LLW	8:15	8:15
Full	KQ720	HRE	6:50	7:14	KQ604	MBA	10:15	10:42
Full	KQ731	LLW	13:30	13:30	KQ484	DAR	15:55	15:55
Full	KQ749	APL	18:05	17:48	KQ436	JRO	19:20	19:49
Arr	KQ752	BLZ	19:45	19:45	KQ410	EBB	21:09	21:09
Park	KQ752	BLZ	21:15	21:15	KQ410	EBB	6:24	6:34
Dep	KQ752	BLZ	6:30	6:40	KQ410	EBB	8:00	8:10
Full	KQ761	JNB	17:40	17:43	KQ204	BOM	21:25	21:30
Full	KQ763	JNB	21:25	22:28	KQ304	DXB	22:30	22:58
Full	KQ765	JNB	6:55	7:17	KQ602	MBA	8:30	8:40
Full	KQ8603	MBA	12:25	12:20	KQ8606	MBA	14:00	14:00
Full	KQ8607	MBA	16:45	16:55	KQ8608	MBA	19:30	20:25
Arr	KQ8609	MBA	22:15	22:05	KQ8602	MBA	23:39	23:29
Park	KQ8609	MBA	23:45	23:35	KQ8602	MBA	8:04	8:04
Dep	KQ8609	MBA	8:10	8:10	KQ8602	MBA	9:40	9:40
Full	KQ8609	MBA	22:15	22:23			23:59	23:59
Full	KQ8651	KIS	8:30	8:44	KQ8690	UKU	9:10	9:34
Arr	KQ8655	KIS	20:00	19:59	KQ8650	KIS	21:24	21:23
Park	KQ8655	KIS	21:30	21:29	KQ8650	KIS	4:54	4:54
Dep	KQ8655	KIS	5:00	5:00	KQ8650	KIS	6:30	6:30
Full	KQ8655	KIS	20:00	19:05			23:59	23:59
Full	KQ8661	EDL	9:00	8:56	KQ8680	LAU	9:40	9:40
Arr	KQ8665	EDL	19:10	19:08	KQ8660	EDL	20:34	20:32
Park	KQ8665	EDL	20:40	20:38	KQ8660	EDL	5:24	5:43
Dep	KQ8665	EDL	5:30	5:49	KQ8660	EDL	7:00	7:19
Full	KQ8665	EDL	19:10	19:20			23:59	23:59
Full	KQ8681	MYD	13:30	13:30	KQ8654	KIS	18:00	18:00
Full	KQ8691	UKU	11:30	11:10	KQ8692	UKU	14:10	14:20
Full	KQ8693	UKU	16:30	16:34	KQ8664	EDL	17:10	17:10
Arr	KQ887	BKK	6:45	6:34	KQ886	BKK	8:09	7:58
Park	KQ887	BKK	8:15	8:04	KQ886	BKK	21:34	21:34
Dep	KQ887	BKK	21:40	21:40	KQ886	BKK	23:10	23:10
Full	LX294	ZRH	18:40	18:50	LX295	DAR	19:35	19:45
Full	MK534	MRU	11:50	12:04	MK535	MRU	13:05	13:29
Full	MS849	CAI	7:10	7:20	MS850	CAI	8:10	8:25
Full	PW715	ZNZ	21:15	21:11			23:59	23:59
Full	PW723	JRO	7:00	7:00	PW722	JRO	8:30	8:30
Arr	PW725	JRO	19:20	19:20	PW710	ZNZ	20:44	20:44
Park	PW725	JRO	20:50	20:50	PW710	ZNZ	6:34	6:52
Dep	PW725	JRO	6:40	6:58	PW710	ZNZ	8:10	8:28
Full	PW725	JRO	19:20	18:15			23:59	23:59
Full	PW727	JRO	16:00	16:00	PW726	JRO	16:50	16:50
Full	QR1337	DOH	9:30	9:35	QR1338	DOH	12:35	12:40
Full	QR1339	DOH	13:10	13:20	QR1340	DOH	17:35	18:05
Full	SA184	JNB	15:15	15:20	SA185	JNB	16:05	16:10
Full	SN463	BRU	21:45	21:45	SN463	BRU	22:45	22:50
Full	SV431	JED	11:32	11:52	SV430	JED	13:10	13:40
Full	TK6510	FIH	18:30	18:27	TK6492	IST	21:00	21:00
Full	TM4462	MPM	14:25	14:24	TM4463	MPM	15:45	15:45
Full	WB402	KGL	15:40	15:10	WB403	KGL	16:30	16:30
Full	WB450	EBB	10:40	10:40	WB450	KGL	11:25	11:30
Full	WB460	KGL	20:15	20:25	WB460	EBB	21:35	22:05
Full			6:50	6:50	KQ210	BOM	7:50	8:04
Full			22:25	22:25	KQ102	LHR	23:25	23:33
Arr	CZ633	CAN	7:00	7:00	CZ634	CAN	8:24	8:24
Park	CZ633	CAN	8:30	8:30	CZ634	CAN	11:59	12:09
Dep	CZ633	CAN	12:05	12:15	CZ634	CAN	13:35	13:45
Full	EK721	DXB	19:00	19:00	EK722	DUB	22:50	22:50
Arr	SA180	JNB	22:40	22:40	SA181	JNB	0:04	0:04
Park	SA180	JNB	0:10	0:10	SA181	JNB	6:54	6:54
Dep	SA180	JNB	7:00	7:00	SA181	JNB	8:30	8:30
Full	TK607	IST	7:25	7:20	TK608	IST	10:35	10:35

Table D.6: Simulation case 6

Inbound					Outbound			
Flight Type	Fl No.	Origin	ETA	ATA	Fl No.	Dest	ETD	ATD
Full	BA065	LHR	20:30	20:35	BA064	LHR	23:15	23:20
Full	EK719	DXB	14:30	15:00	EK720	DUB	16:40	17:30
Full	ET302	ADD	10:20	10:40	ET303	ADD	11:35	12:05
Arr	ET304	ADD	12:20	12:20	ET305	ADD	13:44	13:44
Park	ET304	ADD	13:50	13:50	ET305	ADD	15:59	16:31
Dep	ET304	ADD	16:05	16:37	ET305	ADD	17:35	18:07
Full	ET306	ADD	18:15	18:25	ET307	ADD	19:35	19:45
Arr	ET308	ADD	23:40	23:40	ET309	ADD	1:04	1:04
Park	ET308	ADD	1:10	1:10	ET309	ADD	4:24	4:24
Dep	ET308	ADD	4:30	4:30	ET309	ADD	6:00	6:00
Arr	ET308	ADD	23:45	23:45	ET309	ADD	1:09	1:09
Park	ET308	ADD	1:15	1:15	ET309	ADD	4:24	4:34
Dep	ET308	ADD	4:30	4:40	ET309	ADD	6:00	6:10
Full	EY641	AUH	12:47	12:47	EY642	AUH	13:40	13:40
Full	G9734	SHJ	13:06	13:03	G9735	SHJ	13:40	13:40
Full	KL565	AMS	20:25	20:35	KL566	AMS	22:25	22:35
Arr	KQ101	LHR	6:30	6:30	KQ310	DXB	7:54	7:54
Park	KQ101	LHR	8:00	8:00	KQ310	DXB	17:39	18:16
Dep	KQ101	LHR	17:45	18:22	KQ310	DXB	19:15	19:52
Full	KQ117	AMS	6:10	6:19	KQ116	AMS	8:35	9:14
Full	KQ205	BOM	10:30	10:37	KQ704	LUN	12:05	12:05
Full	KQ251	SEZ	18:25	19:31	KQ330	JED	21:30	21:50
Arr	KQ252	HAH	18:25	18:10			19:49	19:34
Park	KQ252	HAH	19:55	19:40			22:23	22:23
Dep	KQ252	HAH	22:29	22:29			23:59	23:59
Arr	KQ257	TNR	20:15	20:15	KQ536	ABV	21:39	21:39
Park	KQ257	TNR	21:45	21:45	KQ536	ABV	6:19	6:19
Dep	KQ257	TNR	6:25	6:25	KQ536	ABV	7:55	7:55
Full	KQ257	TNR	20:15	20:32	KQ708	HRE	23:00	23:00
Arr	KQ311	DXB	6:55	6:55	KQ554	FIH	8:19	8:19
Park	KQ311	DXB	8:25	8:25	KQ554	FIH	10:29	10:29
Dep	KQ311	DXB	10:35	10:35	KQ554	FIH	12:05	12:05
Full	KQ349	KRT	6:35	6:25	KQ402	JIB	8:15	8:15
Full	KQ351	JUB	12:10	12:27	KQ608	MBA	14:15	14:31
Full	KQ353	JUB	18:00	17:45	KQ624	MBA	22:55	23:52
Full	KQ403	ADD	17:30	16:16	KQ416	EBB	19:10	20:10
Full	KQ411	EBB	11:05	10:16	KQ412	EBB	12:00	12:23
Arr	KQ413	EBB	15:05	15:05			16:29	16:29
Park	KQ413	EBB	16:35	16:35			22:23	22:23
Dep	KQ413	EBB	22:29	22:29			23:59	23:59
Full	KQ415	EBB	19:25	20:05	KQ488	DAR	22:55	23:52
Full	KQ417	EBB	22:15	21:12	KQ466	KGL	23:20	23:31
Full	KQ419	EBB	6:35	5:27	KQ432	JRO	8:00	8:09
Arr	KQ433	JRO	10:45	10:33	KQ444	BJM	12:09	11:57
Park	KQ433	JRO	12:15	12:03	KQ444	BJM	14:34	15:04
Dep	KQ433	JRO	14:40	15:10	KQ444	BJM	16:10	16:40
Full	KQ437	JRO	22:00	21:10			23:59	23:59
Arr	KQ444	BJM	21:15	20:51	KQ650	KIS	22:39	22:15
Park	KQ444	BJM	22:45	22:21	KQ650	KIS	5:14	5:19
Dep	KQ444	BJM	5:20	5:25	KQ650	KIS	6:50	6:55
Full	KQ444	BJM	21:15	20:16	KQ498	ZNZ	23:00	23:16
Arr	KQ447	KGL	6:05	6:01	KQ748	APL	7:29	7:25
Park	KQ447	KGL	7:35	7:31	KQ748	APL	10:49	11:45
Dep	KQ447	KGL	10:55	11:51	KQ748	APL	12:25	13:21
Arr	KQ448	BJM	12:50	12:50	KQ486	DAR	14:14	14:14
Park	KQ448	BJM	14:20	14:20	KQ486	DAR	17:14	18:22
Dep	KQ448	BJM	17:20	18:28	KQ486	DAR	18:50	19:58
Full	KQ481	DAR	11:10	12:16	KQ586	NLA	12:30	13:31
Full	KQ483	DAR	15:30	15:27	KQ414	EBB	16:20	16:20
Arr	KQ485	DAR	19:20	18:34	KQ448	BJM	20:44	19:58
Park	KQ485	DAR	20:50	20:04	KQ448	BJM	6:09	6:09
Dep	KQ485	DAR	6:15	6:15	KQ448	BJM	7:45	7:45
Full	KQ485	DAR	19:20	19:34	KQ734	LUN	22:45	22:45
Arr	KQ487	DAR	22:15	21:59	KQ256	TNR	23:39	23:23
Park	KQ487	DAR	23:45	23:29	KQ256	TNR	11:09	12:11
Dep	KQ487	DAR	11:15	12:17	KQ256	TNR	12:45	13:47
Full	KQ487	DAR	22:15	22:00			23:59	23:59
Full	KQ489	DAR	6:40	6:24	KQ494	ZNZ	8:05	8:12
Full	KQ495	ZNZ	11:15	11:15	KQ482	DAR	12:05	12:05
Full	KQ509	ACC	6:10	6:08	KQ760	JNB	8:30	8:30
Full	KQ521	ABJ	6:20	6:09	KQ504	FNA	10:35	10:35
Full	KQ522	NSI	21:40	22:10			23:59	23:59
Arr	KQ524	DLA	18:20	18:20	KQ522	NSI	19:44	19:44
Park	KQ524	DLA	19:50	19:50	KQ522	NSI	9:44	10:09
Dep	KQ524	DLA	9:50	10:15	KQ522	NSI	11:20	11:45
Arr	KQ533	LOS	19:50	19:50	KQ542	COO	21:14	21:14
Park	KQ533	LOS	21:20	21:20	KQ542	COO	6:19	7:07
Dep	KQ533	LOS	6:25	7:13	KQ542	COO	7:55	8:43
Arr	KQ537	ABV	18:25	18:25			19:49	19:49
Park	KQ537	ABV	19:55	19:55			22:23	22:23
Dep	KQ537	ABV	22:29	22:29			23:59	23:59
Full	KQ542	LOS	21:00	21:54			23:59	23:59
Full	KQ555	FIH	20:25	20:07	KQ112	CDG	23:05	23:30
Arr	KQ584	FBM	20:05	20:05	KQ252	HAH	21:29	21:29
Park	KQ584	FBM	21:35	21:35	KQ252	HAH	9:54	10:49
Dep	KQ584	FBM	10:00	10:55	KQ252	HAH	11:30	12:25
Full	KQ586	NLA	20:05	19:40			23:59	23:59
Arr	KQ601	MBA	9:30	9:20			10:54	10:44
Park	KQ601	MBA	11:00	10:50			22:23	22:23
Dep	KQ601	MBA	22:29	22:29			23:59	23:59
Full	KQ603	MBA	11:10	11:10	KQ762	JNB	12:05	12:18
Full	KQ605	MBA	12:55	12:40	KQ352	JUB	13:40	15:08
Full	KQ607	MBA	15:35	15:40	KQ610	MBA	16:25	16:25
Full	KQ609	MBA	16:55	17:15	KQ616	MBA	18:50	19:44
Full	KQ611	MBA	19:05	19:15	KQ618	MBA	19:50	20:53
Arr	KQ617	MBA	21:30	20:45	KQ600	MBA	22:54	22:09
Park	KQ617	MBA	23:00	22:15	KQ600	MBA	5:14	6:05
Dep	KQ617	MBA	5:20	6:11	KQ600	MBA	6:50	7:41
Full	KQ617	MBA	21:30	21:35	KQ418	EBB	22:55	22:55
Arr	KQ619	MBA	22:40	22:25	KQ350	JUB	0:04	23:49
Park	KQ619	MBA	0:10	23:55	KQ350	JUB	6:14	6:14
Dep	KQ619	MBA	6:20	6:20	KQ350	JUB	7:50	7:50
Full	KQ625	MBA	6:15	6:10	KQ640	MYD	8:55	8:55
Full	KQ641	MYD	11:45	11:29	KQ606	MBA	12:55	13:25
Full	KQ651	KIS	9:10	8:57	KQ654	KIS	9:55	10:58
Full	KQ655	KIS	12:15	12:09	KQ656	KIS	13:05	13:05

Inbound					Outbound			
Flight Type	Fl No.	Origin	ETA	ATA	Fl No.	Dest	ETD	ATD
Full	KQ657	KIS	15:25	15:19	KQ670	KIS	17:30	17:30
Arr	KQ671	KIS	19:50	19:05	KQ480	DAR	21:14	20:29
Park	KQ671	KIS	21:20	20:35	KQ480	DAR	6:09	6:09
Dep	KQ671	KIS	6:15	6:15	KQ480	DAR	7:45	7:45
Full	KQ671	KIS	19:50	20:14			23:59	23:59
Arr	KQ704	LUN	20:30	20:30	KQ250	SEZ	21:54	21:54
Park	KQ704	LUN	22:00	22:00	KQ250	SEZ	9:54	9:54
Dep	KQ704	LUN	10:00	10:00	KQ250	SEZ	11:30	11:30
Full	KQ704	LUN	20:30	20:19	KQ764	JNB	21:50	21:58
Full	KQ717	GBE	6:50	7:20	KQ730	LLW	8:15	8:44
Full	KQ720	HRE	6:50	7:48	KQ604	MBA	10:15	10:15
Full	KQ731	LLW	13:30	13:16	KQ484	DAR	15:55	16:04
Full	KQ749	APL	18:05	18:19	KQ436	JRO	19:20	20:05
Arr	KQ752	BLZ	19:45	19:45	KQ410	EBB	21:09	21:09
Park	KQ752	BLZ	21:15	21:15	KQ410	EBB	6:24	6:39
Dep	KQ752	BLZ	6:30	6:45	KQ410	EBB	8:00	8:15
Full	KQ761	JNB	17:40	18:01	KQ204	BOM	21:25	22:00
Full	KQ763	JNB	21:25	21:20	KQ304	DXB	22:30	22:49
Full	KQ765	JNB	6:55	6:39	KQ602	MBA	8:30	8:45
Full	KQ8603	MBA	12:25	12:20	KQ8606	MBA	14:00	14:00
Full	KQ8607	MBA	16:45	16:30	KQ8608	MBA	19:30	19:40
Arr	KQ8609	MBA	22:15	22:05	KQ8602	MBA	23:39	23:29
Park	KQ8609	MBA	23:45	23:35	KQ8602	MBA	8:04	8:04
Dep	KQ8609	MBA	8:10	8:10	KQ8602	MBA	9:40	9:40
Full	KQ8609	MBA	22:15	22:35			23:59	23:59
Full	KQ8651	KIS	8:30	7:37	KQ8690	UKU	9:10	9:34
Arr	KQ8655	KIS	20:00	19:54	KQ8650	KIS	21:24	21:18
Park	KQ8655	KIS	21:30	21:24	KQ8650	KIS	4:54	5:09
Dep	KQ8655	KIS	5:00	5:15	KQ8650	KIS	6:30	6:45
Full	KQ8655	KIS	20:00	20:13			23:59	23:59
Full	KQ8661	EDL	9:00	8:50	KQ8680	LAU	9:40	10:07
Arr	KQ8665	EDL	19:10	18:55	KQ8660	EDL	20:34	20:19
Park	KQ8665	EDL	20:40	20:25	KQ8660	EDL	5:24	5:24
Dep	KQ8665	EDL	5:30	5:30	KQ8660	EDL	7:00	7:00
Full	KQ8665	EDL	19:10	18:55			23:59	23:59
Full	KQ8681	MYD	13:30	13:42	KQ8654	KIS	18:00	18:13
Full	KQ8691	UKU	11:30	11:45	KQ8692	UKU	14:10	14:10
Full	KQ8693	UKU	16:30	15:48	KQ8664	EDL	17:10	17:38
Arr	KQ887	BKK	6:45	6:39	KQ886	BKK	8:09	8:03
Park	KQ887	BKK	8:15	8:09	KQ886	BKK	21:34	21:34
Dep	KQ887	BKK	21:40	21:40	KQ886	BKK	23:10	23:10
Full	LX294	ZRH	18:40	18:50	LX295	DAR	19:35	19:45
Full	MK534	MRU	11:50	11:43	MK535	MRU	13:05	13:13
Full	MS849	CAI	7:10	7:10	MS850	CAI	8:10	8:10
Full	PW715	ZNZ	21:15	20:55			23:59	23:59
Full	PW723	JRO	7:00	6:17	PW722	JRO	8:30	8:42
Arr	PW725	JRO	19:20	19:15	PW710	ZNZ	20:44	20:39
Park	PW725	JRO	20:50	20:45	PW710	ZNZ	6:34	6:34
Dep	PW725	JRO	6:40	6:40	PW710	ZNZ	8:10	8:10
Full	PW725	JRO	19:20	18:10			23:59	23:59
Full	PW727	JRO	16:00	14:54	PW726	JRO	16:50	16:50
Full	QR1337	DOH	9:30	9:50	QR1338	DOH	12:35	12:45
Full	QR1339	DOH	13:10	13:15	QR1340	DOH	17:35	17:35
Full	SA184	JNB	15:15	15:25	SA185	JNB	16:05	16:20
Full	SN463	BRU	21:45	22:15	SN463	BRU	22:45	22:55
Full	SV431	JED	11:32	11:52	SV430	JED	13:10	13:25
Full	TK6510	FIH	18:30	18:30	TK6492	IST	21:00	21:05
Full	TM4462	MPM	14:25	14:37	TM4463	MPM	15:45	15:57
Full	WB402	KGL	15:40	15:40	WB403	KGL	16:30	16:30
Full	WB450	EBB	10:40	10:50	WB450	KGL	11:25	11:35
Full	WB460	KGL	20:15	20:25	WB460	EBB	21:35	21:45
Full			6:50	6:50	KQ210	BOM	7:50	8:50
Full			22:25	22:25	KQ102	LHR	23:25	23:46
Arr	CZ633	CAN	7:00	7:00	CZ634	CAN	8:24	8:24
Park	CZ633	CAN	8:30	8:30	CZ634	CAN	11:59	12:04
Dep	CZ633	CAN	12:05	12:10	CZ634	CAN	13:35	13:40
Full	EK721	DXB	19:00	19:15	EK722	DUB	22:50	22:50
Arr	SA180	JNB	22:40	22:40	SA181	JNB	0:04	0:04
Park	SA180	JNB	0:10	0:10	SA181	JNB	6:54	6:54
Dep	SA180	JNB	7:00	7:00	SA181	JNB	8:30	8:30
Full	TK607	IST	7:25	7:15	TK608	IST	10:35	10:42

Table D.7: Simulation case 7

Inbound					Outbound			
Flight Type	Fl No.	Origin	ETA	ATA	Fl No.	Dest	ETD	ATD
Full	BA065	LHR	20:30	20:40	BA064	LHR	23:15	23:30
Full	EK719	DXB	14:30	14:40	EK720	DUB	16:40	16:53
Full	ET302	ADD	10:20	10:20	ET303	ADD	11:35	11:40
Arr	ET304	ADD	12:20	12:20	ET305	ADD	13:44	13:44
Park	ET304	ADD	13:50	13:50	ET305	ADD	15:59	16:33
Dep	ET304	ADD	16:05	16:39	ET305	ADD	17:35	18:09
Full	ET306	ADD	18:15	18:20	ET307	ADD	19:35	19:40
Arr	ET308	ADD	23:40	23:40	ET309	ADD	1:04	1:04
Park	ET308	ADD	1:10	1:10	ET309	ADD	4:24	4:44
Dep	ET308	ADD	4:30	4:50	ET309	ADD	6:00	6:20
Arr	ET308	ADD	23:45	23:45	ET309	ADD	1:09	1:09
Park	ET308	ADD	1:15	1:15	ET309	ADD	4:24	4:39
Dep	ET308	ADD	4:30	4:45	ET309	ADD	6:00	6:15
Full	EY641	AUH	12:47	12:36	EY642	AUH	13:40	13:50
Full	G9734	SHJ	13:06	14:36	G9735	SHJ	13:40	15:00
Full	KL565	AMS	20:25	20:30	KL566	AMS	22:25	22:25
Arr	KQ101	LHR	6:30	5:45	KQ310	DXB	7:54	7:09
Park	KQ101	LHR	8:00	7:15	KQ310	DXB	17:39	17:51
Dep	KQ101	LHR	17:45	17:57	KQ310	DXB	19:15	19:27
Full	KQ117	AMS	6:10	6:25	KQ116	AMS	8:35	8:59
Full	KQ205	BOM	10:30	11:47	KQ704	LUN	12:05	12:45
Full	KQ251	SEZ	18:25	19:26	KQ330	JED	21:30	21:49
Arr	KQ252	HAH	18:25	18:25			19:49	19:49
Park	KQ252	HAH	19:55	19:55			22:23	22:23
Dep	KQ252	HAH	22:29	22:29			23:59	23:59
Arr	KQ257	TNR	20:15	20:15	KQ536	ABV	21:39	21:39
Park	KQ257	TNR	21:45	21:45	KQ536	ABV	6:19	6:19
Dep	KQ257	TNR	6:25	6:25	KQ536	ABV	7:55	7:55
Full	KQ257	TNR	20:15	19:51	KQ708	HRE	23:00	23:00
Arr	KQ311	DXB	6:55	6:55	KQ554	FIH	8:19	8:19
Park	KQ311	DXB	8:25	8:25	KQ554	FIH	10:29	10:46
Dep	KQ311	DXB	10:35	10:52	KQ554	FIH	12:05	12:22
Full	KQ349	KRT	6:35	6:35	KQ402	JIB	8:15	8:15
Full	KQ351	JUB	12:10	11:50	KQ608	MBA	14:15	14:31
Full	KQ353	JUB	18:00	17:55	KQ624	MBA	22:55	22:55
Full	KQ403	ADD	17:30	17:40	KQ416	EBB	19:10	19:10
Full	KQ411	EBB	11:05	11:05	KQ412	EBB	12:00	12:00
Arr	KQ413	EBB	15:05	15:05			16:29	16:29
Park	KQ413	EBB	16:35	16:35			22:23	22:23
Dep	KQ413	EBB	22:29	22:29			23:59	23:59
Full	KQ415	EBB	19:25	19:48	KQ488	DAR	22:55	23:58
Full	KQ417	EBB	22:15	21:19	KQ466	KGL	23:20	23:45
Full	KQ419	EBB	6:35	6:19	KQ432	JRO	8:00	8:00
Arr	KQ433	JRO	10:45	10:45	KQ444	BJM	12:09	12:09
Park	KQ433	JRO	12:15	12:15	KQ444	BJM	14:34	15:04
Dep	KQ433	JRO	14:40	15:10	KQ444	BJM	16:10	16:40
Full	KQ437	JRO	22:00	21:10			23:59	23:59
Arr	KQ444	BJM	21:15	21:15	KQ650	KIS	22:39	22:39
Park	KQ444	BJM	22:45	22:45	KQ650	KIS	5:14	5:21
Dep	KQ444	BJM	5:20	5:27	KQ650	KIS	6:50	6:57
Full	KQ444	BJM	21:15	20:40	KQ498	ZNZ	23:00	23:00
Arr	KQ447	KGL	6:05	6:05	KQ748	APL	7:29	7:29
Park	KQ447	KGL	7:35	7:35	KQ748	APL	10:49	11:19
Dep	KQ447	KGL	10:55	11:25	KQ748	APL	12:25	12:55
Arr	KQ448	BJM	12:50	12:50	KQ486	DAR	14:14	14:14
Park	KQ448	BJM	14:20	14:20	KQ486	DAR	17:14	18:04
Dep	KQ448	BJM	17:20	18:10	KQ486	DAR	18:50	19:40
Full	KQ481	DAR	11:10	12:05	KQ586	NLA	12:30	12:42
Full	KQ483	DAR	15:30	15:18	KQ414	EBB	16:20	17:33
Arr	KQ485	DAR	19:20	18:34	KQ448	BJM	20:44	19:58
Park	KQ485	DAR	20:50	20:04	KQ448	BJM	6:09	7:16
Dep	KQ485	DAR	6:15	7:22	KQ448	BJM	7:45	8:52
Full	KQ485	DAR	19:20	18:29	KQ734	LUN	22:45	23:46
Arr	KQ487	DAR	22:15	22:15	KQ256	TNR	23:39	23:39
Park	KQ487	DAR	23:45	23:45	KQ256	TNR	11:09	11:35
Dep	KQ487	DAR	11:15	11:41	KQ256	TNR	12:45	13:11
Full	KQ487	DAR	22:15	21:56			23:59	23:59
Full	KQ489	DAR	6:40	6:40	KQ494	ZNZ	8:05	8:05
Full	KQ495	ZNZ	11:15	10:53	KQ482	DAR	12:05	12:24
Full	KQ509	ACC	6:10	6:08	KQ760	JNB	8:30	8:30
Full	KQ521	ABJ	6:20	6:18	KQ504	FNA	10:35	10:35
Full	KQ522	NSI	21:40	21:37			23:59	23:59
Arr	KQ524	DLA	18:20	18:20	KQ522	NSI	19:44	19:44
Park	KQ524	DLA	19:50	19:50	KQ522	NSI	9:44	9:54
Dep	KQ524	DLA	9:50	10:00	KQ522	NSI	11:20	11:30
Arr	KQ533	LOS	19:50	19:50	KQ542	COO	21:14	21:14
Park	KQ533	LOS	21:20	21:20	KQ542	COO	6:19	6:30
Dep	KQ533	LOS	6:25	6:36	KQ542	COO	7:55	8:06
Arr	KQ537	ABV	18:25	18:22			19:49	19:46
Park	KQ537	ABV	19:55	19:52			22:23	22:23
Dep	KQ537	ABV	22:29	22:29			23:59	23:59
Full	KQ542	LOS	21:00	21:49			23:59	23:59
Full	KQ555	FIH	20:25	20:19	KQ112	CDG	23:05	23:05
Arr	KQ584	FBM	20:05	20:05	KQ252	HAH	21:29	21:29
Park	KQ584	FBM	21:35	21:35	KQ252	HAH	9:54	10:44
Dep	KQ584	FBM	10:00	10:50	KQ252	HAH	11:30	12:20
Full	KQ586	NLA	20:05	20:25			23:59	23:59
Arr	KQ601	MBA	9:30	9:30			10:54	10:54
Park	KQ601	MBA	11:00	11:00			22:23	22:23
Dep	KQ601	MBA	22:29	22:29			23:59	23:59
Full	KQ603	MBA	11:10	11:10	KQ762	JNB	12:05	12:05
Full	KQ605	MBA	12:55	12:40	KQ352	JUB	13:40	15:14
Full	KQ607	MBA	15:35	15:50	KQ610	MBA	16:25	16:36
Full	KQ609	MBA	16:55	16:50	KQ616	MBA	18:50	18:50
Full	KQ611	MBA	19:05	19:00	KQ618	MBA	19:50	19:50
Arr	KQ617	MBA	21:30	21:15	KQ600	MBA	22:54	22:39
Park	KQ617	MBA	23:00	22:45	KQ600	MBA	5:14	5:24
Dep	KQ617	MBA	5:20	5:30	KQ600	MBA	6:50	7:00
Full	KQ617	MBA	21:30	21:15	KQ418	EBB	22:55	23:50
Arr	KQ619	MBA	22:40	22:25	KQ350	JUB	0:04	23:49
Park	KQ619	MBA	0:10	23:55	KQ350	JUB	6:14	7:04
Dep	KQ619	MBA	6:20	7:10	KQ350	JUB	7:50	8:40
Full	KQ625	MBA	6:15	6:15	KQ640	MYD	8:55	8:55
Full	KQ641	MYD	11:45	12:57	KQ606	MBA	12:55	13:40
Full	KQ651	KIS	9:10	9:02	KQ654	KIS	9:55	9:55
Full	KQ655	KIS	12:15	12:02	KQ656	KIS	13:05	13:15

Inbound					Outbound			
Flight Type	Fl No.	Origin	ETA	ATA	Fl No.	Dest	ETD	ATD
Full	KQ657	KIS	15:25	15:17	KQ670	KIS	17:30	17:40
Arr	KQ671	KIS	19:50	19:02	KQ480	DAR	21:14	20:26
Park	KQ671	KIS	21:20	20:32	KQ480	DAR	6:09	6:09
Dep	KQ671	KIS	6:15	6:15	KQ480	DAR	7:45	7:45
Full	KQ671	KIS	19:50	19:07			23:59	23:59
Arr	KQ704	LUN	20:30	20:27	KQ250	SEZ	21:54	21:51
Park	KQ704	LUN	22:00	21:57	KQ250	SEZ	9:54	9:54
Dep	KQ704	LUN	10:00	10:00	KQ250	SEZ	11:30	11:30
Full	KQ704	LUN	20:30	20:00	KQ764	JNB	21:50	23:00
Full	KQ717	GBE	6:50	8:20	KQ730	LLW	8:15	9:01
Full	KQ720	HRE	6:50	7:59	KQ604	MBA	10:15	10:15
Full	KQ731	LLW	13:30	13:40	KQ484	DAR	15:55	16:55
Full	KQ749	APL	18:05	18:04	KQ436	JRO	19:20	19:20
Arr	KQ752	BLZ	19:45	19:03	KQ410	EBB	21:09	20:27
Park	KQ752	BLZ	21:15	20:33	KQ410	EBB	6:24	6:39
Dep	KQ752	BLZ	6:30	6:45	KQ410	EBB	8:00	8:15
Full	KQ761	JNB	17:40	18:39	KQ204	BOM	21:25	22:56
Full	KQ763	JNB	21:25	22:27	KQ304	DXB	22:30	22:58
Full	KQ765	JNB	6:55	7:17	KQ602	MBA	8:30	8:37
Full	KQ8603	MBA	12:25	12:33	KQ8606	MBA	14:00	14:00
Full	KQ8607	MBA	16:45	16:45	KQ8608	MBA	19:30	19:30
Arr	KQ8609	MBA	22:15	22:10	KQ8602	MBA	23:39	23:34
Park	KQ8609	MBA	23:45	23:40	KQ8602	MBA	8:04	8:04
Dep	KQ8609	MBA	8:10	8:10	KQ8602	MBA	9:40	9:40
Full	KQ8609	MBA	22:15	22:05			23:59	23:59
Full	KQ8651	KIS	8:30	7:37	KQ8690	UKU	9:10	9:34
Arr	KQ8655	KIS	20:00	20:00	KQ8650	KIS	21:24	21:24
Park	KQ8655	KIS	21:30	21:30	KQ8650	KIS	4:54	5:09
Dep	KQ8655	KIS	5:00	5:15	KQ8650	KIS	6:30	6:45
Full	KQ8655	KIS	20:00	20:56			23:59	23:59
Full	KQ8661	EDL	9:00	9:28	KQ8680	LAU	9:40	11:25
Arr	KQ8665	EDL	19:10	18:55	KQ8660	EDL	20:34	20:19
Park	KQ8665	EDL	20:40	20:25	KQ8660	EDL	5:24	5:24
Dep	KQ8665	EDL	5:30	5:30	KQ8660	EDL	7:00	7:00
Full	KQ8665	EDL	19:10	19:30			23:59	23:59
Full	KQ8681	MYD	13:30	14:35	KQ8654	KIS	18:00	18:00
Full	KQ8691	UKU	11:30	11:24	KQ8692	UKU	14:10	14:10
Full	KQ8693	UKU	16:30	15:48	KQ8664	EDL	17:10	17:24
Arr	KQ887	BKK	6:45	6:45	KQ886	BKK	8:09	8:09
Park	KQ887	BKK	8:15	8:15	KQ886	BKK	21:34	21:34
Dep	KQ887	BKK	21:40	21:40	KQ886	BKK	23:10	23:10
Full	LX294	ZRH	18:40	18:50	LX295	DAR	19:35	19:55
Full	MK534	MRU	11:50	11:55	MK535	MRU	13:05	13:15
Full	MS849	CAI	7:10	7:10	MS850	CAI	8:10	8:15
Full	PW715	ZNZ	21:15	20:55			23:59	23:59
Full	PW723	JRO	7:00	7:00	PW722	JRO	8:30	8:30
Arr	PW725	JRO	19:20	18:10	PW710	ZNZ	20:44	19:34
Park	PW725	JRO	20:50	19:40	PW710	ZNZ	6:34	6:34
Dep	PW725	JRO	6:40	6:40	PW710	ZNZ	8:10	8:10
Full	PW725	JRO	19:20	18:10			23:59	23:59
Full	PW727	JRO	16:00	15:02	PW726	JRO	16:50	16:50
Full	QR1337	DOH	9:30	9:50	QR1338	DOH	12:35	12:45
Full	QR1339	DOH	13:10	13:20	QR1340	DOH	17:35	17:45
Full	SA184	JNB	15:15	15:25	SA185	JNB	16:05	16:15
Full	SN463	BRU	21:45	21:45	SN463	BRU	22:45	22:50
Full	SV431	JED	11:32	11:42	SV430	JED	13:10	13:25
Full	TK6510	FIH	18:30	18:11	TK6492	IST	21:00	21:20
Full	TM4462	MPM	14:25	14:37	TM4463	MPM	15:45	15:57
Full	WB402	KGL	15:40	15:45	WB403	KGL	16:30	16:30
Full	WB450	EBB	10:40	10:50	WB450	KGL	11:25	11:35
Full	WB460	KGL	20:15	20:25	WB460	EBB	21:35	21:45
Full			6:50	6:50	KQ210	BOM	7:50	8:40
Full			22:25	22:25	KQ102	LHR	23:25	23:41
Arr	CZ633	CAN	7:00	7:00	CZ634	CAN	8:24	8:24
Park	CZ633	CAN	8:30	8:30	CZ634	CAN	11:59	12:19
Dep	CZ633	CAN	12:05	12:25	CZ634	CAN	13:35	13:55
Full	EK721	DXB	19:00	19:20	EK722	DUB	22:50	22:59
Arr	SA180	JNB	22:40	22:40	SA181	JNB	0:04	0:04
Park	SA180	JNB	0:10	0:10	SA181	JNB	6:54	7:09
Dep	SA180	JNB	7:00	7:15	SA181	JNB	8:30	8:45
Full	TK607	IST	7:25	7:15	TK608	IST	10:35	11:05

Table D.8: Simulation case 8

Inbound					Outbound			
Flight Type	Fl No.	Origin	ETA	ATA	Fl No.	Dest	ETD	ATD
Full	BA065	LHR	20:30	21:00	BA064	LHR	23:15	23:25
Full	EK719	DXB	14:30	14:45	EK720	DUB	16:40	17:49
Full	ET302	ADD	10:20	10:35	ET303	ADD	11:35	11:50
Arr	ET304	ADD	12:20	12:19	ET305	ADD	13:44	13:43
Park	ET304	ADD	13:50	13:49	ET305	ADD	15:59	16:07
Dep	ET304	ADD	16:05	16:13	ET305	ADD	17:35	17:43
Full	ET306	ADD	18:15	18:15	ET307	ADD	19:35	19:35
Arr	ET308	ADD	23:40	23:40	ET309	ADD	1:04	1:04
Park	ET308	ADD	1:10	1:10	ET309	ADD	4:24	4:34
Dep	ET308	ADD	4:30	4:40	ET309	ADD	6:00	6:10
Arr	ET308	ADD	23:45	23:45	ET309	ADD	1:09	1:09
Park	ET308	ADD	1:15	1:15	ET309	ADD	4:24	4:24
Dep	ET308	ADD	4:30	4:30	ET309	ADD	6:00	6:00
Full	EY641	AUH	12:47	12:27	EY642	AUH	13:40	13:40
Full	G9734	SHJ	13:06	12:06	G9735	SHJ	13:40	13:55
Full	KL565	AMS	20:25	20:35	KL566	AMS	22:25	22:35
Arr	KQ101	LHR	6:30	6:30	KQ310	DXB	7:54	7:54
Park	KQ101	LHR	8:00	8:00	KQ310	DXB	17:39	17:59
Dep	KQ101	LHR	17:45	18:05	KQ310	DXB	19:15	19:35
Full	KQ117	AMS	6:10	6:17	KQ116	AMS	8:35	8:35
Full	KQ205	BOM	10:30	10:33	KQ704	LUN	12:05	12:05
Full	KQ251	SEZ	18:25	19:31	KQ330	JED	21:30	21:39
Arr	KQ252	HAH	18:25	17:43			19:49	19:07
Park	KQ252	HAH	19:55	19:13			22:23	22:23
Dep	KQ252	HAH	22:29	22:29			23:59	23:59
Arr	KQ257	TNR	20:15	20:15	KQ536	ABV	21:39	21:39
Park	KQ257	TNR	21:45	21:45	KQ536	ABV	6:19	6:19
Dep	KQ257	TNR	6:25	6:25	KQ536	ABV	7:55	7:55
Full	KQ257	TNR	20:15	20:20	KQ708	HRE	23:00	23:00
Arr	KQ311	DXB	6:55	6:55	KQ554	FIH	8:19	8:19
Park	KQ311	DXB	8:25	8:25	KQ554	FIH	10:29	10:46
Dep	KQ311	DXB	10:35	10:52	KQ554	FIH	12:05	12:22
Full	KQ349	KRT	6:35	6:30	KQ402	JIB	8:15	8:15
Full	KQ351	JUB	12:10	11:53	KQ608	MBA	14:15	14:31
Full	KQ353	JUB	18:00	19:05	KQ624	MBA	22:55	23:47
Full	KQ403	ADD	17:30	17:05	KQ416	EBB	19:10	19:35
Full	KQ411	EBB	11:05	10:24	KQ412	EBB	12:00	12:23
Arr	KQ413	EBB	15:05	15:05			16:29	16:29
Park	KQ413	EBB	16:35	16:35			22:23	22:23
Dep	KQ413	EBB	22:29	22:29			23:59	23:59
Full	KQ415	EBB	19:25	19:40	KQ488	DAR	22:55	23:46
Full	KQ417	EBB	22:15	21:33	KQ466	KGL	23:20	23:40
Full	KQ419	EBB	6:35	6:13	KQ432	JRO	8:00	8:00
Arr	KQ433	JRO	10:45	10:33	KQ444	BJM	12:09	11:57
Park	KQ433	JRO	12:15	12:03	KQ444	BJM	14:34	14:34
Dep	KQ433	JRO	14:40	14:40	KQ444	BJM	16:10	16:10
Full	KQ437	JRO	22:00	20:59			23:59	23:59
Arr	KQ444	BJM	21:15	21:15	KQ650	KIS	22:39	22:39
Park	KQ444	BJM	22:45	22:45	KQ650	KIS	5:14	6:31
Dep	KQ444	BJM	5:20	6:37	KQ650	KIS	6:50	8:07
Full	KQ444	BJM	21:15	20:59	KQ498	ZNZ	23:00	23:09
Arr	KQ447	KGL	6:05	6:01	KQ748	APL	7:29	7:25
Park	KQ447	KGL	7:35	7:31	KQ748	APL	10:49	11:06
Dep	KQ447	KGL	10:55	11:12	KQ748	APL	12:25	12:42
Arr	KQ448	BJM	12:50	11:52	KQ486	DAR	14:14	13:16
Park	KQ448	BJM	14:20	13:22	KQ486	DAR	17:14	17:14
Dep	KQ448	BJM	17:20	17:20	KQ486	DAR	18:50	18:50
Full	KQ481	DAR	11:10	12:06	KQ586	NLA	12:30	12:50
Full	KQ483	DAR	15:30	15:43	KQ414	EBB	16:20	16:43
Arr	KQ485	DAR	19:20	18:37	KQ448	BJM	20:44	20:01
Park	KQ485	DAR	20:50	20:07	KQ448	BJM	6:09	6:29
Dep	KQ485	DAR	6:15	6:35	KQ448	BJM	7:45	8:05
Full	KQ485	DAR	19:20	19:20	KQ734	LUN	22:45	22:45
Arr	KQ487	DAR	22:15	22:13	KQ256	TNR	23:39	23:37
Park	KQ487	DAR	23:45	23:43	KQ256	TNR	11:09	12:19
Dep	KQ487	DAR	11:15	12:25	KQ256	TNR	12:45	13:55
Full	KQ487	DAR	22:15	22:00			23:59	23:59
Full	KQ489	DAR	6:40	6:22	KQ494	ZNZ	8:05	8:12
Full	KQ495	ZNZ	11:15	10:20	KQ482	DAR	12:05	12:20
Full	KQ509	ACC	6:10	6:08	KQ760	JNB	8:30	8:30
Full	KQ521	ABJ	6:20	6:20	KQ504	FNA	10:35	10:35
Full	KQ522	NSI	21:40	20:53			23:59	23:59
Arr	KQ524	DLA	18:20	18:20	KQ522	NSI	19:44	19:44
Park	KQ524	DLA	19:50	19:50	KQ522	NSI	9:44	10:59
Dep	KQ524	DLA	9:50	11:05	KQ522	NSI	11:20	12:35
Arr	KQ533	LOS	19:50	19:50	KQ542	COO	21:14	21:14
Park	KQ533	LOS	21:20	21:20	KQ542	COO	6:19	6:44
Dep	KQ533	LOS	6:25	6:50	KQ542	COO	7:55	8:20
Arr	KQ537	ABV	18:25	18:15			19:49	19:39
Park	KQ537	ABV	19:55	19:45			22:23	22:23
Dep	KQ537	ABV	22:29	22:29			23:59	23:59
Full	KQ542	LOS	21:00	20:09			23:59	23:59
Full	KQ555	FIH	20:25	20:19	KQ112	CDG	23:05	23:16
Arr	KQ584	FBM	20:05	20:05	KQ252	HAH	21:29	21:29
Park	KQ584	FBM	21:35	21:35	KQ252	HAH	9:54	11:00
Dep	KQ584	FBM	10:00	11:06	KQ252	HAH	11:30	12:36
Full	KQ586	NLA	20:05	20:25			23:59	23:59
Arr	KQ601	MBA	9:30	9:20			10:54	10:44
Park	KQ601	MBA	11:00	10:50			22:23	22:23
Dep	KQ601	MBA	22:29	22:29			23:59	23:59
Full	KQ603	MBA	11:10	11:15	KQ762	JNB	12:05	12:05
Full	KQ605	MBA	12:55	12:45	KQ352	JUB	13:40	15:10
Full	KQ607	MBA	15:35	15:35	KQ610	MBA	16:25	16:25
Full	KQ609	MBA	16:55	17:45	KQ616	MBA	18:50	20:06
Full	KQ611	MBA	19:05	19:12	KQ618	MBA	19:50	20:55
Arr	KQ617	MBA	21:30	21:15	KQ600	MBA	22:54	22:39
Park	KQ617	MBA	23:00	22:45	KQ600	MBA	5:14	5:34
Dep	KQ617	MBA	5:20	5:40	KQ600	MBA	6:50	7:10
Full	KQ617	MBA	21:30	21:20	KQ418	EBB	22:55	0:16
Arr	KQ619	MBA	22:40	22:25	KQ350	JUB	0:04	23:49
Park	KQ619	MBA	0:10	23:55	KQ350	JUB	6:14	7:13
Dep	KQ619	MBA	6:20	7:19	KQ350	JUB	7:50	8:49
Full	KQ625	MBA	6:15	6:10	KQ640	MYD	8:55	8:55
Full	KQ641	MYD	11:45	11:29	KQ606	MBA	12:55	13:25
Full	KQ651	KIS	9:10	9:05	KQ654	KIS	9:55	9:55
Full	KQ655	KIS	12:15	12:15	KQ656	KIS	13:05	13:05

Inbound					Outbound			
Flight Type	Fl No.	Origin	ETA	ATA	Fl No.	Dest	ETD	ATD
Full	KQ657	KIS	15:25	15:10	KQ670	KIS	17:30	17:40
Arr	KQ671	KIS	19:50	19:06	KQ480	DAR	21:14	20:30
Park	KQ671	KIS	21:20	20:36	KQ480	DAR	6:09	7:19
Dep	KQ671	KIS	6:15	7:25	KQ480	DAR	7:45	8:55
Full	KQ671	KIS	19:50	19:08			23:59	23:59
Arr	KQ704	LUN	20:30	19:35	KQ250	SEZ	21:54	20:59
Park	KQ704	LUN	22:00	21:05	KQ250	SEZ	9:54	9:54
Dep	KQ704	LUN	10:00	10:00	KQ250	SEZ	11:30	11:30
Full	KQ704	LUN	20:30	19:20	KQ764	JNB	21:50	23:01
Full	KQ717	GBE	6:50	8:20	KQ730	LLW	8:15	9:07
Full	KQ720	HRE	6:50	7:12	KQ604	MBA	10:15	10:26
Full	KQ731	LLW	13:30	12:35	KQ484	DAR	15:55	16:45
Full	KQ749	APL	18:05	17:48	KQ436	JRO	19:20	20:05
Arr	KQ752	BLZ	19:45	18:49	KQ410	EBB	21:09	20:13
Park	KQ752	BLZ	21:15	20:19	KQ410	EBB	6:24	6:35
Dep	KQ752	BLZ	6:30	6:41	KQ410	EBB	8:00	8:11
Full	KQ761	JNB	17:40	17:55	KQ204	BOM	21:25	22:17
Full	KQ763	JNB	21:25	21:11	KQ304	DXB	22:30	0:08
Full	KQ765	JNB	6:55	6:35	KQ602	MBA	8:30	8:37
Full	KQ8603	MBA	12:25	12:48	KQ8606	MBA	14:00	14:00
Full	KQ8607	MBA	16:45	17:08	KQ8608	MBA	19:30	19:47
Arr	KQ8609	MBA	22:15	22:15	KQ8602	MBA	23:39	23:39
Park	KQ8609	MBA	23:45	23:45	KQ8602	MBA	8:04	9:12
Dep	KQ8609	MBA	8:10	9:18	KQ8602	MBA	9:40	10:48
Full	KQ8609	MBA	22:15	22:05			23:59	23:59
Full	KQ8651	KIS	8:30	7:26	KQ8690	UKU	9:10	9:30
Arr	KQ8655	KIS	20:00	19:50	KQ8650	KIS	21:24	21:14
Park	KQ8655	KIS	21:30	21:20	KQ8650	KIS	4:54	5:09
Dep	KQ8655	KIS	5:00	5:15	KQ8650	KIS	6:30	6:45
Full	KQ8655	KIS	20:00	19:59			23:59	23:59
Full	KQ8661	EDL	9:00	8:50	KQ8680	LAU	9:40	9:55
Arr	KQ8665	EDL	19:10	18:18	KQ8660	EDL	20:34	19:42
Park	KQ8665	EDL	20:40	19:48	KQ8660	EDL	5:24	5:31
Dep	KQ8665	EDL	5:30	5:37	KQ8660	EDL	7:00	7:07
Full	KQ8665	EDL	19:10	18:18			23:59	23:59
Full	KQ8681	MYD	13:30	13:50	KQ8654	KIS	18:00	18:00
Full	KQ8691	UKU	11:30	12:24	KQ8692	UKU	14:10	14:45
Full	KQ8693	UKU	16:30	15:42	KQ8664	EDL	17:10	17:30
Arr	KQ887	BKK	6:45	6:31	KQ886	BKK	8:09	7:55
Park	KQ887	BKK	8:15	8:01	KQ886	BKK	21:34	21:47
Dep	KQ887	BKK	21:40	21:53	KQ886	BKK	23:10	23:23
Full	LX294	ZRH	18:40	18:55	LX295	DAR	19:35	19:45
Full	MK534	MRU	11:50	12:20	MK535	MRU	13:05	13:29
Full	MS849	CAI	7:10	7:40	MS850	CAI	8:10	8:30
Full	PW715	ZNZ	21:15	22:35			23:59	23:59
Full	PW723	JRO	7:00	6:15	PW722	JRO	8:30	8:30
Arr	PW725	JRO	19:20	18:15	PW710	ZNZ	20:44	19:39
Park	PW725	JRO	20:50	19:45	PW710	ZNZ	6:34	6:34
Dep	PW725	JRO	6:40	6:40	PW710	ZNZ	8:10	8:10
Full	PW725	JRO	19:20	18:06			23:59	23:59
Full	PW727	JRO	16:00	15:07	PW726	JRO	16:50	16:50
Full	QR1337	DOH	9:30	9:40	QR1338	DOH	12:35	12:45
Full	QR1339	DOH	13:10	13:20	QR1340	DOH	17:35	17:50
Full	SA184	JNB	15:15	15:35	SA185	JNB	16:05	16:15
Full	SN463	BRU	21:45	21:45	SN463	BRU	22:45	22:50
Full	SV431	JED	11:32	12:02	SV430	JED	13:10	13:20
Full	TK6510	FIH	18:30	18:20	TK6492	IST	21:00	21:10
Full	TM4462	MPM	14:25	14:33	TM4463	MPM	15:45	15:53
Full	WB402	KGL	15:40	15:21	WB403	KGL	16:30	16:30
Full	WB450	EBB	10:40	10:50	WB450	KGL	11:25	11:40
Full	WB460	KGL	20:15	20:25	WB460	EBB	21:35	21:50
Full			6:50	6:50	KQ210	BOM	7:50	8:55
Full			22:25	22:25	KQ102	LHR	23:25	23:41
Arr	CZ633	CAN	7:00	7:00	CZ634	CAN	8:24	8:24
Park	CZ633	CAN	8:30	8:30	CZ634	CAN	11:59	12:29
Dep	CZ633	CAN	12:05	12:35	CZ634	CAN	13:35	14:05
Full	EK721	DXB	19:00	19:15	EK722	DUB	22:50	22:50
Arr	SA180	JNB	22:40	22:40	SA181	JNB	0:04	0:04
Park	SA180	JNB	0:10	0:10	SA181	JNB	6:54	6:54
Dep	SA180	JNB	7:00	7:00	SA181	JNB	8:30	8:30
Full	TK607	IST	7:25	7:35	TK608	IST	10:35	11:05

Table D.9: Simulation case 9

Inbound				Outbound				
Flight Type	Fl No.	Origin	ETA	ATA	Fl No.	Dest	ETD	ATD
Full	BA065	LHR	20:30	20:40	BA064	LHR	23:15	23:25
Full	EK719	DXB	14:30	14:30	EK720	DUB	16:40	16:40
Full	ET302	ADD	10:20	10:30	ET303	ADD	11:35	11:50
Arr	ET304	ADD	12:20	12:20	ET305	ADD	13:44	13:44
Park	ET304	ADD	13:50	13:50	ET305	ADD	15:59	17:04
Dep	ET304	ADD	16:05	17:10	ET305	ADD	17:35	18:40
Full	ET306	ADD	18:15	18:45	ET307	ADD	19:35	19:45
Arr	ET308	ADD	23:40	23:40	ET309	ADD	1:04	1:04
Park	ET308	ADD	1:10	1:10	ET309	ADD	4:24	4:39
Dep	ET308	ADD	4:30	4:45	ET309	ADD	6:00	6:15
Arr	ET308	ADD	23:45	23:45	ET309	ADD	1:09	1:09
Park	ET308	ADD	1:15	1:15	ET309	ADD	4:24	4:34
Dep	ET308	ADD	4:30	4:40	ET309	ADD	6:00	6:10
Full	EY641	AUH	12:47	12:36	EY642	AUH	13:40	13:40
Full	G9734	SHJ	13:06	14:01	G9735	SHJ	13:40	14:50
Full	KL565	AMS	20:25	20:30	KL566	AMS	22:25	22:30
Arr	KQ101	LHR	6:30	5:49	KQ310	DXB	7:54	7:13
Park	KQ101	LHR	8:00	7:19	KQ310	DXB	17:39	17:52
Dep	KQ101	LHR	17:45	17:58	KQ310	DXB	19:15	19:28
Full	KQ117	AMS	6:10	6:21	KQ116	AMS	8:35	8:46
Full	KQ205	BOM	10:30	11:34	KQ704	LUN	12:05	12:29
Full	KQ251	SEZ	18:25	19:28	KQ330	JED	21:30	21:39
Arr	KQ252	HAH	18:25	18:25			19:49	19:49
Park	KQ252	HAH	19:55	19:55			22:23	22:23
Dep	KQ252	HAH	22:29	22:29			23:59	23:59
Arr	KQ257	TNR	20:15	20:15	KQ536	ABV	21:39	21:39
Park	KQ257	TNR	21:45	21:45	KQ536	ABV	6:19	6:38
Dep	KQ257	TNR	6:25	6:44	KQ536	ABV	7:55	8:14
Full	KQ257	TNR	20:15	21:02	KQ708	HRE	23:00	23:21
Arr	KQ311	DXB	6:55	6:55	KQ554	FIH	8:19	8:19
Park	KQ311	DXB	8:25	8:25	KQ554	FIH	10:29	11:46
Dep	KQ311	DXB	10:35	11:52	KQ554	FIH	12:05	13:22
Full	KQ349	KRT	6:35	6:20	KQ402	JIB	8:15	8:29
Full	KQ351	JUB	12:10	12:25	KQ608	MBA	14:15	14:45
Full	KQ353	JUB	18:00	18:15	KQ624	MBA	22:55	0:04
Full	KQ403	ADD	17:30	16:16	KQ416	EBB	19:10	20:10
Full	KQ411	EBB	11:05	12:05	KQ412	EBB	12:00	13:00
Arr	KQ413	EBB	15:05	14:45			16:29	16:09
Park	KQ413	EBB	16:35	16:15			22:23	22:23
Dep	KQ413	EBB	22:29	22:29			23:59	23:59
Full	KQ415	EBB	19:25	18:32	KQ488	DAR	22:55	23:48
Full	KQ417	EBB	22:15	21:12	KQ466	KGL	23:20	23:31
Full	KQ419	EBB	6:35	5:29	KQ432	JRO	8:00	8:00
Arr	KQ433	JRO	10:45	10:45	KQ444	BJM	12:09	12:09
Park	KQ433	JRO	12:15	12:15	KQ444	BJM	14:34	14:54
Dep	KQ433	JRO	14:40	15:00	KQ444	BJM	16:10	16:30
Full	KQ437	JRO	22:00	21:10			23:59	23:59
Arr	KQ444	BJM	21:15	20:40	KQ650	KIS	22:39	22:04
Park	KQ444	BJM	22:45	22:10	KQ650	KIS	5:14	5:19
Dep	KQ444	BJM	5:20	5:25	KQ650	KIS	6:50	6:55
Full	KQ444	BJM	21:15	22:20	KQ498	ZNZ	23:00	23:14
Arr	KQ447	KGL	6:05	6:01	KQ748	APL	7:29	7:25
Park	KQ447	KGL	7:35	7:31	KQ748	APL	10:49	12:04
Dep	KQ447	KGL	10:55	12:10	KQ748	APL	12:25	13:40
Arr	KQ448	BJM	12:50	11:46	KQ486	DAR	14:14	13:10
Park	KQ448	BJM	14:20	13:16	KQ486	DAR	17:14	17:23
Dep	KQ448	BJM	17:20	17:29	KQ486	DAR	18:50	18:59
Full	KQ481	DAR	11:10	12:18	KQ586	NLA	12:30	13:10
Full	KQ483	DAR	15:30	15:48	KQ414	EBB	16:20	16:35
Arr	KQ485	DAR	19:20	19:13	KQ448	BJM	20:44	20:37
Park	KQ485	DAR	20:50	20:43	KQ448	BJM	6:09	7:17
Dep	KQ485	DAR	6:15	7:23	KQ448	BJM	7:45	8:53
Full	KQ485	DAR	19:20	18:39	KQ734	LUN	22:45	22:58
Arr	KQ487	DAR	22:15	22:00	KQ256	TNR	23:39	23:24
Park	KQ487	DAR	23:45	23:30	KQ256	TNR	11:09	12:12
Dep	KQ487	DAR	11:15	12:18	KQ256	TNR	12:45	13:48
Full	KQ487	DAR	22:15	22:00			23:59	23:59
Full	KQ489	DAR	6:40	6:27	KQ494	ZNZ	8:05	8:05
Full	KQ495	ZNZ	11:15	10:26	KQ482	DAR	12:05	12:20
Full	KQ509	ACC	6:10	5:55	KQ760	JNB	8:30	8:48
Full	KQ521	ABJ	6:20	7:10	KQ504	FNA	10:35	10:35
Full	KQ522	NSI	21:40	22:00			23:59	23:59
Arr	KQ524	DLA	18:20	18:20	KQ522	NSI	19:44	19:44
Park	KQ524	DLA	19:50	19:50	KQ522	NSI	9:44	10:41
Dep	KQ524	DLA	9:50	10:47	KQ522	NSI	11:20	12:17
Arr	KQ533	LOS	19:50	19:50	KQ542	COO	21:14	21:14
Park	KQ533	LOS	21:20	21:20	KQ542	COO	6:19	6:47
Dep	KQ533	LOS	6:25	6:53	KQ542	COO	7:55	8:23
Arr	KQ537	ABV	18:25	18:25			19:49	19:49
Park	KQ537	ABV	19:55	19:55			22:23	22:23
Dep	KQ537	ABV	22:29	22:29			23:59	23:59
Full	KQ542	LOS	21:00	21:50			23:59	23:59
Full	KQ555	FIH	20:25	20:01	KQ112	CDG	23:05	23:24
Arr	KQ584	FBM	20:05	19:02	KQ252	HAH	21:29	20:26
Park	KQ584	FBM	21:35	20:32	KQ252	HAH	9:54	10:12
Dep	KQ584	FBM	10:00	10:18	KQ252	HAH	11:30	11:48
Full	KQ586	NLA	20:05	19:15			23:59	23:59
Arr	KQ601	MBA	9:30	9:15			10:54	10:39
Park	KQ601	MBA	11:00	10:45			22:23	22:23
Dep	KQ601	MBA	22:29	22:29			23:59	23:59
Full	KQ603	MBA	11:10	11:27	KQ762	JNB	12:05	12:45
Full	KQ605	MBA	12:55	13:40	KQ352	JUB	13:40	14:40
Full	KQ607	MBA	15:35	15:25	KQ610	MBA	16:25	16:34
Full	KQ609	MBA	16:55	16:42	KQ616	MBA	18:50	19:57
Full	KQ611	MBA	19:05	18:15	KQ618	MBA	19:50	20:42
Arr	KQ617	MBA	21:30	21:20	KQ600	MBA	22:54	22:44
Park	KQ617	MBA	23:00	22:50	KQ600	MBA	5:14	5:34
Dep	KQ617	MBA	5:20	5:40	KQ600	MBA	6:50	7:10
Full	KQ617	MBA	21:30	21:57	KQ418	EBB	22:55	23:52
Arr	KQ619	MBA	22:40	22:40	KQ350	JUB	0:04	0:04
Park	KQ619	MBA	0:10	0:10	KQ350	JUB	6:14	6:21
Dep	KQ619	MBA	6:20	6:27	KQ350	JUB	7:50	7:57
Full	KQ625	MBA	6:15	6:10	KQ640	MYD	8:55	8:55
Full	KQ641	MYD	11:45	11:34	KQ606	MBA	12:55	13:25
Full	KQ651	KIS	9:10	8:57	KQ654	KIS	9:55	11:02
Full	KQ655	KIS	12:15	12:00	KQ656	KIS	13:05	13:05

Inbound					Outbound			
Flight Type	Fl No.	Origin	ETA	ATA	Fl No.	Dest	ETD	ATD
Full	KQ657	KIS	15:25	15:17	KQ670	KIS	17:30	17:39
Arr	KQ671	KIS	19:50	19:08	KQ480	DAR	21:14	20:32
Park	KQ671	KIS	21:20	20:38	KQ480	DAR	6:09	7:09
Dep	KQ671	KIS	6:15	7:15	KQ480	DAR	7:45	8:45
Full	KQ671	KIS	19:50	19:07			23:59	23:59
Arr	KQ704	LUN	20:30	20:30	KQ250	SEZ	21:54	21:54
Park	KQ704	LUN	22:00	22:00	KQ250	SEZ	9:54	10:18
Dep	KQ704	LUN	10:00	10:24	KQ250	SEZ	11:30	11:54
Full	KQ704	LUN	20:30	21:14	KQ764	JNB	21:50	23:00
Full	KQ717	GBE	6:50	8:04	KQ730	LLW	8:15	8:55
Full	KQ720	HRE	6:50	7:14	KQ604	MBA	10:15	10:26
Full	KQ731	LLW	13:30	13:40	KQ484	DAR	15:55	16:55
Full	KQ749	APL	18:05	17:50	KQ436	JRO	19:20	20:05
Arr	KQ752	BLZ	19:45	19:45	KQ410	EBB	21:09	21:09
Park	KQ752	BLZ	21:15	21:15	KQ410	EBB	6:24	6:24
Dep	KQ752	BLZ	6:30	6:30	KQ410	EBB	8:00	8:00
Full	KQ761	JNB	17:40	17:55	KQ204	BOM	21:25	22:22
Full	KQ763	JNB	21:25	21:40	KQ304	DXB	22:30	22:56
Full	KQ765	JNB	6:55	7:17	KQ602	MBA	8:30	8:42
Full	KQ8603	MBA	12:25	12:35	KQ8606	MBA	14:00	14:00
Full	KQ8607	MBA	16:45	16:27	KQ8608	MBA	19:30	20:09
Arr	KQ8609	MBA	22:15	22:15	KQ8602	MBA	23:39	23:39
Park	KQ8609	MBA	23:45	23:45	KQ8602	MBA	8:04	8:23
Dep	KQ8609	MBA	8:10	8:29	KQ8602	MBA	9:40	9:59
Full	KQ8609	MBA	22:15	22:25			23:59	23:59
Full	KQ8651	KIS	8:30	8:45	KQ8690	UKU	9:10	9:34
Arr	KQ8655	KIS	20:00	20:00	KQ8650	KIS	21:24	21:24
Park	KQ8655	KIS	21:30	21:30	KQ8650	KIS	4:54	4:54
Dep	KQ8655	KIS	5:00	5:00	KQ8650	KIS	6:30	6:30
Full	KQ8655	KIS	20:00	20:56			23:59	23:59
Full	KQ8661	EDL	9:00	8:50	KQ8680	LAU	9:40	9:52
Arr	KQ8665	EDL	19:10	19:00	KQ8660	EDL	20:34	20:24
Park	KQ8665	EDL	20:40	20:30	KQ8660	EDL	5:24	5:30
Dep	KQ8665	EDL	5:30	5:36	KQ8660	EDL	7:00	7:06
Full	KQ8665	EDL	19:10	19:30			23:59	23:59
Full	KQ8681	MYD	13:30	13:42	KQ8654	KIS	18:00	18:00
Full	KQ8691	UKU	11:30	12:24	KQ8692	UKU	14:10	14:10
Full	KQ8693	UKU	16:30	15:48	KQ8664	EDL	17:10	17:40
Arr	KQ887	BKK	6:45	6:40	KQ886	BKK	8:09	8:04
Park	KQ887	BKK	8:15	8:10	KQ886	BKK	21:34	22:08
Dep	KQ887	BKK	21:40	22:14	KQ886	BKK	23:10	23:44
Full	LX294	ZRH	18:40	18:55	LX295	DAR	19:35	19:50
Full	MK534	MRU	11:50	12:04	MK535	MRU	13:05	13:21
Full	MS849	CAI	7:10	7:25	MS850	CAI	8:10	8:20
Full	PW715	ZNZ	21:15	20:55			23:59	23:59
Full	PW723	JRO	7:00	7:00	PW722	JRO	8:30	8:30
Arr	PW725	JRO	19:20	18:10	PW710	ZNZ	20:44	19:34
Park	PW725	JRO	20:50	19:40	PW710	ZNZ	6:34	6:34
Dep	PW725	JRO	6:40	6:40	PW710	ZNZ	8:10	8:10
Full	PW725	JRO	19:20	18:15			23:59	23:59
Full	PW727	JRO	16:00	14:59	PW726	JRO	16:50	17:00
Full	QR1337	DOH	9:30	9:45	QR1338	DOH	12:35	12:45
Full	QR1339	DOH	13:10	13:20	QR1340	DOH	17:35	17:45
Full	SA184	JNB	15:15	15:25	SA185	JNB	16:05	16:15
Full	SN463	BRU	21:45	21:55	SN463	BRU	22:45	22:55
Full	SV431	JED	11:32	11:42	SV430	JED	13:10	13:20
Full	TK6510	FIH	18:30	18:27	TK6492	IST	21:00	21:05
Full	TM4462	MPM	14:25	14:33	TM4463	MPM	15:45	15:57
Full	WB402	KGL	15:40	16:52	WB403	KGL	16:30	17:44
Full	WB450	EBB	10:40	10:40	WB450	KGL	11:25	11:30
Full	WB460	KGL	20:15	20:25	WB460	EBB	21:35	22:05
Full			6:50	6:50	KQ210	BOM	7:50	8:50
Full			22:25	22:25	KQ102	LHR	23:25	23:47
Arr	CZ633	CAN	7:00	7:00	CZ634	CAN	8:24	8:24
Park	CZ633	CAN	8:30	8:30	CZ634	CAN	11:59	12:09
Dep	CZ633	CAN	12:05	12:15	CZ634	CAN	13:35	13:45
Full	EK721	DXB	19:00	19:10	EK722	DUB	22:50	23:00
Arr	SA180	JNB	22:40	22:40	SA181	JNB	0:04	0:04
Park	SA180	JNB	0:10	0:10	SA181	JNB	6:54	7:24
Dep	SA180	JNB	7:00	7:30	SA181	JNB	8:30	9:00
Full	TK607	IST	7:25	7:14	TK608	IST	10:35	10:51

Table D.10: Simulation case 10

Inbound				Outbound				
Flight Type	Fl No.	Origin	ETA	ATA	Fl No.	Dest	ETD	ATD
Full	BA065	LHR	20:30	20:45	BA064	LHR	23:15	23:25
Full	EK719	DXB	14:30	14:40	EK720	DUB	16:40	17:04
Full	ET302	ADD	10:20	10:30	ET303	ADD	11:35	11:55
Arr	ET304	ADD	12:20	12:20	ET305	ADD	13:44	13:44
Park	ET304	ADD	13:50	13:50	ET305	ADD	15:59	17:04
Dep	ET304	ADD	16:05	17:10	ET305	ADD	17:35	18:40
Full	ET306	ADD	18:15	18:25	ET307	ADD	19:35	20:05
Arr	ET308	ADD	23:40	23:40	ET309	ADD	1:04	1:04
Park	ET308	ADD	1:10	1:10	ET309	ADD	4:24	4:34
Dep	ET308	ADD	4:30	4:40	ET309	ADD	6:00	6:10
Arr	ET308	ADD	23:45	23:45	ET309	ADD	1:09	1:09
Park	ET308	ADD	1:15	1:15	ET309	ADD	4:24	4:34
Dep	ET308	ADD	4:30	4:40	ET309	ADD	6:00	6:10
Full	EY641	AUH	12:47	12:28	EY642	AUH	13:40	13:50
Full	G9734	SHJ	13:06	14:01	G9735	SHJ	13:40	14:50
Full	KL565	AMS	20:25	20:35	KL566	AMS	22:25	22:35
Arr	KQ101	LHR	6:30	6:30	KQ310	DXB	7:54	7:54
Park	KQ101	LHR	8:00	8:00	KQ310	DXB	17:39	17:54
Dep	KQ101	LHR	17:45	18:00	KQ310	DXB	19:15	19:30
Full	KQ117	AMS	6:10	6:20	KQ116	AMS	8:35	8:55
Full	KQ205	BOM	10:30	11:02	KQ704	LUN	12:05	12:13
Full	KQ251	SEZ	18:25	19:26	KQ330	JED	21:30	21:50
Arr	KQ252	HAH	18:25	18:25			19:49	19:49
Park	KQ252	HAH	19:55	19:55			22:23	22:23
Dep	KQ252	HAH	22:29	22:29			23:59	23:59
Arr	KQ257	TNR	20:15	20:15	KQ536	ABV	21:39	21:39
Park	KQ257	TNR	21:45	21:45	KQ536	ABV	6:19	6:32
Dep	KQ257	TNR	6:25	6:38	KQ536	ABV	7:55	8:08
Full	KQ257	TNR	20:15	21:01	KQ708	HRE	23:00	23:00
Arr	KQ311	DXB	6:55	6:55	KQ554	FIH	8:19	8:19
Park	KQ311	DXB	8:25	8:25	KQ554	FIH	10:29	10:44
Dep	KQ311	DXB	10:35	10:50	KQ554	FIH	12:05	12:20
Full	KQ349	KRT	6:35	6:15	KQ402	JIB	8:15	8:26
Full	KQ351	JUB	12:10	11:53	KQ608	MBA	14:15	14:22
Full	KQ353	JUB	18:00	18:49	KQ624	MBA	22:55	0:04
Full	KQ403	ADD	17:30	17:12	KQ416	EBB	19:10	20:08
Full	KQ411	EBB	11:05	10:23	KQ412	EBB	12:00	12:20
Arr	KQ413	EBB	15:05	15:05			16:29	16:29
Park	KQ413	EBB	16:35	16:35			22:23	22:23
Dep	KQ413	EBB	22:29	22:29			23:59	23:59
Full	KQ415	EBB	19:25	20:11	KQ488	DAR	22:55	23:45
Full	KQ417	EBB	22:15	21:20	KQ466	KGL	23:20	23:39
Full	KQ419	EBB	6:35	5:29	KQ432	JRO	8:00	8:31
Arr	KQ433	JRO	10:45	10:33	KQ444	BJM	12:09	11:57
Park	KQ433	JRO	12:15	12:03	KQ444	BJM	14:34	14:44
Dep	KQ433	JRO	14:40	14:50	KQ444	BJM	16:10	16:20
Full	KQ437	JRO	22:00	21:13			23:59	23:59
Arr	KQ444	BJM	21:15	21:15	KQ650	KIS	22:39	22:39
Park	KQ444	BJM	22:45	22:45	KQ650	KIS	5:14	6:22
Dep	KQ444	BJM	5:20	6:28	KQ650	KIS	6:50	7:58
Full	KQ444	BJM	21:15	21:34	KQ498	ZNZ	23:00	23:20
Arr	KQ447	KGL	6:05	6:01	KQ748	APL	7:29	7:25
Park	KQ447	KGL	7:35	7:31	KQ748	APL	10:49	11:15
Dep	KQ447	KGL	10:55	11:21	KQ748	APL	12:25	12:51
Arr	KQ448	BJM	12:50	12:50	KQ486	DAR	14:14	14:14
Park	KQ448	BJM	14:20	14:20	KQ486	DAR	17:14	18:08
Dep	KQ448	BJM	17:20	18:14	KQ486	DAR	18:50	19:44
Full	KQ481	DAR	11:10	11:59	KQ586	NLA	12:30	12:50
Full	KQ483	DAR	15:30	15:39	KQ414	EBB	16:20	16:43
Arr	KQ485	DAR	19:20	18:28	KQ448	BJM	20:44	19:52
Park	KQ485	DAR	20:50	19:58	KQ448	BJM	6:09	6:09
Dep	KQ485	DAR	6:15	6:15	KQ448	BJM	7:45	7:45
Full	KQ485	DAR	19:20	18:16	KQ734	LUN	22:45	23:08
Arr	KQ487	DAR	22:15	22:15	KQ256	TNR	23:39	23:39
Park	KQ487	DAR	23:45	23:45	KQ256	TNR	11:09	12:22
Dep	KQ487	DAR	11:15	12:28	KQ256	TNR	12:45	13:58
Full	KQ487	DAR	22:15	21:59			23:59	23:59
Full	KQ489	DAR	6:40	6:27	KQ494	ZNZ	8:05	8:15
Full	KQ495	ZNZ	11:15	10:26	KQ482	DAR	12:05	12:13
Full	KQ509	ACC	6:10	5:55	KQ760	JNB	8:30	10:12
Full	KQ521	ABJ	6:20	7:25	KQ504	FNA	10:35	10:48
Full	KQ522	NSI	21:40	22:37			23:59	23:59
Arr	KQ524	DLA	18:20	17:30	KQ522	NSI	19:44	18:54
Park	KQ524	DLA	19:50	19:00	KQ522	NSI	9:44	10:09
Dep	KQ524	DLA	9:50	10:15	KQ522	NSI	11:20	11:45
Arr	KQ533	LOS	19:50	19:50	KQ542	COO	21:14	21:14
Park	KQ533	LOS	21:20	21:20	KQ542	COO	6:19	7:08
Dep	KQ533	LOS	6:25	7:14	KQ542	COO	7:55	8:44
Arr	KQ537	ABV	18:25	16:57			19:49	18:21
Park	KQ537	ABV	19:55	18:27			22:23	22:23
Dep	KQ537	ABV	22:29	22:29			23:59	23:59
Full	KQ542	LOS	21:00	21:53			23:59	23:59
Full	KQ555	FIH	20:25	20:09	KQ112	CDG	23:05	23:18
Arr	KQ584	FBM	20:05	20:05	KQ252	HAH	21:29	21:29
Park	KQ584	FBM	21:35	21:35	KQ252	HAH	9:54	10:12
Dep	KQ584	FBM	10:00	10:18	KQ252	HAH	11:30	11:48
Full	KQ586	NLA	20:05	19:38			23:59	23:59
Arr	KQ601	MBA	9:30	9:20			10:54	10:44
Park	KQ601	MBA	11:00	10:50			22:23	22:23
Dep	KQ601	MBA	22:29	22:29			23:59	23:59
Full	KQ603	MBA	11:10	11:20	KQ762	JNB	12:05	12:29
Full	KQ605	MBA	12:55	12:45	KQ352	JUB	13:40	15:14
Full	KQ607	MBA	15:35	15:25	KQ610	MBA	16:25	16:35
Full	KQ609	MBA	16:55	17:10	KQ616	MBA	18:50	19:52
Full	KQ611	MBA	19:05	18:55	KQ618	MBA	19:50	20:38
Arr	KQ617	MBA	21:30	21:20	KQ600	MBA	22:54	22:44
Park	KQ617	MBA	23:00	22:50	KQ600	MBA	5:14	6:05
Dep	KQ617	MBA	5:20	6:11	KQ600	MBA	6:50	7:41
Full	KQ617	MBA	21:30	21:20	KQ418	EBB	22:55	23:59
Arr	KQ619	MBA	22:40	22:25	KQ350	JUB	0:04	23:49
Park	KQ619	MBA	0:10	23:55	KQ350	JUB	6:14	7:04
Dep	KQ619	MBA	6:20	7:10	KQ350	JUB	7:50	8:40
Full	KQ625	MBA	6:15	6:10	KQ640	MYD	8:55	8:55
Full	KQ641	MYD	11:45	12:57	KQ606	MBA	12:55	13:34
Full	KQ651	KIS	9:10	9:00	KQ654	KIS	9:55	10:03
Full	KQ655	KIS	12:15	12:00	KQ656	KIS	13:05	13:05

Inbound					Outbound			
Flight Type	Fl No.	Origin	ETA	ATA	Fl No.	Dest	ETD	ATD
Full	KQ657	KIS	15:25	15:17	KQ670	KIS	17:30	17:40
Arr	KQ671	KIS	19:50	19:50	KQ480	DAR	21:14	21:14
Park	KQ671	KIS	21:20	21:20	KQ480	DAR	6:09	7:49
Dep	KQ671	KIS	6:15	7:55	KQ480	DAR	7:45	9:25
Full	KQ671	KIS	19:50	19:01			23:59	23:59
Arr	KQ704	LUN	20:30	20:30	KQ250	SEZ	21:54	21:54
Park	KQ704	LUN	22:00	22:00	KQ250	SEZ	9:54	11:24
Dep	KQ704	LUN	10:00	11:30	KQ250	SEZ	11:30	13:00
Full	KQ704	LUN	20:30	19:40	KQ764	JNB	21:50	23:07
Full	KQ717	GBE	6:50	7:45	KQ730	LLW	8:15	8:44
Full	KQ720	HRE	6:50	7:42	KQ604	MBA	10:15	10:29
Full	KQ731	LLW	13:30	13:20	KQ484	DAR	15:55	17:14
Full	KQ749	APL	18:05	17:50	KQ436	JRO	19:20	20:05
Arr	KQ752	BLZ	19:45	19:45	KQ410	EBB	21:09	21:09
Park	KQ752	BLZ	21:15	21:15	KQ410	EBB	6:24	6:34
Dep	KQ752	BLZ	6:30	6:40	KQ410	EBB	8:00	8:10
Full	KQ761	JNB	17:40	16:53	KQ204	BOM	21:25	22:37
Full	KQ763	JNB	21:25	21:40	KQ304	DXB	22:30	23:10
Full	KQ765	JNB	6:55	6:35	KQ602	MBA	8:30	8:39
Full	KQ8603	MBA	12:25	12:08	KQ8606	MBA	14:00	14:17
Full	KQ8607	MBA	16:45	16:25	KQ8608	MBA	19:30	20:25
Arr	KQ8609	MBA	22:15	22:15	KQ8602	MBA	23:39	23:39
Park	KQ8609	MBA	23:45	23:45	KQ8602	MBA	8:04	8:27
Dep	KQ8609	MBA	8:10	8:33	KQ8602	MBA	9:40	10:03
Full	KQ8609	MBA	22:15	22:02			23:59	0:29
Full	KQ8651	KIS	8:30	7:37	KQ8690	UKU	9:10	9:30
Arr	KQ8655	KIS	20:00	20:00	KQ8650	KIS	21:24	21:24
Park	KQ8655	KIS	21:30	21:30	KQ8650	KIS	4:54	5:09
Dep	KQ8655	KIS	5:00	5:15	KQ8650	KIS	6:30	6:45
Full	KQ8655	KIS	20:00	20:13			23:59	23:59
Full	KQ8661	EDL	9:00	8:50	KQ8680	LAU	9:40	9:44
Arr	KQ8665	EDL	19:10	19:10	KQ8660	EDL	20:34	20:34
Park	KQ8665	EDL	20:40	20:40	KQ8660	EDL	5:24	5:24
Dep	KQ8665	EDL	5:30	5:30	KQ8660	EDL	7:00	7:00
Full	KQ8665	EDL	19:10	18:58			23:59	23:59
Full	KQ8681	MYD	13:30	13:41	KQ8654	KIS	18:00	18:00
Full	KQ8691	UKU	11:30	11:53	KQ8692	UKU	14:10	14:10
Full	KQ8693	UKU	16:30	15:47	KQ8664	EDL	17:10	17:33
Arr	KQ887	BKK	6:45	6:45	KQ886	BKK	8:09	8:09
Park	KQ887	BKK	8:15	8:15	KQ886	BKK	21:34	21:56
Dep	KQ887	BKK	21:40	22:02	KQ886	BKK	23:10	23:32
Full	LX294	ZRH	18:40	18:50	LX295	DAR	19:35	19:55
Full	MK534	MRU	11:50	12:20	MK535	MRU	13:05	13:31
Full	MS849	CAI	7:10	7:20	MS850	CAI	8:10	8:20
Full	PW715	ZNZ	21:15	22:35			23:59	23:59
Full	PW723	JRO	7:00	6:10	PW722	JRO	8:30	8:30
Arr	PW725	JRO	19:20	18:15	PW710	ZNZ	20:44	19:39
Park	PW725	JRO	20:50	19:45	PW710	ZNZ	6:34	6:49
Dep	PW725	JRO	6:40	6:55	PW710	ZNZ	8:10	8:25
Full	PW725	JRO	19:20	18:10			23:59	23:59
Full	PW727	JRO	16:00	15:05	PW726	JRO	16:50	17:23
Full	QR1337	DOH	9:30	9:45	QR1338	DOH	12:35	12:45
Full	QR1339	DOH	13:10	13:20	QR1340	DOH	17:35	17:45
Full	SA184	JNB	15:15	15:25	SA185	JNB	16:05	16:15
Full	SN463	BRU	21:45	22:15	SN463	BRU	22:45	22:55
Full	SV431	JED	11:32	11:42	SV430	JED	13:10	13:20
Full	TK6510	FIH	18:30	17:39	TK6492	IST	21:00	21:10
Full	TM4462	MPM	14:25	14:37	TM4463	MPM	15:45	15:53
Full	WB402	KGL	15:40	16:03	WB403	KGL	16:30	17:00
Full	WB450	EBB	10:40	10:50	WB450	KGL	11:25	11:35
Full	WB460	KGL	20:15	20:30	WB460	EBB	21:35	22:05
Full			6:50	6:50	KQ210	BOM	7:50	8:45
Full			22:25	22:25	KQ102	LHR	23:25	1:21
Arr	CZ633	CAN	7:00	7:00	CZ634	CAN	8:24	8:24
Park	CZ633	CAN	8:30	8:30	CZ634	CAN	11:59	12:09
Dep	CZ633	CAN	12:05	12:15	CZ634	CAN	13:35	13:45
Full	EK721	DXB	19:00	19:10	EK722	DUB	22:50	22:50
Arr	SA180	JNB	22:40	22:40	SA181	JNB	0:04	0:04
Park	SA180	JNB	0:10	0:10	SA181	JNB	6:54	7:09
Dep	SA180	JNB	7:00	7:15	SA181	JNB	8:30	8:45
Full	TK607	IST	7:25	7:15	TK608	IST	10:35	10:51