# Delft University of Technology

Faculty of Aerospace Engineering

Department of Air Transport and Aerospace Operations


MSc Thesis

# Improving the performance of the turnaround process using Value Operations Methodology


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## Preface

This research is conducted at the department of Air Transport and Aerospace Operations at the faculty of Aerospace Engineering at Delft University of Technology. The research is an MSc thesis to complete the Master of Science in Air Transport and Aerospace Operations.

The focus of this research is to develop a value model for the turnaround process at the airport, based on value-focused thinking, specifically, Value Operations Methodology (VOM). The main purpose of this value model is to evaluate alternative strategies with which the turnaround process can be performed from the perspective of stakeholders. Ultimately, to determine the strategy that adds as much value for the stakeholders within turnaround process.

During this MSc Thesis, I received many supports and guidance to be able to achieve the results presented in this paper. Therefore, I would like thank my supervisor prof. dr. Ricky Curran for his valuable feedback, guidance, understanding, and patience. I would like also to thank Greg O'Callaghan for his provision of data from Kenya Airways. Without this data I would not be able to perform the calculations and complete the thesis.

My special thanks go to my parents who supported me and motivated me during my entire life. Without their support and their faith in me, I would not be able to have come this far.

Thank you all.

Yours Truly,

M'hamed Samsam

Delft University of Technology,

September, 2015

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## List of Symbols

| | |
|---|---|
| AHP: | Analytical Hierarchy Process |
| ATC: | Air Traffic Control |
| CI: | Consistency Index |
| CPF: | Corner Point Feasible |
| DMAIC: | Define Measure Analyze Improve Control |
| FTA: | Flight Turnaround Application |
| JKIA: | Jomo Kenyatta International Airport |
| KPI: | Key Performance Indicator |
| KQ: | Kenya Airways |
| PDA: | Portable Digital Assistant |
| RC: | Random Consistency Index |
| STA: | Scheduled Time of Arrival |
| STD: | Scheduled Time of Departure |
| VOM: | Value Operations Methodology |

## Summary

By improving the performance of turnaround process, there would be multiple benefits for the airlines and the airports. Cost can be saved and more profit can be made. Most available literatures on the turnaround process focused on reducing the turnaround time, or improving its punctuality. The novelty of this MSc thesis is to determine a strategy that improves the performance of turnaround process based on all its value drivers from the perspective of stakeholders. This had led to the research question:

***"How can a change in value be measured for relevant stakeholders within turnaround process when evaluating new ideas in improving its performance?"***

The methodology implemented in approaching this research and ultimately, answering the research question, is to develop a value model of the turnaround process based on value-focused thinking, specifically, value operations methodology (VOM). With this value model, the alternative strategies aiming at improving the performance of turnaround process can be evaluated. Eventually, the strategy that adds as much value for the relevant stakeholders can be determined.

However, VOM lacked details and further developments. The main improvements implemented in VOM in this research are:

- VOM lacked a detailed approach with which the identification and the selection of relevant stakeholders could be performed. After a detailed analysis of the methods proposed by previous MSC researches Smulders (2010); Repko (2011); and Bennebroek (2012), it was proposed to use the same approach as defined by Bennebroek (2012). Except instead of using the numerical method to rank and classify the stakeholders based on their potential for threat and cooperation, a new qualitative method is defined. This qualitative method is more practical, easier to perform, and more self-evident compared to numerical method.
- In the formulation of set of objectives, again VOM lacked a clear method on how to perform this step. It is also proposed to use the same systematic approach as defined by Bennebroek (2012). Except, in a different order and with additional steps in order to ensure a proper formulation of objectives.
- VOM states that Analytical Hierarchy Process (AHP) is the method used in determining the weight factors of the formulated objectives. However, AHP lacked two main steps namely, the rating scale and the recombination of assessments from relevant stakeholders. Therefore, it was proposed to use power series rating scale with base a=2. According to the analysis, this rating scale fits more with AHP than the proposed rating scale in previous MSC research namely, Bennebroek (2012). While in order to recombine different assessments from relevant stakeholders, it is proposed to use AHP twice. It will be used to determine the importance of relevant stakeholders relative to their firm or to their organization, and it will be used to determine the weight factors of the formulated objectives according to each relevant stakeholder. Finally, the objective weight factors for all relevant stakeholders are determined by multiplying vector V by matrix A. Vector V contains the weights which determine the importance

of relevant stakeholders relative to the centered firm. While matrix A contains the weight factors of objectives according to each relevant stakeholder.

- For the formulation of attributes, this step is considered relatively clear as defined in VOM. Thus no major additions have been made.
- For the determination of attributes weight factors in VOM, it is proposed to use AHP with power series rating scale with base a=2. Since this rating scale fits more with AHP than the proposed rating scales in previous MSc researches on VOM namely, Smulders (2010), Repko (2011), and Bennebroek (2012).
- The last step in VOM is to combine all into one model in order to evaluate the alternatives relative to the reference situation, based on added value for the relevant stakeholders. As stated in previous MSC researches namely, Repko (2011) and Bennebroek (2012), the consistent ratios will be applied and the feasible ranges will be introduced to the attributes before including them in the value model. This is in order to avoid mathematical issues during calculations.

With this improved version of VOM, the value model of the turnaround process is developed. By using this value model, the relevant stakeholders within turnaround process are identified: airport operator, airline operator, air traffic control, passengers, and national government. As well as, the value drivers within turnaround process are determined: cost, turnaround time, safety, environmental impacts, comfort level, and reliability. Here, the reliability is defined as on-time performance. The importance of these value drivers is determined based on literature review and previous MSc researches on VOM namely, Repko (2011) and Bennebroek (2012). Equation (0.1) represents the value model of the turnaround process.

$$\Delta V = 0.0662\frac{C_1}{C_0} + 0.1573\frac{T_1}{T_0} + 0.3431\frac{S_1}{S_0} + 0.1093\frac{En_1}{En_0} + 0.0756\frac{Cl_1}{Cl_0} + 0.2478\frac{R_1}{R_0} \qquad (0.1)$$

Where C represents cost; T represents turnaround time; S represents safety; En represents environmental impacts; and R represents reliability. This equation is used to answer the proposed research question.

The turnarounds performed by Kenya Airways (KQ) at Jomo Kenyatta International Airport (JKIA) of Boeing 737-300 from January till June 2012 are used as a case study in this research. Due to time span of this MSc thesis, it was decided to focus only on turnaround sub processes on the critical path. These turnaround sub processes are: passengers disembark, catering, cabin cleaning, fueling, and passengers boarding.

Due to unavailability of data, only the performance of turnaround time and reliability of the current strategy implemented in the turnaround sub processes on the critical path are determined. However, first the external factors are investigated. If there is an effect of an external factor on a turnaround sub process, then this effect is extracted out of data. The available external factors on data are: amount of passengers and bags on outbound flight, airport busyness, type of parking bay, and length of outbound flight. The results of the current strategy without the effect of the external factors of turnaround sub processes on the critical path of (KQ) at (JKIA) are summarized in figure (0.1). In this figure, the duration and standard deviation denote turnaround time and reliability respectively.

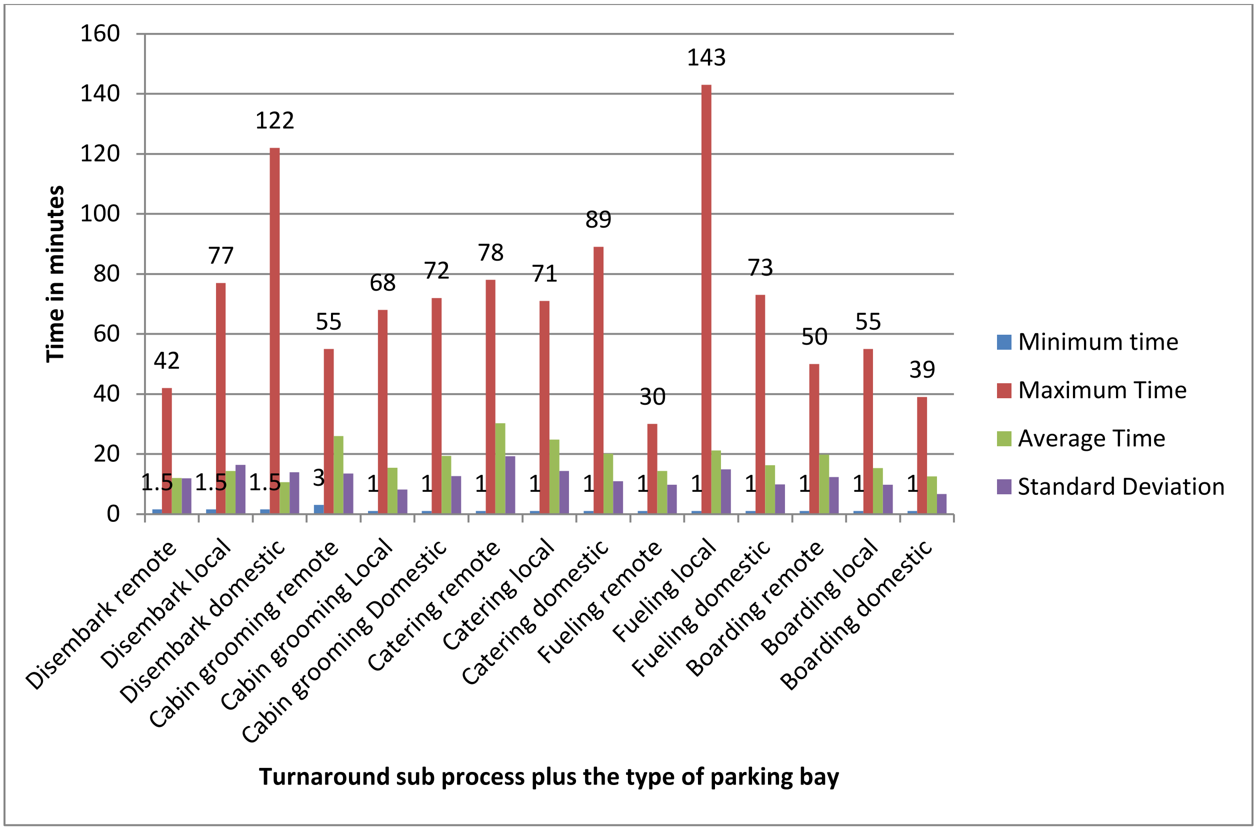
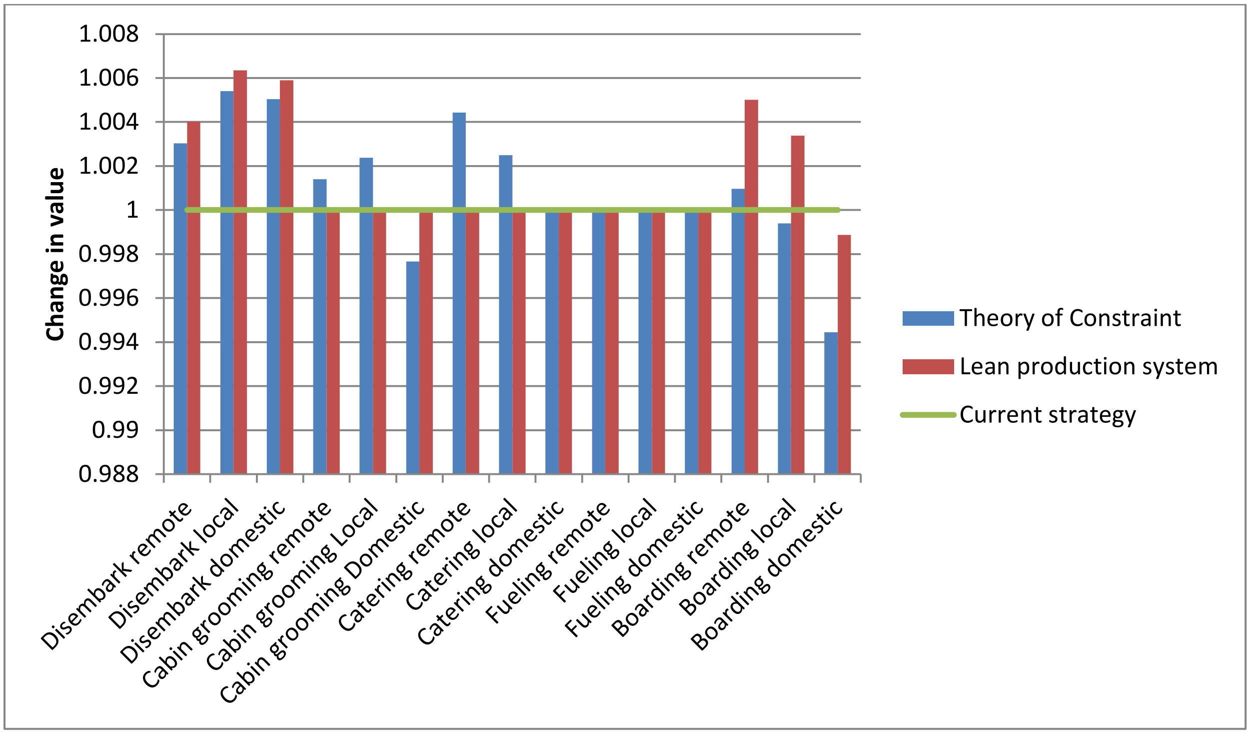



Figure 0-1: Summary of current performance of turnaround sub processes of (KQ) at (JKIA)

The performance of the turnaround time and the reliability of two alternatives namely, theory of constraints and lean production system are estimated, if implemented by (KQ) at (JKIA). By using the value model of the turnaround process, the performances of these alternative strategies are evaluated as can be seen in figure (0.2). If the change in value is larger than 1, then the alternative strategy adds more value, if it equals 1 then it adds equal value, and if it is smaller than 1 then it adds less value. Based on these results, it is recommended to implement the solutions proposed by lean production system within passengers disembark and boarding, and to implement the solutions proposed by theory of constraints within catering and cabin cleaning.  The reason why lean production system and theory of constraints add less value than the current strategy for cabin grooming and boarding at domestic parking bays, because of the inaccurate estimations of the reliability at domestic parking bays.

There is no change in value of fueling sub process at (JKIA) of alternative strategies relative to the current strategy. This is because both alternative strategies did not implement any improvements in fueling sub process.

This research has number of contributions to the academia and also to airport airline operations (turnaround process). The main contribution to the academia is to further develop VOM in order to make it a feasible decision supporting tool. This tool can be used by the executers and managers in different aerospace and industrial operations to enhance their decision making performance. This will lead to better performance of their operations. On the other hand, the main contribution to turnaround process is to enhance the capabilities of relevant stakeholders to decide whether an alternative strategy is an improvement from their perspective.

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# 1. Introduction

In this chapter, an introduction into the research will be provided by first defining the problem statement in section (1.1), followed by defining the research scope and the methodology used in approaching this research, which are covered in section (1.2). At the end of this chapter, the report structure will be provided in section (1.3).

## 1.1 Problem Statement

One of the daily operations that a civil airplane goes through is the turnaround of ground handling process or what commonly known as turnaround process. The entire process takes place on airside and landside of the airport (Ashford, Coutu & Beasley, 2013). However, during this research the focus lies only on operations which are performed on the airside namely, at the aircraft parking stands. The turnaround process starts when the aircraft arrives at the parking stand, which is known as in-block or on-chocks. The process finishes when the aircraft is pushed back out of the parking stand, which is known as off-blocks or off-chocks (Leeuwen & Witteveen, 2009).

The time required for all activities or sub processes within turnaround process to be performed and completed, is referred to as turnaround time. This turnaround time depends on several external and internal factors. The external factors are: aircraft type, airport busyness, type of parking bay, amount of passengers on inbound and outbound flight, amount of baggage and cargo on inbound and outbound flight, length of outbound flight, and delay of inbound flight (O'Callaghan, 2012). The internal factors that need to be investigated could be the management and the strategies implemented behind the execution of turnaround sub processes.

By improving the performance of turnaround process (e.g. reducing the turnaround time), there would be multiple benefits for the airlines and also for the airports; costs can be saved and more profit can be made due to higher usability of aircraft (Beelaerts van Blokland,  Huijzer, Stahls & Santema, 2008). Also, the punctuality of airlines and airports can be enhanced by decreasing the amount of delays caused by turnaround process. Figure (1.1) indicates how large the contribution of turnaround process to delays occurred between September 2010 and September 2011 at Kenya Airways (KQ). This accounts for 28% (Schellekens, 2011), and as illustrated in figure (1.1), the turnaround process is the second largest contributor to delays after network connectivity. This proves how significant the performance of turnaround process is to airlines and airports.

The previous research (O'Callaghan, 2012), focused on improving the flight schedule by developing a model which accurately predicts the duration of turnaround sub processes on the critical path, and by doing so the delays which are caused by turnaround process could be reduced. This research focuses on evaluating the management and the strategies behind the execution of turnaround sub processes and eventually, determining the strategy that adds as much value for the relevant stakeholders within turnaround process.

The main purpose of this thesis is to develop a value model for the turnaround process, based on value focused thinking, specifically, value operations methodology (VOM). This model will be used to evaluate alternative strategies aiming at improving the performance of turnaround process from the perspective of stakeholders. This leads to the following research question:

***"How can a change in value be measured for relevant stakeholders within turnaround process when evaluating new ideas in improving its performance?"***

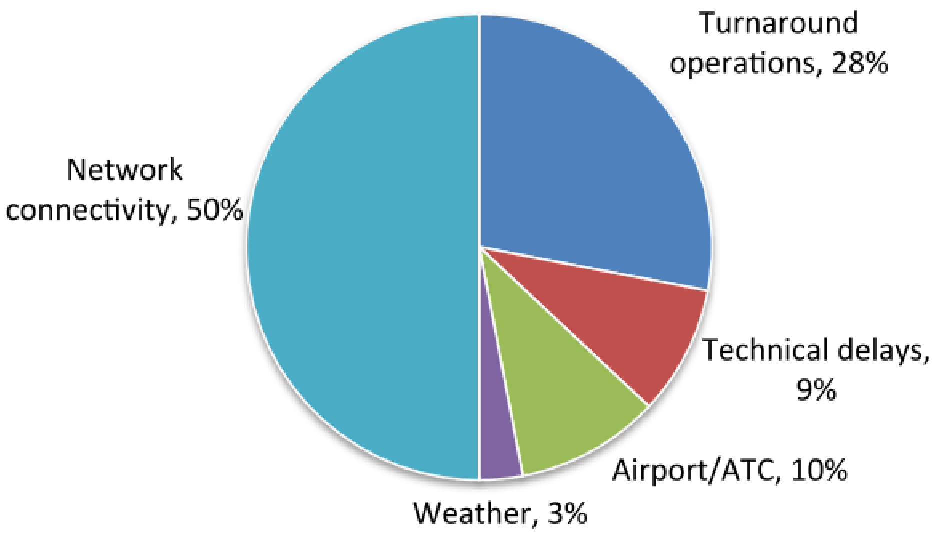


Figure 1-1: A breakdown of delays occurred between September 2010 and September 2011 at Kenya Airways (KQ) (O'Callaghan, 2012); (Schellekens, 2011)

## 1.2 Research scope

This section elaborates on methodology used in approaching and conducting the research, as well as the hypotheses which will be tested during this MSc thesis. Subsection (1.2.1), defines the sub questions which need to be answered in order to answer the research question. Subsection (1.2.2) describes the methodology implemented in this research. Subsection (1.2.2), determines the hypothesis which will be tested during this research.

### 1.2.1 Identification of Sub-questions

The problem has been divided into three main sub questions which are further subdivided into elements necessary to answer the main research question. The sub questions are proposed as follows:

**Q1: What is the current concept of turnaround process?**

i) What activities or sub processes constitute the current concept of turnaround process?
ii) How many types of turnaround process are there? And how they are defined?
iii) Which turnaround sub processes have high potential in improving the performance of turnaround?
iv) What are the involved stakeholders and their responsibilities within turnaround process?

v) How are the tasks divided within turnaround process?

vi) What are the key performance indicators (KPIs) of turnaround process?

vii) What statistical methods can be used to analyze and compute the performance of turnaround process?

The first sub question aims at defining the current concept of turnaround process and the involved actors including their roles and responsibilities.

**Q2: How can the current concept of turnaround process be improved or optimized?**

i) What are the lean principles? And how could they be implemented in improving the current concept of turnaround process?

ii) What are the linear and nonlinear optimization techniques which have the potential to be used in optimizing the current concept of turnaround process?

The aim of this sub question is to describe the improvement and optimization techniques, which can be used in creating meaningful alternative strategies of turnaround process aiming at improving its performance.

**Q3: How is value defined?**

i) What is value-focused thinking? And how is it different than the traditional alternative-focused thinking?

ii) How is value operations methodology (VOM) developed?

iii) What are the current limitations of VOM?

iv) How can VOM be further developed?

The objective of this sub question is to define the current state of VOM, which is still under development phase and discover its current limitations. These limitations should be improved in order to be used to set up the value model of the turnaround process, which enables the evaluation of alternatives based on added value for relevant stakeholders.

### 1.2.2 Methodology

The methodology implemented in this research is illustrated in figure (1.2). The first step is to perform the literature study on the main topics of this research which are; turnaround process, value operations methodology (VOM), and improvement and optimization techniques. Subsequently, the theoretical improvements of VOM will be performed based on previous MSC researches on VOM and their recommendations. Step four in the methodology is to use the improved version of VOM to set up the value model of the turnaround process. This value model will identify the value drivers of the turnaround process and their weight factors, which determine their importance compared to each other from the perspective of stakeholders. Subsequently, a case study will be performed at (KQ) in which their turnarounds performed between January to June (2012) at (JKIA), will be statistically analyzed in order to estimate the performance of the value drivers of the turnaround process. This performance will be considered as the performance of the current strategy with which the turnaround processes are performed at KQ. Step six and seven in the methodology are to define the alternative strategies and to estimate their performance respectively. Eventually, the value model of the turnaround will be applied to determine the strategy that adds as much value for the relevant stakeholders. This will answer the main research question on which this thesis is based.

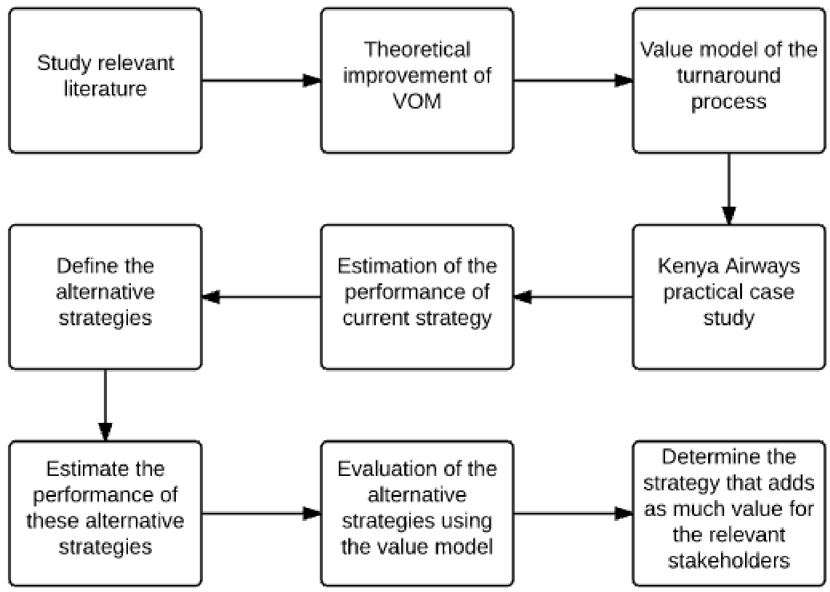


**Figure 1-2: Research methodology**

### 1.2.3 Research Hypothesis

The research focuses on two main areas:

- Developing a value model which will improve the capabilities of relevant stakeholders within turnaround process to decide whether an alternative strategy is an improvement relative to the current state
- By improving the strategies behind the execution of turnaround process will lead to better performance

The focus of these two main areas has led to the following two hypotheses:

1. ***The value model of the turnaround process will improve the decision making process of relevant stakeholders to decide whether an alternative strategy or a new idea is an improvement***
2. ***Modifying the current strategy within the turnaround process will enhance its performance***

## 1.3 Report Structure

The report consists of six chapters and (3) appendices. Starting with chapter (1) in which the problem definition and the research scope are defined. Chapter (2) deals with literature review in which all relevant literatures and information are covered in order to answer the proposed sub questions and their elements. Chapter (3) covers the theoretical background of VOM in which the theoretical improvements are implemented in order to make VOM a feasible decision supporting tool. Moving on to chapter (4), in which the improved version of VOM will be implemented in developing the value model of the turnaround process. This model should be able to evaluate the alternative strategies based on added value for relevant stakeholders. Chapter (5) deals with (KQ) practical case study in which the performance of the current state of their turnarounds performed from January until June 2012 will be analyzed and defined. Thereafter, the performance of alternative strategies will be evaluated relative to the current state by using the value model of the turnaround process. Finally, the conclusions and recommendations are provided in chapter (6).

# 2 Literature Study

This chapter consists of four main sections. Section (2.1) describes the current concept of turnaround process and the involved stakeholders and their responsibilities. Section (2.2) introduces the main improvements and optimization techniques which can be implemented in creating meaningful alternatives of turnaround process. Section (2.3) explains the philosophy behind VOM and its current development phase. Finally, section (2.4) summarizes the main contents of these covered literatures and synthesizes the information gathered from them.

## 2.1 Current Concept of Turnaround Process

### 2.1.1 Organization of Turnaround Activities

The turnaround activities at aircraft parking stand or the so-called apron gate system, can be divided into four types of services namely, ramp services, on-ramp aircraft servicing, onboard servicing and external ramp equipment (Ashford et al., 2013). The activities under each type of these services are listed in table (2.1). These turnaround activities or sub processes are organized and performed in the order illustrated in figure (2.1). Note that each of these activities can be further divided into one or more sub activities. The main flows within turnaround process are; baggage and cargo flow, passenger and cabin flow, fueling flow and aircraft technical services flow (Leeuwen, 2007). If an activity on a specific flow or path is delayed, it affects the subsequent activities on that path such that, they start later than originally scheduled depending on the amount of delay.

Planning and managing the apron is a complex task, because the number of aircraft parking areas that are required for efficient operations depends on number of factors. Among these factors are; number and type of aircraft scheduled to use an aircraft parking stand, each aircraft's scheduled turnaround time, and the type of gate usage agreement between airline and airport (Wijnen, 2013, p. 52).

**Table 2-1: Turnaround sub processes under each type of services at aircraft parking stand (Ashford et al., 2013); (Smulders, 2010)**

| Ramp services | Aircraft ramp servicing | Onboard servicing | External ramp equipment |
|---|---|---|---|
| • **Supervision**<br>• **Marshaling**<br>• **Start up**<br>• **Pushback**<br>• **Safety measures** | • Repair of faults<br>• Fueling<br>• Wheels and tires check<br>• Ground power supply<br>• Deicing<br>• Cooling/heating<br>• Toilet servicing<br>• Potable water<br>• Routine and Non-routine maintenance<br>• Walk around check | • Cleaning<br>• Catering | • Passengers Boarding<br>• Passengers disembark<br>• Loading of baggage/cargo/mail<br>• Unloading of baggage/cargo/mail |

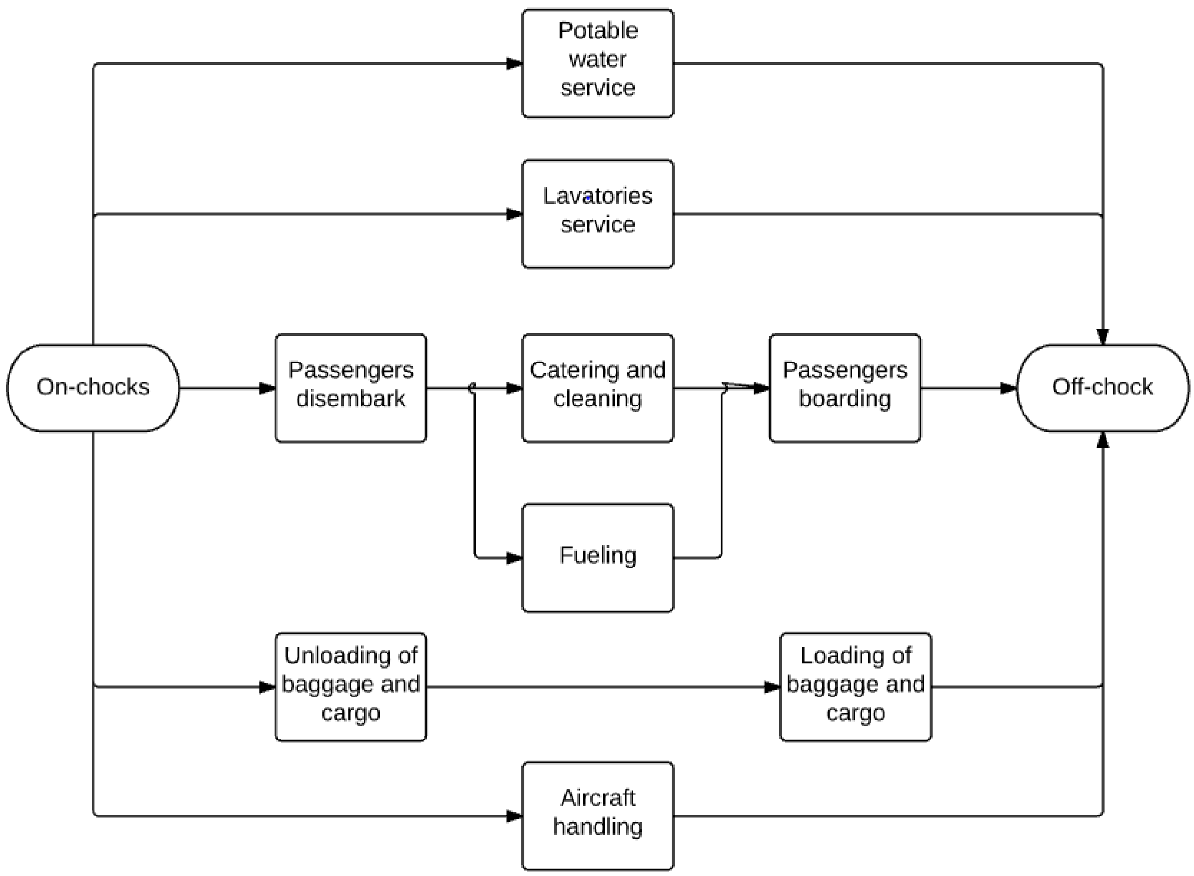


Figure 2-1: High level work flow of a general concept of turnaround process based on following literatures (Vidosavljevic & Tosic, 2010); (O'Callaghan, 2012); (Leeuwen, 2007)

Most of turnaround activities which are listed in table (2.1) and cannot be visualized in figure (2.1), are either supporting or safety related activities (See table (2.2)).

Table 2-2: Division of activities within turnaround process (Huisjer, 2008)

| Supporting activities | Safety related activities | Value adding activities |
|---|---|---|
| • Placing boarding stairs<br>• Removing boarding stairs<br>• Connecting passenger bridge<br>• Disconnecting passenger bridge<br>• Clamping by push-back truck | • Placing wheel chocks nose landing gear<br>• Placing safety cones<br>• Placing wheel chocks main landing gear<br>• Removing safety cones<br>• Removing wheel chocks nose landing gear<br>• Pre-departure service<br>• Removing wheel chocks main landing gear | • Connecting GPU<br>• Unloading baggage and freight<br>• Loading baggage and freight<br>• De-boarding<br>• Boarding<br>• Catering service<br>• Cabin cleaning<br>• Cabin check<br>• Cabin security check<br>• Fuel service |

| | |
|---|---|
| | • Water service<br>• Toilet service<br>• Technical handling<br>• Disconnecting GPU |

The turnaround sub processes are carried out by airline, by airport, or by a mix of handling companies either hired by airline, by airport, or by airline and airport, depending on the situation at a specific airport (Ashford et al, 2013). Table (2.3) illustrates the tasks divisions of turnaround activities at Schiphol Amsterdam Airport (SAA).

**Table 2-3: Distributions of responsibilities of turnaround operations at SAA (Moore, Stanton & Ashford, 1996)**

| Turnaround activities | Amsterdam Netherlands |
|---|---|
| **Ramp services:** | |
| • **Supervision** | Handling company for the airport and airline |
| • **Marshaling** | Airport |
| • **Start-up** | Airlines and handling company for airline |
| • **Moving/towing aircraft** | - |
| • **Safety measures** | Airport |
| **On-ramp aircraft servicing:** | |
| • **Repair of faults** | Handling company for airline |
| • **Fueling** | Handling company for airline |
| • **Wheel and tire check** | Handling company for airline |
| • **Ground power supply** | Handling company for airline |
| • **Deicing** | Handling company for airline |
| • **Cooling/heating** | Handling company for airline |
| • **Toilet servicing** | Handling company for airline |
| • **Portable water** | Handling company for airline |
| • **Demineralized water** | Handling company for airline |
| • **Routine maintenance** | Handling company for airline |
| • **Non routine maintenance** | Handling company for airline |
| • **Cleaning of cockpit, windows…** | Handling company for airline |
| **Onboard servicing** | |
| • **Cleaning** | Handling company for airline |
| • **Catering** | Handling company for airline |
| • **In-flight entertainment** | Handling company for airline |
| • **Cabin fitting and alteration of seat configuration** | Handling company for airline |
| **External ramp equipment:** | |
| • **Passenger steps** | Handling company for airline |
| • **Catering loaders** | Handling company for airline |
| • **Mail and equipment loading** | Handling company for airline |
| • **Baggage loading or de-loading** | Handling company for airline |
| • **Crew steps (freight aircraft)** | Handling company for airline |

| | |
|---|---|
| • **Apron passenger busses and mobile lounges** | Airport |

### 2.1.2 Airport Stakeholders and Their Responsibilities

The performance of turnaround process may affect all airport stakeholders. These stakeholders can be classified into four groups namely, airport, airline, user, and non-user (Ashford et al, 1996). These groups can be further subdivided into different organizations or actors as could be seen in table (2.4).Within turnaround process several operations and services are outsourced and carried out by third party companies or what commonly called ground handling companies or service providers (Smulders, 2010)**.** The responsibilities and interests of these stakeholders may differ within turnaround process and therefore, they should be clearly defined.

**Table 2-4: Airport stakeholders and their associated organizations (Repko, 2011); (Schaar & Sherry, 2010); (Zwaan, 2012)**

| Principal actor | Associated organizations |
|---|---|
| **Airport** | - Airport operator<br>- Local authorities and municipals<br>- Central government<br>- Concessionaires<br>- Investors and bond holders<br>- Suppliers<br>- Utilities<br>- Police<br>- Parking operators and ground transportation providers<br>- Fire service<br>- Ambulance and medical services<br>- Air Traffic Control<br>- Meteorology<br>- General aviation users (e.g. flight instruction, aircraft rental) |
| **Airline** | - Airline operator<br>- Service providers (supply of aviation fuel and oil, baggage handling and sorting, loading and unloading of aircraft, interior cleaning of aircraft, toilet and water service, passenger transport from/to remote stands, catering transport, routine inspection and maintenance at parking stands, aircraft starting, marshaling and parking, aircraft de-icing, passenger handling (e.g. ticketing am check-in), cargo and mail handling, information services preparation of handling and load-control documents, supervisory or administrative |

| | | |
|---|---|---|
| | | duties) |
| **Users** | - | Visitors |
| | - | Passengers |
| | - | Shippers of cargo/mail |
| **Nonusers** | - | Local community groups affected by airport operations |
| | - | Local chambers of commerce (represented by the local authorities) |
| | - | Anti-noise groups (represented by the local community groups) |
| | - | Environmental activists (represented by the local community/authorities) |
| | - | Neighborhood residents affected by airport operations (represented by the local community groups) |

The involved stakeholders and their responsibilities within turnaround process are briefly described as follows:

- **Airport operator**

Airport operator runs the airport and may responsible for the performance of all processes and operations from ground handling until air traffic control (Smulders, 2010). However, depending on the situation at a specific airport, several airport operations are outsourced to certain companies (third party companies or service providers) or to the airlines (Ashford et al, 2013).

- **Airline**

Airlines are the main players on the airport, providing air travel service to the users (Smulders, 2010)**.** In most airports in United States (US), airlines have extended their operations and they are responsible for carrying out the ground handling activities. Some of these airlines have even extended their operations to perform the ground handling activities for other airlines through interline agreements (Ashford et al., 1996).

- **Air Traffic Control (ATC)**

ATC is provided by ground based controllers and their major task is to guide and survey aircraft on the ground and in the air by means of visual or instruments. As well as to prevent collisions by separating aircraft, organize the flow of traffic efficiently and finally provide information and support to pilots. ATC has three priorities in the following order: safety, noise abatement and efficiency (Mulder & Borst, 2013). In some airports ATC is a military task (Smulders, 2010)**.**

- **Ground handling company**

As aforementioned, several activities in the airport such ground handling or security are outsourced to third party companies or service providers especially, the turnaround activities for instance: cleaning and catering companies, fuels suppliers, maintenance providers etc. if many activities are outsourced then a great number of companies will exist at a specific airport.

- **Users**

Passengers are the main users of the airport and they are the source of the income. Therefore, their interests should be highly considered.

- **Society**

This includes specifically the local residents living nearby the airport and also people working at the airport. The airport operator, airlines, ATC, and ground handlers should plan and conduct their operations with taking into consideration the local residents and employees' complaints and interests.

- **Government and local municipalities**

This group of stakeholders may include local municipalities or regional governments and also higher government on national level (Smulders, 2010). Their main responsibilities are to create and enforce rules and regulations which must be followed by the airports and the airlines in order to protect the local residents, the users, the employees etc. Their main interests are to create employment opportunities and to sustain the growth of the economy (Smulders, 2010).

Now that the current concept of turnaround process is introduced, the improvement and optimization techniques that may improve its performance are described in next section.

## 2.2 Improvement and Optimization Techniques

### 2.2.1 Improvement Techniques

The main improvement techniques which will be discussed in this subsection are; lean thinking on which the lean production system is based; theory of constraints; and lean Six Sigma.

#### *2.2.1.1 Lean Thinking*

Lean thinking is derived from Toyota Production System which is proved to outperform other existing production systems for instance: mass production. The key element of lean production is eliminating waste and creating value. Waste is defined as any activity which absorbs resources but creates no value (Womack & Jones, 1996). There are different types of waste, Toyota has defined seven major types of them which are listed in table (2.5) (Liker, 2004).

**Table 2-5: Seven major types of waste defined by Toyota (Liker, 2004)**

| Type of waste | Description |
|---|---|
| Correction /scrap | Mistakes which require rectification |

| | |
|---|---|
| **Over-production** | Producing too much and producing too early which leads to the growth of the stock and increase in labor hour for stock-control |
| **Waiting** | Any waiting due to breakdowns, changeovers, delays, poor layout or work sequence needs to be eliminated |
| **Conveyance** | Inefficient layouts and facility design results in conveying parts, materials and people more than necessary. |
| **Processing** | Over processing is as wasteful as insufficient processing. Employees must learn to identify over processing waste and perform appropriate amount of processing on parts without spending more time and efforts than is necessary |
| **Inventory** | The smooth continuous flow of work through each process ensures that excess amounts of inventory are minimized. Inventory often requires additional handling which results in additional labor and equipment |
| **Processing** | Over processing is as wasteful as insufficient processing. Employees must learn to identify over processing waste and perform appropriate amount of processing on parts without spending more time and efforts than is necessary |

In order to eliminate all waste and create value in a company or a certain process, lean thinking or philosophy has defined five lean principles that should be implemented. These five lean principles are (Womack & Jones, 1996):

1. Specify value
2. Identify value stream
3. Flow
4. Pull
5. Perfection

### Specify value

The starting point in lean thinking is to define value. According to Womack and Jones (1996), "value is defined as a capability provided to the customer at the right time and at an appropriate price, as defined in each case by the customer" (p. 311). What can be concluded from here is that the value should be defined by the end customer and it is only meaningful when expressed in terms of a specific product which fulfills the end customer's needs and requirements. Therefore, the first main criterion in specifying value is to discover what the end customer truly needs and wants and based on this, the product should be defined.

### Identify value stream

This step of lean thinking is the identification of value stream for each product. The value stream includes all actions required to bring a specific product through the three critical management tasks of any business (Womack & Jones, 1996):

- Problem solving task: Running from concept through detailed design and engineering to production launch

- Information management task: Running from order-taking through detailed scheduling to delivery
- Physical transformation task: Proceeding from raw materials to a finished product in the hands of the customer

An entire analysis of the value stream will always show that there are three types of actions that occur through the value stream (Womack & Jones, 1996):

- Steps that create value as perceived by the end customer
- Steps that do not create value but it cannot be removed from the process with current technology (type one waste)
- Steps that do not create value as perceived by end the customer and can be deleted (type two waste)

According to the lean principles the identified waste in value stream should be removed.

#### Flow

After the reduction and elimination of wastes from the value stream comes the third principle in lean thinking, which is the flow. This principle strives at creating value on the product continuously from the beginning to the final product. This will lead to the following (Womack & Jones, 1996):

- No Stoppages, scraps or backflows so that the production of the product can flow continuously
- Removing the traditional batch and queue system and implement just in time production
- Enabling quick changes of tools in manufacturing
- Right sizing machines and locating sequential steps adjacent to one another

#### Pull

This principle is defined as that no upstream should produce a product or a service until the customer downstream asks for it (Womack & Jones, 1996). Pull in production process means that a production step is only executed when it is pulled by the next step. This is in contrast with push system, which is unresponsive for customer and results in unnecessary inventory buildup (Womack & Jones, 1996).

#### Perfection

The last step in lean thinking suggests that there is no end to the previous four steps. In order to pursue perfection there should be a continuous implementation of radical and incremental improvements. Therefore, there exist always activities that are considered waste in the value stream which should be continuously eliminated (Womack & Jones, 1996).

By implementing these principles within turnaround process, an alternative scenario can be created which might have potentials to improve its performance.

### *2.2.1.2 Theory of Constraints*

Theory of constraints focuses on defining bottlenecks in processes and strives to eliminate them. This theory consists of five main steps (Goldratt, Cox & Whitford, 2004)**:**

1. Identify the system’s constraints
2. Decide how to exploit the system’s constraints
3. Subordinate everything else to the above decision
4. Elevate system’s constraints
5. If a constrain is moved, iterate the process

The first step is to identify the system’s constraints. These constraints can be either physical or non-physical. Examples of physical constraints are: people, material, machine etc. While examples of non-physical constraints are: procedures, ways of thinking, policy etc.

After the bottlenecks are identified, the second step is to decide how to exploit the constraints. There are multiple ways to reduce or completely solve the bottleneck problems. However they should be solved without undergoing expensive changes. One way to solve or reduce a bottleneck problem is to reduce or eliminate the downtime of bottleneck operations (Goldratt et al., 2004).

The third step in theory of constraints is to subordinate everything else to the above decision. In this step, the focus is not on the bottleneck but on the non-constraints processes upstream and downstream of the bottleneck. These upstream and downstream processes should operate such that the bottleneck operates at its maximum effectiveness. Thereafter, the system is evaluated. If there are no bottlenecks in the system due to step two and three, then one should proceed with step five. However, if bottlenecks have appeared in the system then one should proceed with step four.

The fourth step is to elevate the identified system’s constraints in step one since step two and three have not been successful. In this step a decision must be made in order to elevate the system’s constraints.

The completion of the fourth step has the result that the bottleneck is elevated which means that the problem is solved. However, since theory of constraints is an on-going process, one should keep applying it in order to strive for a continuous improvement.

By implementing theory of constraints within turnaround process, the current bottlenecks can be determined and number of improvements can be implemented to eventually remove these bottlenecks. By doing so, the current performance of turnaround process can be enhanced.

#### *2.2.1.3 Lean Six Sigma*

Lean Six Sigma is a combination of two powerful approaches namely lean principles and Six Sigma. By integrating both of these approaches into one approach will lead to further reduction in cost, lead-time and an increase in quality (Goerge, 2002). Lean focuses on reducing the non-added values from the process which enables faster lead-time and reduction in cost. While Six Sigma focuses on determining the root causes of problems and solving them effectively which enables less defects and higher quality of the process output.

There are five main stages known as DMAIC to implement Lean Six Sigma successfully. These phases are described as follows (Goerge, 2002):

- Define: confirm opportunities, define scope and goals, and identify teams and sponsors
- Measure: define current state, collect, and display data
- Analyze: Interpret data for cause and effect relationships, determine a measure of process capability, speed, sources of variation and bottlenecks
- Improve: develop solutions targeted at the confirmed causes and implement solutions
- Control: Standardization, monitor performance and mistake proofing

By implementing these stages within turnaround process, an alternative concept can be defined that has the potential to improve the performance of turnaround process.

### 2.2.2 Optimization Techniques

This subsection deals with optimization techniques that can be used to determine optimal ways to conduct activities within turnaround process. There are two types of optimization methods: linear optimization methods and nonlinear optimization methods.

#### *2.2.2.1 Linear Optimization Methods*

Linear optimization methods deal with solving linear problems in which the objective and constraint functions are linear functions of decision variables. There exist different approaches in solving linear optimization problems. In this section, the simplex method will be explained since it can solve all types of linear problems (linear problems with multiple variables), and this is applicable for processes with numerous activities such as turnaround process.

Before explaining the simplex method, the general form of the linear mathematical model is given as follows (Curran & Snellen, 2015):

Maximize $Z = C_1X_1 + C_2X_2 + \cdots + C_nX_n$ (Objective function) (2.1)

Subject to:

$a_{11}X_1 + a_{12}X_2 + \cdots + a_{1n}X_n \leq b_1$ (Functional constraints) (2.2)

$a_{11}X_1 + a_{12}X_2 + \cdots + a_{1n}X_n \leq b_1$ (Functional constraints) (2.3)

$a_{m1}X_1 + a_{m2}X_2 + \cdots + a_{mn}X_n \leq b_m$ (Functional constraints) (2.4)

And

$X_1 \geq 0, X_2 \geq 0, \ldots, X_n \geq 0$ (Non-negativity constraints) (2.5)

### Simplex method

This method is valid in solving the general form of linear mathematical model as presented in equations (2.1), (2.2), (2.3), (2.4) and (2.5). Any linear problem with feasible solutions and a bounded feasible region must possess corner-point feasible (CPF) solutions (solutions at the corner of the feasible region) and at least one optimal solution (Hillier & Lieberman, 2001). The best CPF solution must be an optimal solution. If there are multiple optimal solutions, at least two must be CPF solutions. This principle is known as the optimality property and is used by simplex method to find the optimal solution as can be visualized in figure (2.2).

The first step of the simplex method is the initialization at a CPF solution. In this step, the slack variables are introduced which convert inequality constraints to equality constraints. The second step is known as the iterative step. In each iteration, the simplex method moves from the current solution to a better adjacent solution, by choosing an entering and leaving variable and solving for the corresponding system of equations. Finally, when the current solution has no adjacent solution that is better, the current solution is optimal and the algorithm stops.

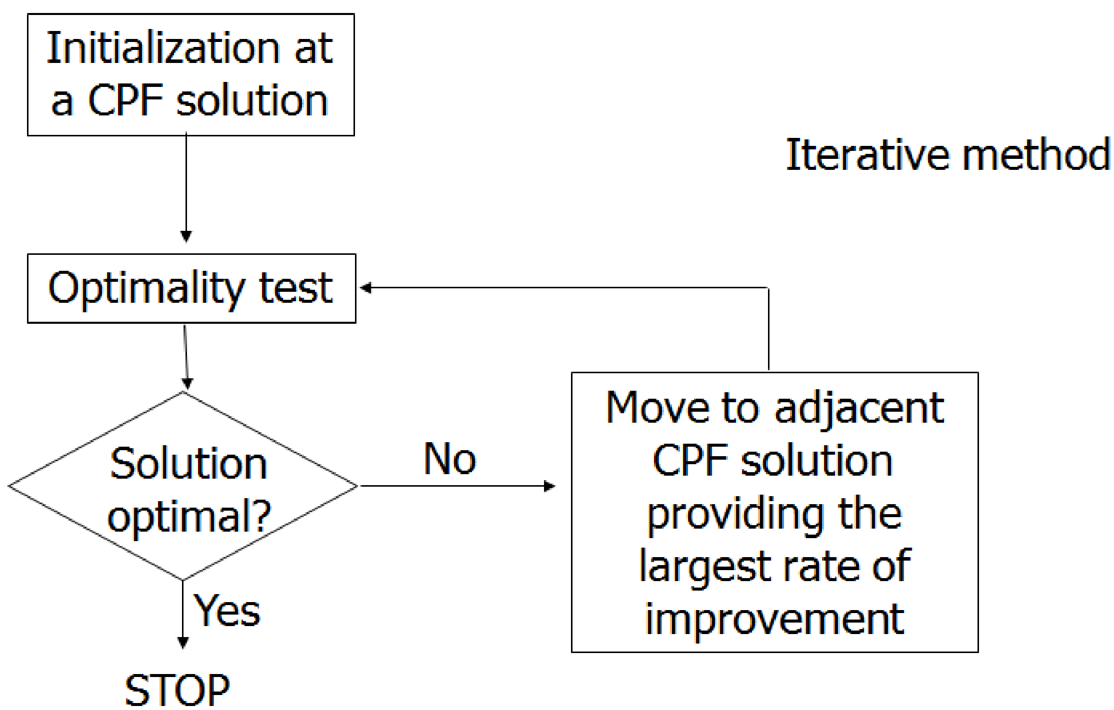


Figure 2-2: Flow diagram of Simplex method (Hillier & Lieberman, 2001)

### *2.2.2.2 Nonlinear Optimization Methods*

Nonlinear optimization methods are used to solve problems in which the objective function and/or the constraint functions are no longer linear functions of decision variables. Unlike the linear problems, there exists no single method that could solve all nonlinear problems. Each nonlinear problem depending on the objective functions and the constraint functions can be solved by a certain nonlinear method which is developed for that special case. The optimal solutions of nonlinear problems are no longer necessarily corner point feasible (CPF) solutions and also a local maximum is not necessarily a global maximum only in the following two conditions (Hillier & Lieberman, 2001):

- For unconstrained problems a local maximum (minimum) is the global maximum if the objective function is concave (convex)
- For constrained problems the additional requirement is that the feasible region is a convex set (convex programming)

In this section, the nonlinear constrained problems with multiple variables will be discussed since they are more applicable for this research.

#### Convex programming

Convex programming is a nonlinear problem which is characterized by a concave objective function and each constraint function is a convex function. Both of these assumptions ensure that a local maximum is a global maximum. The methods that can be used to solve this type of problem are (Curran & Snellen, 2015):

- Frank-Wolf Algorithm
- Sequential unconstrained optimization
- Sequential approximation techniques (linear and quadratic approximation)
- Downhill simplex method

#### Non-convex programming

This type of nonlinear problems covers all problems that do not satisfy the assumption of convex programming. For this problem, even if a local maximum is found, there is no assurance that it also will be a global maximum (Hillier & Lieberman, 2001). There is no algorithm that will guarantee finding an optimal solution for all these non-convex problems. However, there exist some algorithms which are relatively suited for finding local maxima, especially when the forms of the nonlinear functions do not deviate too strongly from those assumed for convex programming (Hillier & Lieberman, 2001). Some of these algorithms are:

- Stimulated annealing
- General algorithm
- Differential evolution

This section has discussed both linear and nonlinear methods that can be used to optimize the turnaround activities or sub processes.

## 2.3 Value Operations Methodology (VOM)

### 2.3.1 Value Focused Thinking

Value operations methodology (VOM) is a decision supporting tool which will be used in this research to build the value model of the turnaround process. As aforementioned, this value model will be used to evaluate the alternative strategies of turnaround process based on added value for relevant stakeholders.

Examples of decision supporting tools other than VOM are cost benefit analysis and multi criteria analysis. In the cost benefit analysis, all costs and benefits are expressed in monetary terms and the decision is made based on whether the sum of these costs and benefits is positive or negative (Bennebroek, 2012). However, this approach is difficult to implement in real life cases, for example aspects like risks, safety, environmental issues and sustainability are difficult to be quantified with a certain value expressed in monetary terms (Sluis, 2013). Because of these complexities, another approach may be considered which is known as multi criteria analysis. With this approach, not only the costs are used to evaluate the options, but here each criterion is weighted according to its importance and then all options are analyzed to assess their performance based on these criteria. Finally all options are compared and then the decision can be made (Bennebroek, 2012).

From the brief description of both approaches, one can conclude that the starting point of these both methods is the creation or collection of alternatives. Here, Keeney (1992) argues that the decision makers should focus primarily on the reasons or values why they are making the decisions not on alternatives. Furthermore, Keeney (1992) states that by first specifying the values and translating them into objectives, one is able to select meaningful decisions and create better alternatives than those already identified by traditionally alternative focused thinking. Finally these alternatives can be better compared with respect to each other. Figure (2.3) illustrates the main difference between value-focused thinking and traditional alternative-focused thinking.

By focusing on values in the early stage, the objectives and preferences of all relevant stakeholders are considered from the start (Bennebroek, 2012). This makes this approach useful for problems with multiple stakeholders which may have different interests.

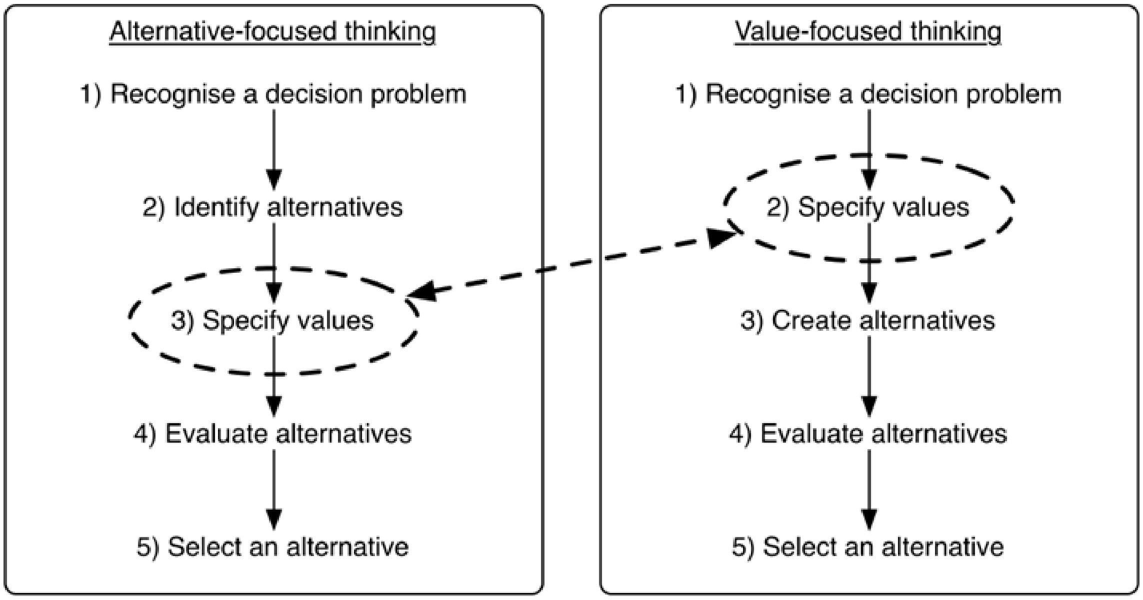


Figure 2-3: Main difference between alternative-focused thing and value-focused thinking (Keeney, 1992)

In order to make the value focused thinking approach a useful tool for the decision makers, Keeney (1992) has introduced a value model which is a mathematical foundation for value focused thinking. This model is a utility function and it consists of objectives and attributes as can be seen in figure (2.4). The attributes ($x_1$,…, $x_n$) measure the fulfillment of objectives ($u_1$,…, $u_n$) and the fulfillment of these objectives determines the total value (u).

If the attributes are independent then the utility function is additive and can be expressed as in equation (2.6). If the attributes are dependent then the utility function is multiplicative and can be expressed as in equation (2.7).

$$U(x1, \dots, xn) = \sum_{i=1}^{n} KiUi(xi) \tag{2.6}$$

$$KU(x1, \dots, xn) + 1 = \prod_{i=1}^{n} (KKiUi(xi) + 1) \tag{2.7}$$

In equations (2.6) and (2.7), Ki is scalar constant and it expresses the importance of the objectives compared to each other.

In value focused thinking approach, it is possible to include qualitative objectives, however the model works best when all attributes and objectives are quantified (Bennebroek, 2012).

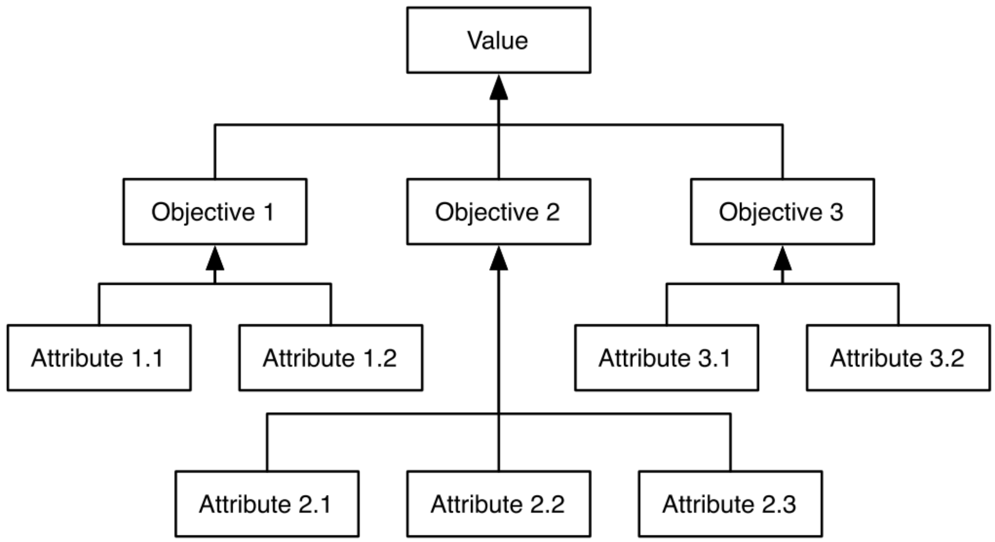


**Figure 2-4: Value model consisting of objectives and attributes (Bennebroek, 2012); (Repko, 2011); (Smulders, 2010); (Sluis, 2013)**

### 2.3.2 Current Development Phase of VOM

Based on value-focused philosophy and the value model represented in figure (2.4), Curran et al. (2010) came up with value operations methodology (VOM) which combines the differential and additive principles.

The additive principle represents the utility function (2.6) and the differential principle is described as follows; instead of trying to establish a measure of absolute value of a certain strategy, it makes more sense to measure the value of an alternative strategy relative to the current strategy (Curran et al., 2010). This yields three decisive simple rules for comparing the alternative strategies as stated as follows:

- $\Delta V > 1$, alternative strategy creates value relative to the reference (current strategy)
- $\Delta V = 1$, alternative has equal value as reference
- $\Delta V < 1$, Alternative reduces value relative to the reference

Now the differential principle is simply the ratio of the total value of an alternative strategy with respect to the total value of the reference strategy or current situation. While, the additive principle is exactly the same as the utility function, adding up all ratios of independent values of each objective (j) as can be seen in equation (2.8):

$$\Delta V(V1, V2, \dots, Vn) = \sum_{j=1}^{n} \lambda_j \frac{V_{j_1}}{V_{j_0}} (x1, x2 \dots xq) \tag{2.8}$$

In this equation, $\lambda_i$ is the objective's weight factor and it represents a scaling constant which determines the importance of an objective, exactly the same as Ki in equations (2.6) and (2.7). The ratio $V_{j_1}$ and $V_{j_0}$ is a function of the attributes ($x_1, \dots, x_n$) which can be written as follows:

$$\frac{V_{j_1}}{V_{j_0}}(x1, x2 \ldots xq) = \sum_{j=1}^{m} \omega_j \frac{(x_{ij})1}{(x_{ij})0} \tag{2.9}$$

In this equation, $\omega_j$ is the attribute's weight factor and it represents a scaling constant which determines the importance of an attribute. Here also the differential and additive principles are applied.

Thus one could observe that VOM depends on the objectives and attributes and also on the determination of the objective weight factors and the attributes weight factors. Fortunately the analytical hierarchy process can be used in determining the objective weight factors and the attribute weight factors.

### *Analytical Hierarchy Process (AHP)*

AHP process was founded by Saaty (1997) and is one of the multi criteria analysis approaches. Curran et al. (2010) modified this approach and applied it in determining the weight factors for objectives and attributes. This modified approach could be summarized as follows (Bennebroek, 2012):

1. Compare the objectives in pair-wise fashion
2. Collect the results of these comparisons in a reciprocal comparison matrix
3. Use the largest eigenvalue from this matrix and related normalized eigenvectors to determine the weight factors for the objectives
4. Compute the consistency ratio of eigenvalue to check the consistency of the comparison matrix

- **Pair-wise comparison of objectives**

Here the pairwise comparison focuses on comparing two elements on each single property and the results are collected in a reciprocal matrix as follows:

$$M = \begin{bmatrix} 1 & \frac{wa}{wb} & \cdots & \frac{wa}{wn} \\ \frac{wb}{wa} & 1 & \cdots & \frac{wb}{wn} \\ \vdots & & \ddots & \vdots \\ \frac{wn}{wa} & \frac{wn}{wb} & \cdots & 1 \end{bmatrix} \tag{2.10}$$

According to Saaty (1977), the largest eigenvalue of the reciprocal matrix M is a real positive number and its corresponding normalized eigenvector contains the objectives weight factors.

In practice, the decision makers are unlikely to determine precise and consistent values of the weight ratios collected in matrix M. Therefore, it should be checked whether the weight factors result in a sufficient level of consistency. The consistency ratio CR indicates the degree of inconsistency and the higher CR the lower the consistency. CR is determined by equation (2.11):

$$CR = \frac{CI}{RI} = \frac{\frac{\lambda - n}{n-1}}{RI} \tag{2.11}$$

In this equation, CI is the consistency index, $\lambda$ is the maximum eigenvalue, n is the size of the comparison matrix and RI is the random consistency index and it can be obtained from table (2.6).

Table 2-6: Random consistency index for reciprocal comparison matrix of size (n x n) (Curran et al, 2010)

| n | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| **RI** | 0 | 0 | 0.58 | 0.9 | 1.12 | 1.24 | 1.32 | 1.41 | 1.45 | 1.49 |

Now if CR is smaller than 0.10 (or 10 percent), then the inconsistency is satisfactory and the weight factors can be used for decision making, However if CR is larger than 0.10 then the inconsistencies are large and the weight factors should be recalculated by the decision maker (Sluis, 2013).

VOM, as a decision supporting tool can be summarized into six steps in the following order: Identify and select relevant stakeholders, formulate set of objectives, formulate set of attributes, determine the objectives weight factors using AHP, determine the attributes weight factors using AHP and the final step, combine all into one model using equations (2.8) and (2.9) (Bennebroek, 2012).

## 2.4 Summary

In this section, the main findings of previous covered literatures related to current concept of turnaround process, improvement and optimization techniques, and VOM will be summarized and related to each other.

In the current concept of turnaround process, the main stakeholders are airport, airline, users, and non-users, see table (2.4). These stakeholders and the relations among them should be clearly analyzed, since the main purpose is to improve the performance of turnaround process from their perspective. The improvement and optimization techniques that have the potential to improve the performance of turnaround process are: lean production system, theory of constraints, Lean Six Sigma, and linear and nonlinear optimization methods. Lean production system and theory of constraints were already implemented in turnaround process by Doig, Howard, and Ritter (2003) and Beelaerts van Blokland et al. (2008) respectively. However, with their proposed solutions, they only predicted the potential reduction in turnaround time and not the performance of other value drivers of turnaround process. To fill this gap, it was proposed to develop the value model for the turnaround process based on VOM in which all value drivers from the perspective of stakeholders will be included. The improvement and optimization techniques will be used in creating alternative scenarios and the value model will be used in evaluating these alternatives based on added value for the stakeholders. Ultimately, the turnaround concept that adds as much value for the stakeholders will be recommended.

VOM can be summarized into six steps namely, identify and select relevant stakeholders, formulate set of objectives, formulate set of attributes, determine objectives weight factors using AHP, determine attributes weight factors using AHP, and combine all into one model using equations (2.8) and (2.9). However, each of these steps lacks details and needs further developments. For instance, it is not specified which stakeholder methodology could be used in identifying and selecting the relevant stakeholders. The other 5 steps suffer almost from the same issues. These issues and further developments of VOM will be covered in the next chapter which is a theoretical improvement of VOM.

# 3 Theoretical Improvements of VOM

In previous chapter, it was described that VOM could be summarized into six main steps; identify and select relevant stakeholders, formulate set of objectives, formulate set of attributes, determine objectives weight factors using AHP, determine attributes weight factors using AHP, and combine all in one model using equations (2.8) and (2.9). However as aforementioned, each of these steps lacks details and requires further developments in order for VOM to be used as a feasible decision supporting tool which will be the basis in building the value model for the turnaround process.

In this chapter, each step of VOM will be analyzed in details and further developments and improvements will be proposed. This will be presented in this chapter in the following order:

1 Identify and select the relevant stakeholders (section 3.1)
2 Formulate set of objectives (section 3.2)
3 Formulate set of attributes (section 3.3
4 Determine objectives weight factors (section 3.4)
5 Determine attributes weight factors (section 3.5)
6 Combine all into one model (section 3.6)
7 Finally a brief summary will be provided in section (3.7)

## 3.1 Identify and Select Relevant Stakeholders

In the general form of VOM as introduced by Curran et al. (2010), it was not specifically defined which stakeholder methodology could be used which enables the identification and the selection of relevant stakeholders when considering a specific decision context. As well as in previous MSC researches done on VOM namely, Smulders (2010), Repko (2011), and Bennebroek (2012) different stakeholder methods were selected. However, each with several issues which will be discussed in this section and eventually, a stakeholder methodology will be proposed with which the first step of VOM can be performed.

### 3.1.1 Savage's Approach (Savage, Whitehead & Blair, 1991)

Smulders (2010) used Savage's approach in identifying and selecting relevant stakeholders. This method classifies the stakeholders into four different types based on their potential for cooperation and for threat. These four types of stakeholders are described as follows:

- Supportive: this stakeholder has a low potential for threat and a high potential for cooperation
- Mixed blessings: this stakeholder has both a high potential for threat and for cooperation
- Non-supportive: this stakeholder has high a potential for threat and a low potential for cooperation
- Marginal: This stakeholder has both a low potential for threat and for cooperation

Smulders (2010) decided to only include the mixed blessings and non-supportive stakeholders in the airside value model as relevant stakeholders. However, by examining the recommended strategies formulated by Savage et al. (1991), towards supportive, mixed blessings, non-supportive and marginal stakeholders which are involve, collaborate, defend and monitor respectively, not only mixed blessings and non-supportive should be considered as relevant stakeholders but also supportive stakeholders.

This is because the recommended strategies could be considered quite active except the strategy recommended towards marginal stakeholder which is more passive (using the verb monitor) (Bennebroek, 2012). Therefore, only stakeholders which are classified as marginal may be considered as non-relevant considering a decision context.

The main issues with using only Savage's approach to identify and select relevant stakeholders are described as following:

- It is useful when it comes to classification of stakeholders as relevant stakeholders for VOM based on their rankings on potential for threat and for cooperation. However, it is not useful when it comes to identification of all firm's stakeholders
- It does not specify how to rank or classify the stakeholders

### 3.1.2 Analysis of Complex Neighborhoods

This stakeholder method is developed by Enserink, Koppenjan, Thissen, Kamps, and Bekebrede (2003), and it was applied by Repko (2011) to identify and select relevant stakeholders. This method consists of six steps which are outlined as following:

1. Start with the formulation of the problem
2. Provide the overview of the involved stakeholders
    a. Which stakeholders are actively involved?
    b. Which stakeholders have powers that have a role in creating or solving the problem?
    c. Which stakeholders possess resources that can be useful for the problem?
    d. Which stakeholders can be assumed to require involvement at some point?
    e. Which stakeholders are not actively involved but are part of the problem?
3. Provide a chart which presents the formal relations between the stakeholders
4. Determine the interests, objectives and problem perception of each stakeholder
5. Provide an overview which presents the dependencies between each stakeholder
6. Determine the consequences of the findings to the formulation of the problem

The main issues of this method regarding the identification and the selection of relevant stakeholders are briefly explained as following:

- This method is useful when identifying firm's stakeholders. However, it does not contain steps in which relevant stakeholders considering a decision context can be selected. Thus this approach lacks a selection method
- First, fourth, fifth and sixth steps are irrelevant for performing the first step in VOM

### 3.1.3 Stakeholder Method Proposed in the Research of (Bennebroek, 2012)

Bennebroek (2012) decided to combine the most relevant steps of analysis of complex neighborhoods and of Savage's approach, to identify and select relevant stakeholders considering a decision context. The method is defined as following:

1. Identify all stakeholders:
    a. Create a long list of stakeholders using the sub-questions from step 2 from the analysis of complex neighborhoods
    b. Select the stakeholders that fall within the scope of the value model
    c. Map the relationships among the stakeholders using step 3 from the analysis of complex neighborhoods
2. Select relevant stakeholder
    a. Rank the identified stakeholders based on their potential for threat and cooperation using Savage's approach
    b. Based on their rankings, classify the stakeholders in one of the four categories from Savage's approach
    c. Select the stakeholders that are classified as supportive, mixed blessings and non-supportive as the relevant stakeholders

The main issues with this stakeholder method for the identification and the selection of relevant stakeholders considering a decision context are explained as following:

- The method is complete and can be used for performing the first step of VOM. However, the raking in step 2 in order to classify the stakeholder is missing. Bennebroek (2012) defined a numerical method with which the ranking and classification of stakeholders could be performed. However, this method is not self-evident and a full validation is required. This numerical method is described in appendix (A)
- The outcome of the numerical method used to rank and classify the stakeholders using Savage's approach differs than the outcome of the assessments used by the experts, see the research of (Bennebroek, 2012)

### 3.1.4 Proposed Stakeholder Method for This Research

In this research, it is proposed to use the same approach as defined by Bennebroek (2012) to perform the first step of VOM. Only the ranking method used by Bennebroek (2012) will be modified. It is proposed to make the ranking method qualitative rather than numerical. As well as to make it more practical and easier to perform by the managers incorporating their knowledge and expertise compared to numerical method. As aforementioned, the savage's approach judges and classifies the stakeholders based on their potential for threat and cooperation. These two characteristics are affected by four factors namely, control of resources, stakeholder power, likelihood to take opposed action and history with the target company (Smulders, 2010). Each of the identified stakeholders will be tested based on these factors and qualitatively ranked as shown in table (3.1).

Table 3-1: Qualitative ranking of stakeholders based on the influencing factors

| Dimensions | | Threat | Cooperation |
|---|---|---|---|
| **Resources** | Control resources | Significant high | Significant high |
| | Does not control resources | Low | Neutral |

| | | | |
|---|---|---|---|
| **Power** | More powerful than the organization | Significant high | Neutral |
| | Equally powerful as the organization | High | Neutral |
| | Less powerful than the organization | Low | High |
| **Likelihood to take action** | Likely to take supportive action | Significant low | Significant high |
| | Likely to take non-supportive action | Significant high | Significant low |
| | Unlikely to take any action | Neutral | Neutral |
| **Likelihood to form coalition** | Likely to form coalition with others | High | Low |
| | Likely to form coalition with organization | Low | High |
| | Unlikely to form any coalition | Neutral | Low |

The qualitative ranking listed in table (3.1) for each influential factor is based on the matrix P in the numerical method defined by Bennebroek (2012) (see table (A.1) in appendix A). However, with several modifications namely, increase (1) is either replaced by significant high or high, decrease (-1) is either replaced by significant low or low and none (0) is simply replaced by neutral, except in three cases which are explained as follows:

- The first case: when a stakeholder is equally powerful as the organization, potential of threat which is graded none (0) in numerical method is then replaced by high. Because here, the increase in potential of threat should be considered.
- The second case: when a stakeholder is unlikely to take any action, both potentials of threat and cooperation which are graded decrease (-1) in numerical method are then both replaced by neutral. Since unlikely no action will be taken, it has then no effect on potentials for threat and for cooperation.
- The third case: when a stakeholder is unlikely to form any coalition which is graded decrease (-1) in potential of threat in numerical method is then replaced by neutral. Because here, the effect on potential of threat should not be considered low, since the stakeholder is potentially not willing to form any coalition with the organization. Also his potential of threat should not be

considered high because this stakeholder is potentially no willing to form any coalition with other stakeholders as well.

The rationale behind those modifications namely, increase (1) is replaced by either significant high or high and decrease (-1) is replaced by either significant low or low, because the purpose here, is to make qualitative ranking more specific and less general than numerical method in which it claims increase or decrease in the potential of threat or cooperation but not how much increase.

The meaning of qualitative ranking given in table (3.1) is interpreted as shown in table (3.2).

**Table 3-2: Translation of qualitative grading into numerical**

| Qualitative grading | Strength |
|---|---|
| Significant high | ++ |
| High | + |
| Low | - |
| Significant low | -- |
| Neutral | +- |

Each identified stakeholder will be qualitatively ranked based on the influencing factors listed in table (3.1), and then these qualitative rankings will be summed. Depending on total number of positive and negative signs for threat and for cooperation, the stakeholder will be classified as either supportive, non-supportive, mixed blessings or marginal as explained here below:

- Supportive: the total number of positive signs is larger than negative signs for cooperation and the total number of negative signs is equal to or larger than positive signs for threat
- Non-supportive: the total number of negative signs is equal to or larger than positive signs for cooperation and the total number of positive signs is larger than negative signs for threat
- Mixed blessings: the total number of positive signs is larger than negative signs for both cooperation and threat
- Marginal: the total number of negative signs is equal to or larger than positive signs for both cooperation and threat

The differences between this qualitative method and the numerical method used in research of (Bennebroek, 2012) are:

- The qualitative method allows the managers or the decision makers to incorporate their knowledge and expertise to qualitatively judge the stakeholders on potential for cooperation and for threat based on the factors listed in table (3.1). This enables the ranking and classification of stakeholders to be more accurate compared to numerical method
- The qualitative ranking is more specific than numerical method
- The qualitative method is easier and faster to perform and more self-evident compared to numerical method.

The stakeholder method, with which the identification and selection of relevant stakeholders can be performed in this research, is summarized into the following steps and can be visualized in figure (3.1):

1. **Identify all firm's stakeholders:**
    a. **Create a long list of stakeholders using the sub-questions from step 2 from the analysis of complex neighborhoods**
    b. **Select the stakeholders that fall within the scope of the value model**
    c. **Map the relationships among the stakeholders using step 3 from the analysis of complex neighborhoods**
3. **Select relevant stakeholder**
    a. **Rank the identified stakeholders based on their potential for threat and cooperation using qualitative ranking method**
    b. **Based on their rankings, classify the stakeholders in one of the four categories from Savage's approach**
    c. **Select supportive, non-supportive and mixed blessings stakeholders as relevant stakeholders**

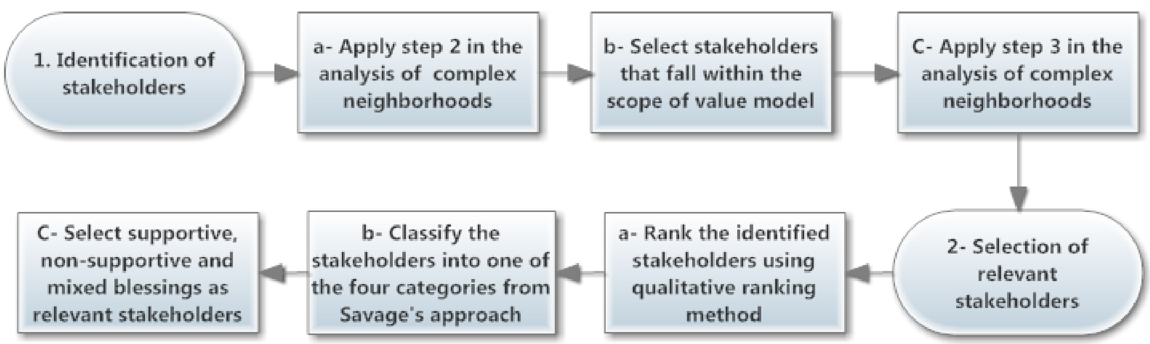


Figure 3-1: High level work flow of the stakeholder methodology proposed in this research

## 3.2 Formulate Set of Objectives

The purpose of this step is to include all relevant stakeholders' objectives into the value model, so that the alternatives will be evaluated based on the achievement of these objectives. Also there are several requirements that the objectives should meet in order to be used as parameters in the value model. In this research, a methodology with which the proper formulation of objectives will be proposed based on the approach proposed by Bennebroek (2012).

In this section, first a brief explanation and analysis of the approach proposed by Bennebroek (2012) for creating set of objectives will be described in the order as illustrated in figure (3.2), followed by defining the method with which this step can be correctly performed.


Figure 3-2: Formulation of objectives as proposed by Bennebroek (2012)

### 3.2.1 Create a Long List of Objectives for Each Relevant Stakeholder

In this step, the focus will lie on each relevant stakeholder separately and based on interviews, a research desk, or a combination of both, a long list of objectives of each relevant stakeholder is compiled. The objectives which are irrelevant to the research scope are removed.

### 3.2.2 Create an Objective Tree

There are different types of objectives namely, fundamental objectives, means objectives, process objectives, and strategic objectives (Bennebroek, 2012); (Smulders, 2010). These four types of objectives are defined as follows (Smulders, 2010, p. 33):

- **Fundamental objectives:** these are the key set of objectives which should be clarified in the decision problem. They are the ends objectives used to describe the consequences that essentially define the reasons for being interested in the decision.
- **Means objectives:** these objectives are important only for their influence on achievement of the fundamental objectives. They are not goals in themselves.
- **Process objectives:** these objectives concern how the decision is made rather than what decision is made.
- **Strategic objectives:** these objectives are influenced by all decisions made over time by the organization or the individual facing the decision at hand. They can be seen as highest level objectives and can be broken down into fundamental objectives, means objectives, or process objectives.

These four types of objectives are related to each other as illustrated in figure (3.3). The objective tree can aid in structuring these different types of objectives and can help in finding the missing objectives (Bennebroek, 2012). This objective tree is made by linking the objectives in a hierarchy in which the strategic objectives are at the top and the other types of objectives follow in steps; as means objectives to the higher level and fundamental objectives to the lower level.

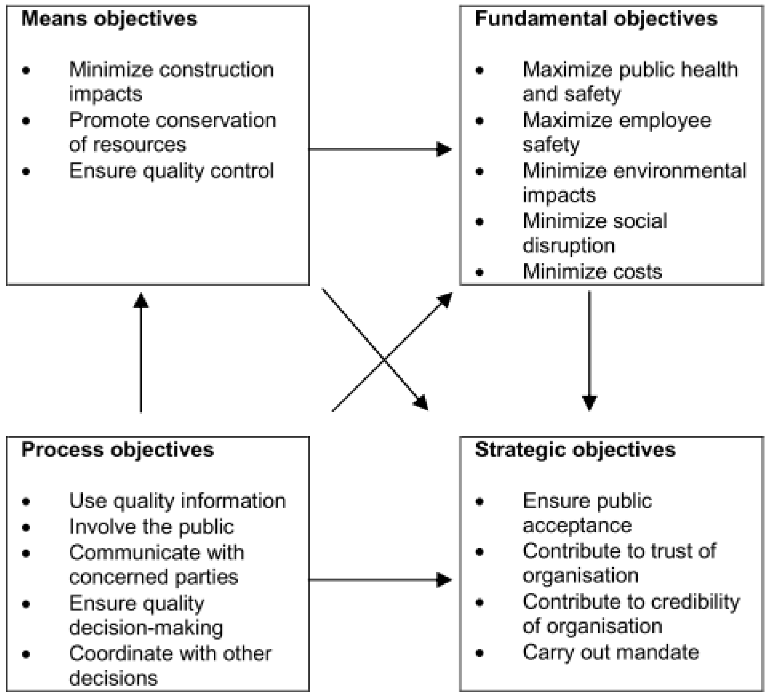


Figure 3-3: Relations among the objective types (Smulders, 2010); (Keeney, 1996)

### 3.2.3 Select the Right Level of Abstraction

The challenge in this step is to select the objectives with the right level of abstraction from the objective tree. As aforementioned, in order for the objectives to be included in the value model they should meet several requirements. Fortunately, Keeney (1992, table (3.2)) offers a useful list of desired properties of the set of fundamental objectives. These desired properties are listed and described as follows:

- **Essential:** all objectives indicate the consequences in terms of the fundamental reasons for interest in the decision situation.
- **Controllable:** the consequences of the decision are only influenced by the choice of alternatives as opposed to some other mechanism that is not included.
- **Complete:** all fundamental aspects of the consequences of the alternatives have been included.
- **Non-redundant:** the set of fundamental objectives should not contain similar items in order to avoid double-counting of the consequences of the alternatives
- **Measurable:** the objectives are defined precisely and specify the degrees to which objectives may be achieved
- **Operational:** the requirements the objectives pose on information gathering for the analysis are reasonable.
- **Decomposable:** this allows objectives to be treated separately in the analysis.
- **Concise:** the set of objectives should not contain more items than necessary to the analysis
- **Understandable:** all fundamental objectives should be easily interpreted by those involved in the decision making process. This facilitates communication and enhances insights.

The objective tree can help with selecting the objectives which adhere only to first four desired properties (Bennebroek, 2012): essential, controllable, complete and non-redundant. Therefore, there exists the next step which is finalized the formulation.

### 3.2.4 Finalized the Formulation

In this step, it must be checked whether the selected fundamental objectives are characterized by three features namely, decision context, object, and direction of preference (reduce or increase). By doing so, the following desirable properties; decomposable, concise, and understandable will be ensured. Now the only issue is to ensure measurable and operational which could be checked by the decision maker with the relevant stakeholders.

### 3.2.5 Proposed Method for Formulation of Objectives

It is proposed in this research to use the same method only in the following steps and order:

1. Create a long list of objectives for each relevant stakeholder
2. Omit the objectives that are unrelated to the research scope
3. Structure the objectives using objective tree
4. Select the right level of abstraction using the following list
    - **Essential:** All objectives indicate the consequences in terms of the fundamental reasons for interest in the decision situation.
    - **Controllable:** the consequences of the decision are only influenced by the choice of alternatives as opposed to some other mechanism that is not included.
    - **Complete:** All fundamental aspects of the consequences of the alternatives have been included.
    - **Non-redundant:** the set of fundamental objectives should not contain similar items in order to avoid double-counting of the consequences of the alternatives
5. The selected objectives should be characterized by the following three features else they should be omitted or redefined:
    - Decision context
    - Object
    - Direction of preference (reduce or increase)
6. The selected objectives should be checked with the following characteristics
    - **Decomposable:** this allows objectives to be treated separately in the analysis.
    - **Concise:** the set of objectives should not contain more items than necessary to the analysis
    - **Understandable:** All fundamental objectives should be easily interpreted by those involved in the decision making process. This facilitates communication and enhances insights.
7. The selected objectives should be checked with the following characteristics by consulting the relevant stakeholders
    - **Measurable:** the objectives are defined precisely and specify the degrees to which objectives may be achieved
    - **Operational:** The requirements the objectives pose on information gathering for the analysis are reasonable

This proposed method can be visualized in figure (3.4).

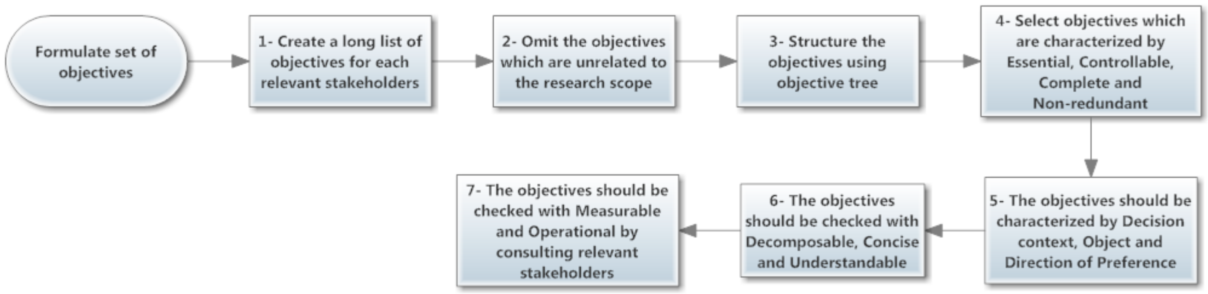


Figure 3-4: Proposed approach for formulation of objectives

## 3.3 Determine Objectives Weight Factors

As stated in VOM, AHP is the method used to determine the weight factors; however there are two main issues with this method which should be solved:

1. It is not specified what rating scale could be used to perform the pairwise comparison of objectives
2. Each relevant stakeholder has their own preferences for determining the importance of the objectives. The issue here, is how to determine the weight factors of the objectives taking into account that not all relevant stakeholders are equally important with respect to the firm or the organization

In this section, both of these issues will be discussed respectively. Eventually, a method will be proposed to cope with those issues.

### 3.3.1 Defining the Rating Scale for AHP

There are three rating scales introduced in the research of (Bennebroek, 2012) which are illustrated in figure (3.5) namely, fundamental rating scale, more/less/equal rating scale, and more/less/equal rating scale with factor-max 8. The fundamental rating scale was not used by Bennebroek (2012) for performing the pairwise comparison of objectives. Because, it contains too many answers and not each answer has its specific meaning which made it difficult for the interviewees to rate the importance of one objective over another.

More/less/equal rating scale is a qualitative rating scale which is also not used by Bennebroek (2012). This is because it is too generic namely, this rating scale contains only three answers; more, less or equally important, but there are times that interviewees gave in-between answers which could not be determined by this rating scale. To cope with this, Bennebroek (2012) suggested more/less/equal rating scale with factor-max 8 to perform the pairwise comparison of objectives, which is further explained as stated in the following equations:

$$I(A) \gg I(B) \rightarrow \frac{W_A}{W_B} = f = 8 \quad (3.1)$$

$$I(A) > I(B) \rightarrow \frac{W_A}{W_B} = \frac{f}{2} = 4 \quad (3.2)$$

$$I(A) = I(B) \rightarrow \frac{W_A}{W_B} = 1 \quad (3.3)$$

$$I(A) < I(B) \rightarrow \frac{W_A}{W_B} = \frac{1}{4} \quad (3.4)$$

$$I(A) \ll I(B) \rightarrow \frac{W_A}{W_B} = \frac{1}{8} \quad (3.5)$$

With this rating scale, there are two answers defined in "more important" as well as two answers defined in "less important", and certainly one answer for equally important. For example equation (3.1) signifies that objective A is significant more important that objective B, while equation (3.2) signifies that objective A is only more important than objective B. By doing so the interviews have more space to give in-between answers and simultaneously each answer has its specific meaning.

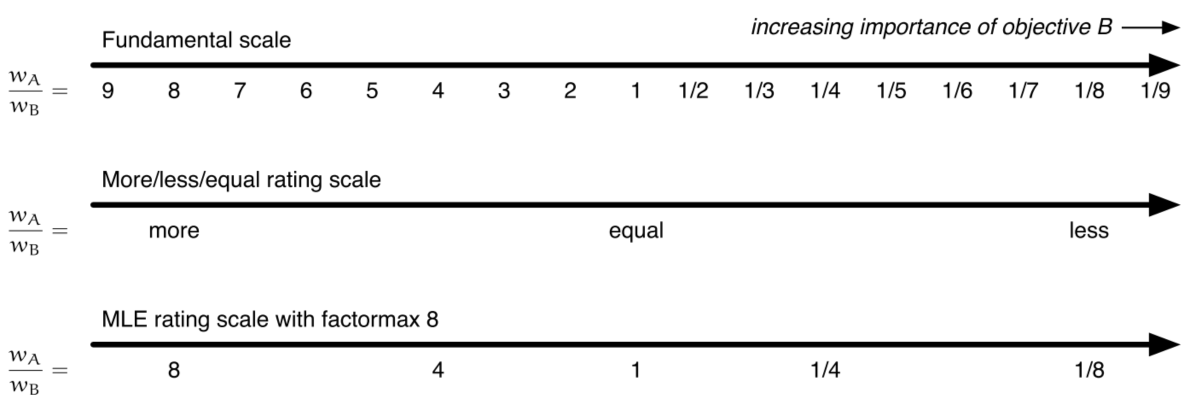


**Figure 3-5: Different rating scales for the pairwise comparison of objectives (Bennebroek, 2012)**

However, the more/less/equal rating scale with factor-max 8 could be still considered too generic to perform the pairwise comparison of objectives. This is because for instance, in the following case when objective A is slightly more or less important than objective B, it is not readable in this rating scale. Therefore, in this research, it is proposed to use power series as the rating scale for performing the pairwise comparison of objectives. As well as, it is decided to select base a=2, as further stated in the following equations:

$$a^3 = 2^3 = 8 \rightarrow significant\ more\ important \quad (3.6)$$

$$a^2 = 2^2 = 4 \rightarrow more\ important \quad (3.7)$$

$$a^1 = 2^1 = 2 \rightarrow slightly\ more\ important \quad (3.8)$$

$$a^0 = 2^0 = 1 \rightarrow equally\ important \quad (3.9)$$

$$a^{-1} = 2^{-1} = \frac{1}{2} \rightarrow slightly\ less\ important \quad (3.10)$$

$$a^{-2} = 2^{-2} = \frac{1}{4} \rightarrow less\ important \quad (3.11)$$

$$a^{-3} = 2^{-3} = \frac{1}{8} \rightarrow significant\ less\ important \quad (3.12)$$

This power series rating scale with base a=2 allows for more answers which makes it more specific compared to more/less/equal rating scale with factor-max 8. Also, each answer is explicitly explained which will make it easy for the interviewees to compare the objectives in pairwise fashion. The random consistency index is built based on the fundamental rating scale which as aforementioned, it contains many answers. Since the power series rating scale with base a=2 allows for more answers compared to more/less/equal rating scale with factor-max 8, it fits more within AHP.

### 3.3.2 Combining Assessments from Relevant Stakeholders

After the rating scale is defined, the next question is how to combine the assessments from multiple relevant stakeholders. Bennebroek (2012) used the average of weight factors to combine these assessments. The advantages of this approach are: its simplicity and easy scalability for more assessment, as well as the reciprocity of the reciprocal matrix is not affected. However with this approach, it is assumed that all relevant stakeholders are equally important relative to the firm which is incorrect. To cope with this the following approach is proposed:

AHP will be used twice, it will be used to determine the weights of relevant stakeholders determining their importance relative to the firm, and then it will be used again to determine the weights of objectives according to each relevant stakeholder. Finally, the weight factors of the formulated objectives for all relevant stakeholders will be computed, by multiplying the vector which contains the weights which determine the importance of relevant stakeholders, by the matrix which contains the weights which determine the importance of objectives according to each relevant stakeholder as further explained here below:

- AHP to determine the weights of relevant stakeholders depending on their importance relative to the firm

Now the question here is how to scale different relevant stakeholders before collecting the scores in the reciprocal matrix for calculating the weights. Here the power series rating scale with base a=2 will be used as explained here below:

- There are three types of relevant stakeholders namely; mixed blessing, supportive and non-supportive. Their importance are scaled as follows:

$$\frac{Mixed\ blessing}{Supportive} = more\ important = a^2 = 4 \quad (3.13)$$

$$\frac{Mixed\ blessing}{Nonsupportive} = slightly\ more\ important = a^1 = 2 \quad (3.14)$$

$$\frac{Nonsupportive}{Supportive} = slightly\ more\ important = a^1 = 2 \quad (3.15)$$

Here the reciprocity is applied and when two relevant stakeholders are classified as the same type then they are considered equally important. The weights are calculated by using the rest of steps of AHP and then collected as scalars in a vector.

- AHP to determine the weights of objectives according to each relevant stakeholder

Here power series with base a=2 will be used to rate the importance of one objective over another and the weights will be calculated using the rest of the steps of AHP and then collected in a matrix.

Finally by multiplying the vector which contains the weights which determine the importance of relevant stakeholders, which may be called V by the matrix which contains the weights which determine the weights of objectives according to each relevant stakeholders, which may be called A. This results in vector W which contains the weights factors of objectives of all relevant stakeholders as can be seen in equation (3.16). Notice that the number of scalars in vector V and the number of columns in matrix A corresponds to the number of relevant stakeholders. While, the number of rows in matrix A corresponds to the number of the formulated objectives as well as to the number of scalars in vector W. Also the summation of the weight factors in vector W equals 1.

$$V.A = W \tag{3.16}$$

The entire approach for determining the objectives weight factors for all relevant stakeholders is summarized as follows:

I. **Perform AHP to determine the weights of relevant stakeholders which determines their importance relative to the centered firm**
   a. Compare the importance of relevant stakeholders in a pair-wise fashion using power series rating scale with the base a=2 as follows:
      - $\frac{Mixed\ blessing}{Supportive} = more\ important = a^2 = 4$
      - $\frac{Mixed\ blessing}{Nonsupportive} = slightly\ more\ important = a^1 = 2$
      - $\frac{Nonsupportive}{Supportive} = slightly\ more\ important = a^1 = 2$
      - $\frac{Nonsupportive}{NonSupportive} = \frac{supportive}{Supportive} = \frac{Mixed\ blessing}{Mixed\ blessing} = equally\ important = a^0 = 1$
      - $\frac{supportive}{Mixed\ blessing} = less\ important = a^{-2} = \frac{1}{4}$
      - $\frac{Nonsupportive}{Mixed\ blessing} = slightly\ less\ important = a^{-1} = \frac{1}{2}$
      - $\frac{supportive}{NonSupportive} = slightly\ less\ important = a^{-1} = \frac{1}{2}$

   b. Collect the results of these comparisons in a reciprocal comparison] see the following equation

$$M = \begin{bmatrix} 1 & \frac{wa}{wb} & \dots & \frac{wa}{wn} \\ \frac{wb}{wa} & 1 & \dots & \frac{wb}{wn} \\ \vdots & & \ddots & \vdots \\ \frac{wn}{wa} & \frac{wn}{wb} & \dots & 1 \end{bmatrix}$$

c. Use the largest eigenvalue from this matrix and related normalized eigenvector to determine the weights for the relevant stakeholders

d. Compute the consistency ratio of eigenvalue to check the consistency of the comparison matrix which is calculated using the following equation

$$CR = \frac{CI}{RI} = \frac{\frac{\lambda - n}{n-1}}{RI}$$

**II. Perform AHP to determine the weights of objectives according to each relevant stakeholders**

a. Compare the objectives in a pair-wise fashion according to each relevant stakeholder using power series rating scale with the base as=2 as follows:
   - $a^3 = 2^3 = 8 \rightarrow significant\ more\ important$
   - $a^2 = 2^2 = 4 \rightarrow more\ important$
   - $a^1 = 2^1 = 2 \rightarrow slightly\ more\ important$
   - $a^0 = 2^0 = 1 \rightarrow equally\ important$
   - $a^{-1} = 2^{-1} = \frac{1}{2} \rightarrow slightly\ less\ important$
   - $a^{-2} = 2^{-2} = \frac{1}{4} \rightarrow less\ important$
   - $a^{-3} = 2^{-3} = \frac{1}{8} \rightarrow significant\ less\ important$

b. Collect the results of these comparisons in a reciprocal comparison matrix according to each relevant stakeholder see the following equation

$$M = \begin{bmatrix} 1 & \frac{wa}{wb} & \dots & \frac{wa}{wn} \\ \frac{wb}{wa} & 1 & \dots & \frac{wb}{wn} \\ \vdots & & \ddots & \vdots \\ \frac{wn}{wa} & \frac{wn}{wb} & \dots & 1 \end{bmatrix}$$

c. Use the largest eigenvalue from this matrix and related normalized eigenvector to determine the weight factors for the objectives according to each relevant stakeholder

d. Compute the consistency ratio of eigenvalue to check the consistency of the comparison matrix which is calculated using the following equation

$$CR = \frac{CI}{RI} = \frac{\frac{\lambda - n}{n-1}}{RI}$$

**III. Determine the objective weight factors for all relevant stakeholders by multiplying vector V by matrix A. Vector V contains the weights which determine the importance of relevant**

**stakeholders relative to the centered firm and matrix A contains the weight factors of objectives according to each relevant stakeholder.**

## 3.4 Formulate Set of Attributes

The goal of this step is to formulate set of attributes which measure the achievement of the objectives. According to Keeney (1992), there are three types of attributes as described as following:

- Natural attributes are logically and obviously connected with their objective. For instance: the objective minimize noise, the natural attribute is noise in decibel.
- Constructed attributes: When a natural attribute is not available, an attribute may be constructed. For instance: the objective reduce nuisance to the local community, an attribute may be constructed that can have integer values 0-5, with 0 expressing no nuisance, and 5 expressing the maximum amount of nuisance (Bennebroek, 2012).
- Proxy attributes: Finally, a proxy attribute measures the achievement of the objective only indirectly. For example the objective reduce the fatalities, one can measure the number of vehicle accidents. Proxy attributes are selected when it is difficult or impossible to measure the achievement of the objectives directly (Bennebroek, 2012).

In general natural attributes are preferred than constructed attributes and constructed attributes are preferred than proxy attributes.

In previous researches (Bennebroek, 2012); (Repko, 2011) there is no generic form on how to select and define the set of attributes. However, there are some guidelines for example the set attributes should adhere to the following list (Keeney, 2007, p.121):

- **Unambiguous**: a clear relationship exists between consequences and description of consequences using the attribute
- **Comprehensive**: the attribute levels cover range of possible consequences for corresponding objective, and value judgment implicit in the attribute are reasonable
- **Direct**: the attributes levels directly describe the consequences of interest
- **Operational**: the information necessary to describe consequences can be obtained and value tradeoffs can reasonably be made
- **Understandable:** consequences and value tradeoffs made using the attribute can readily be understood and clearly communicated

The following generic approach is proposed for this research to formulate the set of attributes:

1 The attributes must be defined such that data required is available in the correct format (here consultation is required with the relevant stakeholders)
2 The selected attributes should adhere to the list proposed by Keeney (2007, p.121)

## 3.5 Determine Attributes Weight Factors

As the objectives, each attributes should be given a weight factor indicating their importance compared to other attributes belonging to the same objectives, and the sum of these attributes weight factors should be equal to 1. The importance of attributes among each other should be scaled depending on their fulfillment of the concerned objective.

It is proposed to use AHP to determine the attributes weight factor as in the research of (Bennebroek, 2012). Only the power series rating scale with base a= 2 will be used to collect the scores for the reciprocal matrix as summarized as following:

a. Compare the attributes in a pair-wise fashion according to their importance for the achievement of the objective using power series rating scale with the base equal 2 (a=2) as follows:
   - $a^3 = 2^3 = 8 \rightarrow significant\ more\ important$
   - $a^2 = 2^2 = 4 \rightarrow more\ important$
   - $a^1 = 2^1 = 2 \rightarrow slightly\ more\ important$
   - $a^0 = 2^0 = 1 \rightarrow equally\ important$
   - $a^{-1} = 2^{-1} = \frac{1}{2} \rightarrow slightly\ less\ important$
   - $a^{-2} = 2^{-2} = \frac{1}{4} \rightarrow less\ important$
   - $a^{-3} = 2^{-3} = \frac{1}{8} \rightarrow significant\ less\ important$

b. Collect the results of these comparisons in a reciprocal comparison matrix see the following equation

$$M = \begin{bmatrix} 1 & \frac{wa}{wb} & \cdots & \frac{wa}{wn} \\ \frac{wb}{wa} & 1 & \cdots & \frac{wb}{wn} \\ \vdots & & \ddots & \vdots \\ \frac{wn}{wa} & \frac{wn}{wb} & \cdots & 1 \end{bmatrix}$$

c. Use the largest eigenvalue from this matrix and related normalized eigenvector to determine the weight factors for attributes

d. Compute the consistency ratio of eigenvalue to check the consistency of the comparison matrix which is calculated using the following equation

$$CR = \frac{CI}{RI} = \frac{\frac{\lambda - n}{n-1}}{RI}$$

## 3.6 Combine All Into One Model

Now that the objectives, the attributes, and their weight factors are determined, the change in value of an alternative compared to the reference state can be calculated using equations (2.8) and (2.9). As aforementioned, if the change in value ($\Delta V$) is larger than 1 then the alternative adds more value, if it is less than 1 it adds less value and if it equals 1 then the alternative adds equal value compared to the reference state. In order to use this method correctly the following guidelines should be strictly followed:

- The consistent ratios should be applied which means that the reference state of attributes should always be at the denominator($x_1/x_0$) as stated in equations (2.8) and (2.9). Because the attributes might have two directions of preference namely, upward in case of increase and downward in case of reduce. Considering only the latest case, in order to create value the attribute of reference should be in the numerator. However, this could create a problem as shown in the two following statements (Bennebroek, 2012):

    - Direction of preference upward: $\Delta V = w\frac{x_1}{x_0} = c_1 x_1$ this is linear
    - Direction of preference downward: $\Delta V = w\frac{x_1}{x_0} = c_2\frac{1}{x_2}$ this is non linear

  In order to avoid this problem, the alternative must always be divided by the reference regardless of the direction of preference.

- Repko (2011) introduced feasible range concept to attributes because of the fact that attributes cannot change from zero to infinity. They are bounded by an upper limit ($x_{max}$) and lower limit ($x_{min}$). The attribute values within the feasible range in case of upward preference direction and in case of downward preference direction, can be determined by equations (3.17) and (3.18) respectively (Repko, 2011); (Bennebroek, 2012):

$$(x_{i_j})_{0,1}^{FR} = \frac{(x_{i_j})_{0,1} - x_{min}}{x_{max} - x_{min}} \quad (3.17)$$

$$(x_{i_j})_{0,1}^{FR} = 1 - \frac{(x_{i_j})_{0,1} - x_{min}}{x_{max} - x_{min}} \quad (3.18)$$

  With equations (3.18), the attributes with downward direction of preference could be included in VOM without inverting the ratio of an alternative over the reference and subsequently, preserving the concept of consistent ratios.

## 3.7 Summary

In this chapter each step in VOM is analyzed and number of improvements and additions has been proposed. The entire improved version of VOM is summarized in Appendix B.

The main improvements of VOM are:

- VOM lacked a detailed approach with which the identification and the selection of relevant stakeholders could be performed. After a detailed analysis of the methods proposed by previous MSC researches Smulders (2010), Repko (2011), and Bennebroek (2012), it was proposed to use the same approach as defined in the research of (Bennebroek, 2012) except instead of using numerical method to rank and classify the stakeholders, a new qualitative method is defined as formulated in section (3.1).

- For the formulation of set of objectives, again VOM lacked a clear method on how to perform this step. It is also proposed to use the same steps as defined in the research of (Bennebroek, 2012) except, in a different order and with additional steps to ensure a proper formulation of objectives, see section (3.2) for more details.
- VOM states the AHP is method used in determining the weight factors of the formulated objectives. However, AHP lacked two main steps namely, the rating scale and the recombination of assessments from the relevant stakeholders. Therefore, it was proposed to use power series rating scale with base a=2 and to recombine different assessments from relevant stakeholders by using AHP twice. It will be used to determine the importance of relevant stakeholders relative to their firm or to their organization, and it will be used to determine the weight factors of the formulated objectives according to each relevant stakeholder. Finally the objectives weight factors for all relevant stakeholders will be calculated using equation (3.16) as explained in section (3.3).
- The fourth step of VOM is the formulation of attributes. This step is considered relatively clear as defined in VOM, thus no major additions have been made. See section (3.4).
- For the determination of attributes weight factors in VOM, it is proposed to use AHP with power series rating scale with base a=2. For more details and explanations see section (3.5).
- The last step in VOM is to combine all in one model using equations (2.17) and (2.18) in order to evaluate the alternatives relative to the reference situation based on added value for the relevant stakeholders. As stated in previous MSC researches (Repko, 2011) and (Bennebroek, 2012), the consistent ratios will be applied and the feasible ranges will be introduced to the attributes before including them in the value model in order to avoid mathematical issues during calculations.

Now that VOM has been improved, the value model for the turnaround process will be constructed in the next chapter.

# 4 Value Model of the Turnaround Process

In this chapter, the value model for the turnaround process will be constructed based on VOM as developed in chapter (3). This chapter is organized as follows:

1 A brief description of turnaround sub processes will be provided in section (4.1)
2 Identify and select relevant stakeholders (section 4.2)
3 Formulate set of objectives (section 4.3)
4 Determine objectives weight factors (section 4.4)
5 Select attributes (section 4.5)
6 Determine attributes weight factors (section 4.6)
7 Combine all into one model (section 4.7)
8 Finally, a brief summary will be provided in section (4.8)

## 4.1 Description of Turnaround Sub Processes

As mentioned in section (2.1.1), the turnaround sub processes can be divided into four types of services namely, ramp services, on ramp aircraft serving, onboard servicing and external ramp equipment. In order to get an insight of the activities and the labor in each sub process, the turnaround sub processes are described according to Ashford et al. (2013), Kingma (2005), O'Callaghan (2012), and Smulders (2010) in the following subsections.

### 4.1.1 Ramp Services

**Supervision:** since there are many activities carried out during turnaround process, an overall supervision is required to ensure a sufficient coordination of operations to prevent delays.

**Marshaling:** it provides guidance to the pilot to park the aircraft in the required position. Also, to position the aircraft out of its parking position, it can be either performed by personnel or by an automatic self-docking guide.

**Start up:** it can be either done by the aircraft itself using its auxiliary power unit (APU), or by a compressed jet air which is delivered by a mobile engine air start-power unit, by the aid of a system of pipes installed on the apron.

**Moving/towing aircraft or pushback:** this activity is required especially when the aircraft needs to leave its parking stand backward. It is usually performed by an aircraft tow tractor.

**Safety measures:** It includes provision of suitable firefighting equipment, other protective equipment and personnel. It also includes notifying the carrier of any noticed damage during turnaround operations.

### 4.1.2 Aircraft Ramp Servicing

**Repair of faults:** the reported faults in the technical log which do not cause the withdrawal of the aircraft from the service, must be repaired under the supervision of a station engineer.

**Fueling:** the aircraft must be supplied with an adequate uncontaminated fuel in a safe and efficient manner. The fuel could be supplied by a mobile truck, apron hydrant system or a combination of two to increase efficiency. The use of apron hydrant system lowers the heavy demand on the airside transport system.

**Wheels and tires check:** this sub process includes the visual and physical inspection of wheels and tires to ensure that the tires are still serviceable.

**Ground power supply:** in order to reduce fuel consumption and noise emission during turnaround, aircraft is powered by a ground electrical supply or in some airports by a central power supplies through a system of cables.

**Deicing:** a deicing washer vehicle is used to spray the fuselage and wings with deicing fluid, in order to remove the ice and prevent it from forming before the flight during the winter or cold weather.

**Cooling/heating:** when aircraft is standing during turnaround operations without function of its APU, auxiliary mobile heating or cooling unit is used to maintain a suitable temperature of aircraft interior.

**Toilet servicing:** it includes draining and flushing the lavatory tank and refilling it with chemicals. It can be either done by a toilet service truck or by a toilet service pit which has connections to wastewater, chemicals and flush water.

**Potable water:** it includes refilling the water tank and occasionally draining it. It can be done either by a water truck or by a water pit system.

**Routine and Non-routine maintenance:** they are types of maintenance which are scheduled and performed during turnaround operations

**Walk around check:** it is performed at the end of turnaround process to check whether the aircraft is damaged and whether all connections are closed etc.

### 4.1.3 Onboard Servicing

**Cleaning:** this process is performed to ensure the cleanliness of the cabin for the passengers for the next flight.

**Catering:** this includes the provision of necessary meals, snacks and drinks which are stored in special trolleys which fit within the aircraft's galleys. The used trolleys from the previous flight are taken out of the aircraft and the loading and unloading of trolleys is performed by a catering service truck.

### 4.1.4 External Ramp Equipment

**Boarding and disembark of passengers:** this sub process is normally coordinated by the flight crew and the provision of steps and buses (to carry the passengers to terminals) can be a task of airport operator, airline, or a separate handling agent.

**Loading and unloading of baggage/cargo/mail:** this process starts immediacy after the aircraft is docked. It includes the unloading of bags from the aircraft into trolleys which are hooked-up to each other or to a tug for transport to the baggage sorting area, passenger terminal, or cargo terminal depending on where it should go (O'Callaghan, 2012). Once the aircraft holds are empty the loading of bags for the next flight starts. After the loading of bags is finished the aircraft holds' doors are closed.

Now that each turnaround sub process is described, the value model for the turnaround process can be developed using VOM as defined in chapter (3).

## 4.2 Identify and Select Relevant Stakeholders

The airport stakeholders which are related to turnaround process will be identified, and then the relevant stakeholders will be selected considering the following decision context; improving the overall performance of turnaround.

### 4.2.1 Identify Stakeholders within Turnaround Process

#### *4.2.1.1 Create a Long List of Stakeholders Using Step 2 of Analysis of Complex Neighborhoods*

- **Which stakeholders are actively involved?**

The list containing all airport stakeholders and their associated organizations is provided in chapter (2) in table (2.4). From this list, the stakeholders who are actively involved within turnaround process are: airport operator, service providers (depending on the outsourced activities served during turnaround process), airline operator, fire service, ambulance and medical services, and meteorology. Air Traffic Control (ATC) is considered inactively involved within turnaround process, because they are involved in performing aircraft pushback (Leeuwen, 2007), which does not occur between aircraft on-chocks and off-chocks. Therefore, their operations may not be considered active within turnaround process.

- **Which stakeholders have powers which have a role in creating or solving the problem?**

The stakeholders who are actively involved may also have powers which have a role in creating or solving the problem. This is reflected by the performance of their operations. National government and local authorities and municipals could also be considered as stakeholders who possess power in solving or creating the problem, because any change or modification to the current situation must comply with their restricted legislation.

- **Which stakeholders possess resources that can be useful for the problem?**

Airline operator and airport operator possess data over turnarounds performed in previous years. By analyzing data, the problems during current operations could be detected and number of alternatives could be proposed to solve these problems.

- **Which stakeholders can be assumed to require involvement at some point?**

The purpose of this research is to improve the overall performance of turnaround process using the value model. One of these potential improvements could be reducing the amount of delays caused by turnaround which might be interesting for ATC. As well as reducing the emission of noise and pollutants which might be interesting for the non-users (e.g. local communities see table (2.4)) and national government. Therefore, it could be assumed that these stakeholders might require involvement at some point.

- **Which stakeholders are not actively involved but are part of the problem?**

The stakeholders who are not actively involved but are part of the problem are: national government, air traffic control, users (passengers), and nonusers. National government requires that the work environment and the labor during turnaround operations should comply with their requirements and restricted legislation. Air Traffic control would appreciate if the punctuality of turnaround process is improved so that their operations would be less disturbed and subsequently, less workload. The users would appreciate the punctuality of the airline and the airport as well therefore; the amount of delays caused by turnaround process should be kept at minimum. Also the passengers require a clean and safe aircraft and services with a convenient quality. While nonusers (local authorities and communities) would appreciate if the airport operations do not induce noise and waste including hazardous emissions (Schaar & Sherry, 2010), which might negatively affect the environment and the residents living nearby the airport.

Thus the identified stakeholders are:

- Airline operator
- Airport operator
- Air Traffic Control
- National government
- local authorities
- Local communities
- Service providers (catering, fuel suppliers…)
- Passengers
- Meteorology
- Ambulance and medical services
- Fire service

The nonusers (e.g. environmental activists, local chambers…) are represented by local authorities and local communities and therefore, they are not included in the identified stakeholders, see table (2.4).

#### *4.2.1.2 Select the Stakeholders that Fall within the Scope of the Value Model*

Fire service, ambulance and medical services operate in the aprons or aircraft parking stand facilities, but only in the emergency circumstances which are not considered day-to-day operations (Bennebroek, 2012). Therefore, it is decided to not include them as identified stakeholders.

In the case of meteorology, their main operations which are the supply of weather data and issuing warnings on hazardous weather for safe aircraft operations will be considered, beyond the scope of this research. Therefore, they will not be included as identified stakeholders within turnaround process.

It could be assumed that the effect of turnaround process on the residents living nearby the airport, which are presented by local communities and local authorities are negligible compared to the outbound or inbound traffic in the airport. Therefore, the local communities and local authorities will not be included as identified stakeholders within turnaround process.

Thus the remaining identified stakeholders within turnaround process are: airline operator, airport operator, air traffic control, national government, service providers and passengers.

### 4.2.2 Map the Relations among the Identified Stakeholders

The formal relations among identified stakeholders are visualized in figure (4.1). The national government represents both Transport and Water Management Inspectorate and Labor inspectorate; moreover they may inspect all the operations which occur in and outside the airport facility. Ground handling company represents the service providers for instance, fuel suppliers, catering and cleaning services etc. Air Traffic Control is included as a part of the airport.

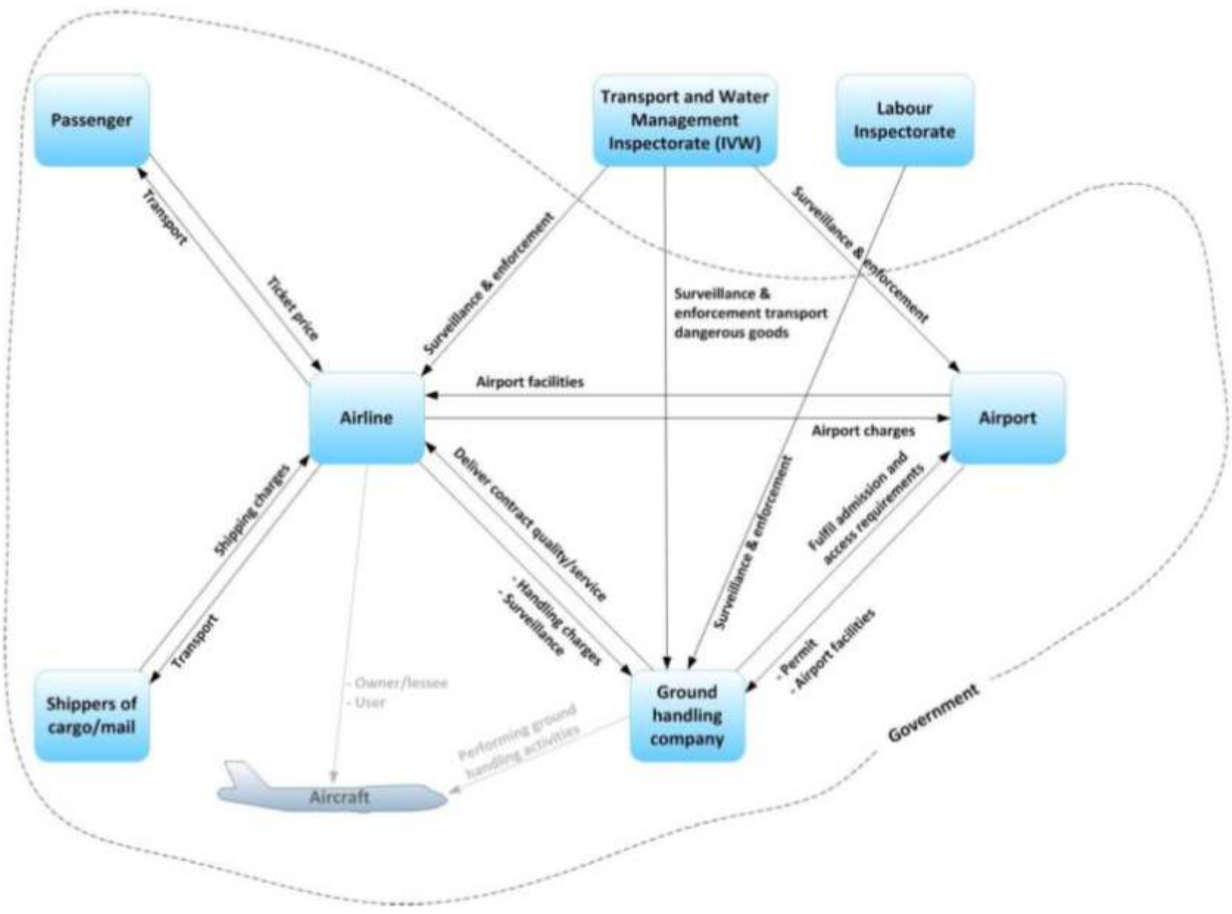


Figure 4-1: Formal relations among identified stakeholders within turnaround process (Zwaan, 2012)

### 4.2.3 Select Relevant Stakeholders

#### *4.2.3.1 Rank Identified Stakeholders*

This subsection deals with ranking of the identified stakeholders based on their potential for threat and cooperation, using qualitative ranking method defined in section (3.1).

- **Airport operator**

Airport operator controls key resources without which the airlines, air traffic control and service providers and their supply chain cannot function, namely the provision of infrastructure (e.g., runways, aprons…). Airport operator could be seen as equally powerful as the organization which is airport itself. They are likely to take supportive action since the purpose is to improve the performance of turnaround process. Airport operator is likely to form coalition with the organization which is represented by itself. The qualitative ranking of airport operator is provided in table (4.1).

**Table 4-1: Qualitative ranking of airport operator**

| Dimensions | | Threat | Cooperation |
|---|---|---|---|
| **Resources** | Control resources | Significant high (++) | Significant high (++) |
| **Power** | Equally powerful as the organization | High (+) | Neutral (+-) |
| **Likelihood to take action** | Likely to take supportive action | Significant low (--) | Significant high (++) |
| **Likelihood to form coalition** | Likely to form coalition with organization | Low (-) | High (+) |
| | Sum of the positive and negative signs | 0 | 5(+) |

- Airline operator

Airline controls key resources which is the provision of flights. They are regarded as equally as powerful as the organization which is represented by the airport operator. They are likely to take supportive action since the purpose is to improve the performance of turnaround process. They are likely to form coalition with airport operator since they both strive to improve the turnaround process. The qualitative ranking of airline operator is provided in table (4.2).

Table 4-2: Qualitative ranking of airline operator

| Dimensions | | Threat | Cooperation |
|---|---|---|---|
| **Resources** | Control resources | Significant high (++) | Significant high (++) |
| **Power** | Equally powerful as the organization | High (+) | Neutral (+-) |
| **Likelihood to take action** | Likely to take supportive action | Significant low (--) | Significant high (++) |
| **Likelihood to form coalition** | Likely to form coalition with organization | Low (-) | High (+) |
| | Sum of the positive and negative signs | 0 | 5(+) |

- Air Traffic Control

Air Traffic Control controls key resources which is the control and allocation of airspace (Bennebroek, 2012). They can be seen as equally powerful as the airport operator. They are likely to take supportive action as well as non-supportive action because their interests may not always coincide with airport operator regarding the improvement of the performance of turnaround process. They are likely to form coalition with airport operator. Qualitative ranking of Air Traffic Control is provided in table (4.3).

Table 4-3: Qualitative ranking of Air Traffic Control

| Dimensions | | Threat | Cooperation |
|---|---|---|---|
| **Resources** | Control resources | Significant high (++) | Significant high (++) |
| **Power** | Equally powerful as the organization | High (+) | Neutral (+-) |
| **Likelihood to take action** | Likely to take supportive action | Significant low (--) | Significant high (++) |
| | Likely to take non-supportive action | Significant high (++) | Significant low (--) |
| **Likelihood** | Likely to form | Low (-) | High (+) |

| | | | |
|---|---|---|---|
| **to form coalition** | coalition with organization | | |
| | Sum of the positive and negative signs | 2(+) | 3(+) |

- National government

They control key resources which are the legislation and regulations which the operations in the airport must comply with. Therefore, they can be seen more powerful than the airport operator (Bennebroek, 2012). They are likely to take supportive actions to improve the airport operations such as turnaround in order to enhance the economy. However they are also likely to take unsupportive actions if the operations of the airport do not comply with their restricted legislation. Since they stand above all the parties, they are unlikely to form any coalition (Bennebroek, 2012). Qualitative ranking of national government is provided in table (4.4).

**Table 4-4: Qualitative ranking of National government**

| Dimensions | | Threat | Cooperation |
|---|---|---|---|
| **Resources** | Control resources | Significant high (++) | Significant high (++) |
| **Power** | More powerful than the organization | Significant High (++) | Neutral (+-) |
| **Likelihood to take action** | Likely to take supportive action | Significant low (--) | Significant high (++) |
| | Likely to take non-supportive action | Significant high (++) | Significant low (--) |
| **Likelihood to form coalition** | Unlikely to form any coalition | Neutral (+-) | Low (-) |
| | Sum of the positive and negative signs | 4(+) | 1(+) |

- Service providers (catering, fuel suppliers…)

They do not control key resources since they are hired by the airport operator or the airline operator and they can be replaced by another competitor (service provider(s)). Therefore, they are considered less powerful than the airport operator. They are unlikely to take any action and also to form any coalition outside the agreed activities formed by the tender (Bennebroek, 2012). The qualitative ranking of service providers is provided in table (4.5).

**Table 4-5: Qualitative ranking of service providers**

| Dimensions | | Threat | Cooperation |
|---|---|---|---|
| **Resources** | Does not control resources | Low (-) | Neutral (+-) |
| **Power** | Less powerful than the organization | Low (-) | High (+) |
| **Likelihood to take action** | Unlikely to take any action | Neutral (+-) | Neutral (+-) |
| **Likelihood to form coalition** | Unlikely to form any coalition | Neutral (+-) | Low (-) |
| | Sum of the positive and negative signs | 2(-) | 0 |

- Users (passengers)

They control key resources which is their choice for the airline and the airport which generates revenues. However, since they act as individuals they are considered less powerful than the airport operator and they are unlikely to take any action or form any coalition. The qualitative ranking of passengers is provided in table (4.6).

**Table 4-6: Qualitative ranking of passengers**

| Dimensions | | Threat | Cooperation |
|---|---|---|---|
| **Resources** | Does control resources | Significant high (++) | High (++) |
| **Power** | Less powerful than the organization | Low (-) | High (+) |
| **Likelihood to take action** | Unlikely to take any action | Neutral (+-) | Neutral (+-) |
| **Likelihood to form coalition** | Unlikely to form any coalition | Neutral (+-) | Low (-) |
| | Sum of the positive and negative signs | 1(+) | 2(+) |

The ranking of the identified stakeholders is summarized in table (4.7). Now that each identified stakeholders is ranked, a classification of these identified stakeholders can be made using Savage's approach. The results of the classification are provided in table (4.8).

Table 4-7: Ranking of the identified stakeholders based on their potentials for threat and cooperation

| Stakeholders | Potential of threat | Potential of cooperation |
|---|---|---|
| Airport operator | 0 | 5+ |
| Airline operator | 0 | 5+ |
| Air traffic control | 2+ | 3+ |
| National government | 4+ | 1+ |
| Service providers | 2- | 0 |
| Users (passengers) | 1+ | 2+ |

Table 4-8: Classification of the identified stakeholders based on Savage's approach

| Stakeholder type | Identified stakeholders |
|---|---|
| Mixed blessings | National government<br>Air Traffic Control<br>Users (passengers) |
| Supportive | Airline operator<br>Airport operator |
| Non-supportive | |
| Marginal | Service providers (e.g. aircraft fueling, catering service…) |

Based on the classification shown in table (4.8), the relevant stakeholders within turnaround process are:

- Airport operator
- Airline operator
- Air traffic control
- National government
- Users (passengers)

## 4.3 Formulate Set of Objectives

In this section, the formulation of objectives within turnaround process will be performed by implementing the method defined in section (3.3).

### 4.3.1 Create a Long List of Objectives for Each Relevant Stakeholder

Table (4.9) shows the objectives of each relevant stakeholder based on literature study.

Table 4-9: Objectives of the relevant stakeholders regarding turnaround process based on following literatures (Zwaan, 2012); (Bennebroek, 2012); (Carney & Mew, 2003); (Sluis, 2013)

| Stakeholder | Objectives regarding turnaround operations |
|---|---|
| **National government** | • Less environmental impacts<br>• Enhancing regional and national economy<br>• Ensure sustainable growth<br>• Ensure safety<br>• Protect residents |
| **Airport operator** | • Reducing turnaround time<br>• Increasing capacity ( apron/aircraft remote parking capacity)<br>• Reliable ground handling process (reliable operations)<br>• Low aeronautical charges (e.g. apron charges)<br>• Low handling charges<br>• Quick and smooth delivery of passengers and packages<br>• Less environmental impacts<br>• Increase safety<br>• Maximize efficiency and minimize cost<br>• Increase predictability |
| **Airline** | • Quick ground handling process (less turnaround time)<br>• Increase availability of fleet<br>• Low aeronautical charges<br>• Punctual service (on-time performance)<br>• High extent of convenience<br>• Less environmental impacts<br>• Grow profitability and sustainability |
| **Air traffic control** | • Reliable and safe ground handling process<br>• Safe aircraft<br>• Punctuality (on-time performance)<br>• Less workload<br>• Increase predictability |
| **Passengers** | • Low tickets prices<br>• High quality services<br>• Ensure punctual arrival and departure times<br>• Clean and safe aircraft<br>• Environmental friendly |

### 4.3.2 Omit the Objectives which are Unrelated to the Research Scope

An objective of national government which is protecting the residents could be removed, because it is covered in less environmental impacts. An objective of Air Traffic Control which is less workload is not considered directly within turnaround process. This is because if the punctuality of turnaround process is decreased which may cause an increase in delays and subsequently, Air Traffic Control has more workload. Thus it could be concluded that this objective is covered in the punctuality of turnaround process and therefore, it is removed.

### 4.3.3 Structure the Objectives Using Objective Tree

By collecting the objectives of the relevant stakeholders within turnaround process and linking them to each other, results in the objective tree illustrated in figure (4.2). At the top of the tree, it could be clearly seen, the strategic objective of the national government which is the growth of the regional and national economy. This could be achieved by ensuring a sustainable growth of the airport which is also a strategic objective of the national government, see table (4.9). This latest strategic objective could be achieved by increasing profitability, ensuring safety (e.g. safe operations), delivering high quality of service to the customers to ensure good sustainable customer relations (Smulders, 2010), and reducing environmental impacts. These objectives are also considered strategic objectives and they can be further divided into several means objectives. Except the safety and the environment related objectives which can be seen as fundamental strategic objectives on their own. The means objectives which are illustrated in the fourth level of the objective tree (see figure (4.2)), can be achieved by the fundamental objectives, which are illustrated in the lowest level of objective tree. These fundamental objectives have the potentials to be included in the value model, however further assessments are required.

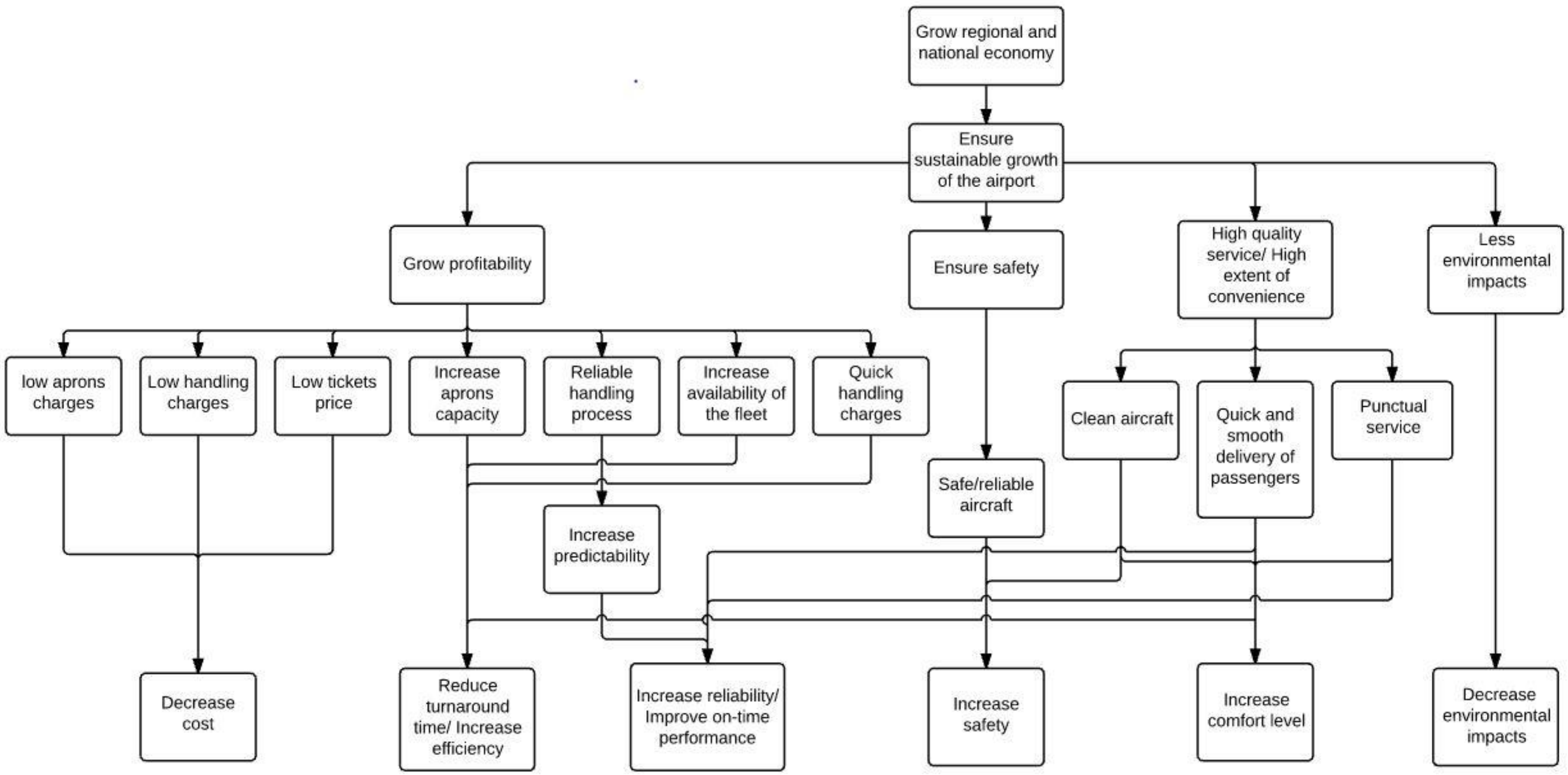


**Figure 4-2: Objective tree regarding turnaround process**

### 4.3.4 Select Right Level of Abstraction

The fundamental objectives which are illustrated in the lowest level of objective tree (see figure (4.2)) meet the following characteristics: essential, controllable, complete, and non-redundant as defined by Keeney (1992).

### 4.3.5 Finalized Objectives

The selected objectives should be checked with the following features namely, a decision context, an object, and a direction of preference. Thus each fundamental objective must meet these features, see table (4.10):

Table 4-10: Testing fundamental objectives based on decision context, object and direction of preference

| Fundamental objective | Decision context | object | Direction of preference |
|---|---|---|---|
| **Decrease cost** | Turnaround operations | cost | Decrease |
| **Decrease environmental impacts** | Turnaround operations | Environmental impacts | Decrease |
| **Increase reliability** | Turnaround operations | reliability | Increase |
| **Decrease turnaround time** | Turnaround operations | Time | Decrease |
| **Increase safety** | Turnaround operations | Safety | Increase |
| **Increase comfort level** | Turnaround operations | Comfort level | Increase |

### 4.3.6 Checking the Requirements of Objectives Based on Set of Characteristics

The selected objectives should be checked with the remaining characteristics as defined by Keeney (1992): decomposable, concise, understandable, measurable, and operational. Before checking whether the remained fundamental objectives fulfill these characteristics, they should be first defined.

- Cost

This objective includes two main components namely, labor cost and operating cost (Smulders, 2010). Where labor cost is defined as the wages paid to employees in a certain amount of time (e.g., hourly, weekly or monthly basis). It can be determined by calculating the number of employees involved within a turnaround sub process and the wages they receive per hour, depending on the type and number of tasks that should be performed. While operating cost includes all other cost such as the aeronautical charges per hour, the charges of equipment and the resources used during each turnaround sub activity.

- Turnaround time

This objective is defined as aforementioned as, the duration the aircraft spends at the apron starting from on-shocks until off-chocks. In order to reduce the turnaround time, the duration of activities on the critical path should be reduced. Thus the average time of the current state of turnaround sub processes on the critical path should be determined and then it should be estimated of the alternatives, in order to be included in the value model of the turnaround process.

- Reliability

Reliability from engineering perspective is defined as the probability that a system will perform in a satisfactory manner for a given period of time when used under specified operating conditions (Curran & Verhagen, 2014).

In this research, the reliability is expressed as the probability that all steps or activities within a turnaround sub process are executed on time as scheduled. Thus one could say that the fewer amounts of delays within a turnaround sub process the higher the reliability is. So during this research, the reliability of the performed turnaround sub processes in a certain amount of time (e.g. a half year or a whole year) should be calculated and then it should be estimated of the alternatives, in order to be included in the value model of the turnaround process.

- Safety

This objective is defined from engineering perspective as the freedom from hazards to human and equipment (Curran & Verhagen, 2014). Since safety is difficult to measure, it could be expressed in term of accidents and number of incidents as in the research of (Smulders, 2010). So as the reliability, the safety of the performed turnaround sub processes in a certain amount of time (e.g. a half year or a whole year) should be measured and then it should be estimated of the alternatives, in order to be included in the value model of the turnaround process.

- Environmental impact

This objective includes the noise and the emissions of any waste or hazardous emissions. This objective can be computed by measuring the noise and the emissions of any waste or hazardous emissions of the current state of a turnaround process. Thereafter, it should be measured or estimated of the alternatives, in order to be included in the value model. In the research of (Smulders, 2010), environmental impacts at airport can be computed, by measuring the Average noise in decibels, water and solid waste per movement, water consumption per movement, and amount of $CO_2$ and $NO_x$ per movement.

- Comfort level

Comfort level is considered varied in this research only for passengers boarding and disembark and constant for the other turnaround sub processes. As there exist different strategies on how to board and disembark the aircraft. Most of these strategies strive at minimizing duration for passenger boarding or disembark. However, some of these strategies consider also the comfort level (Nyquist & McFadden, 2008), which may be a significant performance indicator for some airlines. These strategies attempt to find an optimal trade-off between comfort level and time duration.

The comfort level of the current state and of the alternatives regarding passengers boarding and disembark can be determined by measuring the square meter per occupant for each boarding or disembark strategy, and then define its level of service standard, for instance as defined by IATA see table (4.11). For each defined level of service standard for instance from F to A (see table (4.11)), a certain score can be given which determines the comfort level. By doing so the comfort level of each boarding or disembark strategy could be included in the value model of the turnaround process.

**Table 4-11: IATA LOS Space Standards (Rolling, 2013)**

| | | Level of service standard | | | | | |
|---|---|---|---|---|---|---|---|
| **Activity** | **Situation** | **A** | **B** | **C** | **D** | **E** | **F** |
| **Waiting and circulating** | Moving about freely | 2.7 | 2.3 | 1.9 | 1.5 | 1.0 | Break |
| **Check-in queues** | Moving with bags | 1.8 | 1.6 | 1.4 | 1.2 | 1.0 | break |
| **Hold room, controls** | Queued, without bags | 1.4 | 1.2 | 1.0 | 0.8 | 0.6 | Break |
| **Bag reclaim area** | Moving with bags | 2.0 | 1.8 | 1.6 | 1.4 | 1.2 | Break |

All fundamental objectives are defined such that they meet the following characteristics: decomposable, concise and understandable, but whether they are measurable and operational should be checked by consulting relevant stakeholders.

After consulting Kenya Airways (KQ) which is one of the relevant stakeholders representing airline operator, they possess data of turnaround processes performed from January until July 2012. By using this data, the current state of number of turnaround processes could be determined but only for the following fundamental objectives: turnaround time and reliability. Due to unavailability of data, the objectives cost, comfort level, safety and environmental impacts will be assumed constant in the value model of the turnaround process in this research. Data received from (KQ) will be explained in more details in the next chapter which is a practical case study of KQ's turnaround processes.

## 4.4 Determine Objectives Weight Factors Using AHP

In this section, the weight factors of the formulated set of objectives within turnaround process defined in the previous section will be determined. The higher the weight factor the more important the fundamental objective is.

As explained in section (3.3), the AHP will be used twice in order to determine the objectives weight factors for all relevant stakeholders. It will be used first to compute the weights of objectives according to each relevant stakeholder. Thereafter, to compute the weights which determine the importance of relevant stakeholders relative to the firm (airport). Eventually, by using equation (3.16) the objectives weight factors for all relevant stakeholders within turnaround process can be determined. The calculations using AHP is covered in the following sub sections.

### 4.4.1 Objective Weight Factors According to Each Relevant Stakeholder

In this subsection, the objective weight factors according to each relevant stakeholder within turnaround process will be determined using the method defined in section (3.3).

- **National government**

The first step in AHP is to compare the objectives in pair-wise fashion. This will be done based on the analysis of the literature study (see table (4.9)) and on the findings from the previous MSC researches on VOM at airport namely Repko (2011) and Bennebroek (2012).

According to table (4.9), the following objectives are regarded important to national government; less environmental impacts, enhancing regional and national economy, ensure sustainable growth of the airport, ensure safety and protect residents. Thus, it could be concluded that the following fundamental objectives within turnaround process are important to the national government; environmental impacts and safety. However, in order in to ensure a sustainable growth of the airport which will enhance the regional and national economy, the turnaround time should be reduced and the reliability should be increased, in order to increase the capacity of the airport which will lead to more profit resulting in a sustainable growth.

After reviewing the scores given by authorities to the fundamental objectives of airport outbound traffic which determine their importance (Repko, 2011), see table (4.12), it was decided to relate those fundamental objectives to those of turnaround process and then perform the pairwise comparison of objectives as can be seen in table (4.13).

Table 4-12: Determination of objectives importance relative the identified stakeholders (Repko, 2011)

| | Noise | Capacity | Workload | Flight | Safety | Main port |
|---|---|---|---|---|---|---|
| **Airport** | 7 | 5 | 1 | 2 | 1 | 7 |
| **Airline** | 5 | 5 | 7 | 5 | 5 | 7 |
| **ATC** | 1 | 7 | 10 | 2 | 1 | 5 |
| **Communities** | 10 | 1 | 1 | 1 | 7 | 5 |
| **Authorities** | 7 | 5 | 1 | 2 | 7 | 7 |
| **Sum** | 30 | 23 | 20 | 12 | 21 | 31 |

The fundamental objectives of table (4.12) are related to those of table (4.13) respectively as following: noise is related to environmental impact, safety is related to safety, capacity is related to turnaround time and reliability, workload can be slightly related to cost due to labor cost which can be directly related to workload, and unfortunately the remaining fundamental objectives of table (4.12) cannot be related to comfort level. Thus by using table (4.9) and table (4.12), it was decided to determine the importance of the fundamental objectives of turnaround process from the perspective of national government as follows: safety is considered the most important objective within turnaround process, environment impacts also important but slightly less important than safety. This is because the environmental impacts within turnaround process are assumed less drastic than those of airport outbound traffic. Turnaround time and reliability are considered slightly less important than environmental impacts. Cost and comfort level are assumed the least important objectives of turnaround process from the perspective of national government. This analysis results in table (4.13) which could be translated into reciprocal comparison matrix using power series rating scale with base a=2, see table (4.14).

Table 4-13: Pairwise comparison of fundamental objectives within turnaround process according to national government based on literature study

| Objectives | Turnaround time | Reliability | Cost | Safety | Comfort level | Environmental impacts |
|---|---|---|---|---|---|---|
| **Turnaround time** | Equally important | Equally important | Slightly more important | Less important | Slightly more important | Slightly less important |
| **Reliability** | Equally important | Equally important | Slightly more important | Less important | Slightly more important | Slightly less important |
| **Cost** | Slightly less important | Slightly less important | equally important | Significant less important | Equally important | Less important |
| **Safety** | More important | More important | Significant more important | Equally important | Significant more important | Slightly more important |
| **Comfort level** | Slightly less important | Slightly less important | Equally important | Significant less important | Equally important | Less important |
| **Environmental impacts** | Slightly more important | Slightly more important | More important | Slightly less important | More important | Equally important |

Table 4-14: Reciprocal comparison matrix according to national government based on literature study

| Objectives | Turnaround time | Reliability | Cost | Safety | Comfort level | Environmental impacts |
|---|---|---|---|---|---|---|
| **Turnaround time** | 1 | 1 | 2 | 1/4 | 2 | 1/2 |
| **Reliability** | 1 | 1 | 2 | 1/4 | 2 | 1/2 |
| **Cost** | 1/2 | 1/2 | 1 | 1/8 | 1 | 1/4 |
| **Safety** | 4 | 4 | 8 | 1 | 8 | 2 |
| **Comfort level** | 1/2 | 1/2 | 1 | 1/8 | 1 | 1/4 |
| **Environmental impacts** | 2 | 2 | 4 | 1/2 | 4 | 1 |

The largest eigenvalue of the reciprocal matrix given in table (4.14) is 6 and its corresponding normalized eigenvector is $v = (0.1111, 0.1111, 0.05556, 0.4444, 0.0555, 0.2222)$.Thus the components of vector (v) become the weight factors of the following objectives respectively; turnaround time, reliability, cost, safety, comfort level and environmental impacts. The consistency ratio of the reciprocal matrix given in table (4.14) equals 0 which is less than 0.1, from which it could be concluded that the consistency of the weight factors is satisfactory.

- **Air Traffic Control**

From table (4.9), the objectives of Air Traffic Control regarding turnaround process are: reliable and safe ground handling process, safe aircraft, punctuality (on-time performance), and less workload. With reliable ground handling process means less amount of delays thus higher punctuality. Thus it could be concluded that safety and reliability are considered important fundamental objectives within turnaround process from the perspective of Air Traffic Control.

As in previous paragraph, the fundamental objectives given in table (4.12) will be related to those of turnaround process. By combining the analysis of objectives of Air Traffic Control stated in table (4.9) and the scores given to those fundamental objectives by Air Traffic Control in table (4.12), the pairwise comparison of fundamental objectives within turnaround process can be performed from the perspective of Air Traffic Control, see table (4.15). The fundamental objectives of table (4.12) are related to those of table (4.15) respectively as following: noise is related to environmental impacts, capacity is related to turnaround time, workload is related to reliability as less amount of delays less workloads of Air Traffic Control, safety is related to safety and unfortunately the remaining fundamental objectives of table (4.12) cannot be related to comfort level and to cost.

It was decided to consider the reliability and safety the most important objectives within turnaround process to Air Traffic Control, since they were stated in table (4.9) as objectives of Air Traffic Control although, safety has a low score by Air Traffic Control in table (4.12). Turnaround time is considered also important since the less turnaround time the higher the capacity is. However it will be considered slightly less important than reliability and safety. Comfort level, cost and environmental impacts within turnaround process are considered the least important fundamental objectives from the perspective of Air Traffic Control, since they are not mentioned in table (4.9) as objectives of Air Traffic Control. For the environmental impacts, it could also be concluded because noise has a low score by Air Traffic Control as stated in table (4.12). This analysis results in table (4.15) which could be translated into reciprocal comparison matrix using power series rating scale with base a=2, see table (4.16).

**Table 4-15: Pairwise comparison of fundamental objectives within turnaround process according to Air Traffic Control based on literature study**

| Objectives | Turnaround time | Reliability | Cost | Safety | Comfort level | Environmental impacts |
|---|---|---|---|---|---|---|
| **Turnaround time** | Equally important | Slightly less important | More important | Slightly Less important | More important | More important |
| **Reliability** | Slightly more important | Equally important | Significant more important | Equally important | Significant more important | Significant more important |
| **Cost** | Less important | Significant less | equally important | Significant less | Equally important | Equally important |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | important | | important | | |
| **Safety** | Slightly more important | Equally important | Significant more important | Equally important | Significant more important | Significant more important |
| **Comfort level** | Less important | Significant less important | Equally important | Significant less important | Equally important | Equally important |
| **Environmental impacts** | Less important | Significant less important | Equally important | Significant less important | Equally important | Equally important |

**Table 4-16: Reciprocal comparison matrix according to Air Traffic Control based on literature study**

| Objectives | Turnaround time | Reliability | Cost | Safety | Comfort level | Environmental impacts |
|---|---|---|---|---|---|---|
| **Turnaround time** | 1 | 1/2 | 4 | 1/2 | 4 | 4 |
| **Reliability** | 2 | 1 | 8 | 1 | 8 | 8 |
| **Cost** | 1/4 | 1/8 | 1 | 1/8 | 1 | 1 |
| **Safety** | 2 | 1 | 8 | 1 | 8 | 8 |
| **Comfort level** | 1/4 | 1/8 | 1 | 1/8 | 1 | 1 |
| **Environmental impacts** | 1/4 | 1/8 | 1 | 1/8 | 1 | 1 |

The largest eigenvalue of the reciprocal matrix given in table (4.16) is 6 and its corresponding normalized eigenvector is $v = (0.1739, 0.3478, 0.0434, 0.3478, 0.0434, 0.0434)$.Thus the components of vector (v) become the weight factors of the following objectives respectively; turnaround time, reliability, cost, safety, comfort level and environmental impacts. The consistency ratio of the reciprocal matrix given in table (4.16) equals 0 which is less than 0.1, from which it could be concluded that the consistency of the weight factors is satisfactory.

- **Passengers**

The objectives of passengers stated in table (4.9) are: low tickets prices, high quality of services, punctuality, clean and safe aircraft, and environmental friendly. Thus, it could be concluded that all fundamental objectives within turnaround process are important from the perspective of passengers. Low tickets prices could be achieved by reducing the turnaround time in order to increase the profit and decreasing the cost of turnaround operations. High quality of services means that the comfort of passengers should be taken into consideration. Punctuality is achieved by increasing the reliability. Clean and safe aircraft requires safety, and environmental friendly requires reduced environmental impacts during turnaround operations.

By reviewing the scores given to the fundamental objectives of runway maintenance operations defined by Bennebroek (2012), from the perspective of passengers (see table (4.17)), it was decided to relate those fundamental objectives to those of turnaround process. Thereafter, to perform the pairwise comparison of the fundamental objectives within turnaround process see table (4.18).

Table 4-17: Comparison matrix for the passengers (Bennebroek, 2012)

| Objectives | Capacity | Costs | Predictability | Safety | Environment | Nuisance |
|---|---|---|---|---|---|---|
| Capacity | 1 | 8 | 1 | 8 | 8 | 8 |
| Costs | 1/8 | 1 | 1/8 | 1 | 1 | 1 |
| Predictability | 1 | 8 | 1 | 8 | 8 | 8 |
| Safety | 1/8 | 1 | 1/8 | 1 | 1 | 1 |
| Environment | 1/8 | 1 | 1/8 | 1 | 1 | 1 |
| Nuisance | 1/8 | 1 | 1/8 | 1 | 1 | 1 |

Capacity is related to turnaround time as less turnaround time the more the capacity is. Predictability is related to reliability as the fewer amounts of delays the more predictable the operations are. Costs are simply related to cost, safety to safety, and environment and nuisance to environmental impacts. Unfortunately, the comfort level could not be related to any fundamental objective in table (4.17). Thus based on this analysis, it was decided to consider reliability and safety the most important fundamental objectives within turnaround process from the perspective of passengers although; safety is considered unimportant in table (4.17). The turnaround time and comfort level are also considered important, however slightly less important than reliability and safety. The least important fundamental objectives within turnaround process from the perspective of passengers are the cost and the environmental impacts, see table (4.18).

Table 4-18: Pairwise comparison of fundamental objectives within turnaround process according to passengers based on literature study

| Objectives | Turnaround time | Reliability | Cost | Safety | Comfort level | Environmental impacts |
|---|---|---|---|---|---|---|
| Turnaround time | Equally important | Slightly less important | Slightly more important | Slightly Less important | Equally important | Slightly more important |
| Reliability | Slightly more important | Equally important | More important | Equally important | Slightly more important | More important |
| Cost | Slightly less important | Less important | Equally important | Less important | Slightly less important | Equally important |
| Safety | Slightly more important | Equally important | More important | Equally important | Slightly more important | More important |
| Comfort level | Equally important | Slightly less important | Slightly more important | Slightly less important | Equally important | Slightly more important |
| Environmental impacts | Slight Less important | Less important | Equally important | Less important | Slightly less important | Equally important |

Now the qualitative ranking in table (4.18) is translated into comparison matrix using power series rating scale with base a=2 as could be seen in table (4.19).

Table 4-19: Reciprocal comparison matrix according to passengers based on literature study

| Objectives | Turnaround time | Reliability | Cost | Safety | Comfort level | Environmental impacts |
|---|---|---|---|---|---|---|
| Turnaround time | 1 | 1/2 | 2 | 1/2 | 1 | 2 |
| Reliability | 2 | 1 | 4 | 1 | 2 | 4 |
| Cost | 1/2 | 1/4 | 1 | 1/4 | 1/2 | 1 |
| Safety | 2 | 1 | 4 | 1 | 2 | 4 |
| Comfort level | 1 | 1/2 | 2 | 1/2 | 1 | 2 |
| Environmental impacts | 1/2 | 1/4 | 1 | 1/4 | 1/2 | 1 |

The largest eigenvalue of the reciprocal matrix given in table (4.19) is 6 and its corresponding normalized eigenvector is $v = (0.1428, 0.2857, 0.071, 0.2857, 0.1428, 0.071)$.Thus the components of vector (v) become the weight factors of the following objectives respectively; turnaround time, reliability, cost, safety, comfort level and environmental impacts. The consistency ratio of the reciprocal matrix given in table (4.19) equals 0 which is less than 0.1, from which it could be concluded that the consistency of the weight factors is satisfactory.

- **Airline operator**

The objectives of airline stated in table (4.9) are: reduce turnaround time and increase capacity, reliable ground handling process, low aeronautical and handling charges, quick and smooth delivery of passengers and packages, less environmental impacts, increase safety, and minimize cost. Thus it could be concluded that all fundamental objectives within turnaround process should be regarded important from the perspective of airline operator. However, the importance of these fundamental objectives with respect to each other should also be determined. Therefore, the fundamental objectives of airport outbound traffic (Repko, 2011), will be related to those of turnaround process. Thereafter, the pairwise comparison of these fundamental objectives will be performed as could be seen in table (4.20).

The fundamental objectives of table (4.12) are related to those of table (4.20) respectively as following: noise is related to environmental impact, safety is related to safety, capacity is related to turnaround time and reliability, workload could be slightly related to cost due to labor cost which could be directly related to workload, and unfortunately the remaining fundamental objectives of table (4.12) cannot be related to comfort level. Based on the scores given by the airline to the fundamental objectives in table (4.12) and on the literature study (see table (4.9)), it was decided to consider turnaround time, reliability and safety the most important fundamental objectives within turnaround process from the perspective of airline. The cost is considered slightly less important than these latest fundamental objectives, because it is slightly related to workload, although workload has the highest score by the airline in table (4.12). The least important fundamental objectives within turnaround process from the perspective of airline are; comfort level and environmental impacts. This is because the comfort level as defined in section (4.4) is only relevant for passengers boarding and disembark and although, environmental impacts in table (4.12) have the same score as capacity and safety, but within turnaround process the environmental impacts are less drastic than those of outbound traffic. Therefore, it is considered less important than turnaround time, reliability and safety.

Table 4-20: Pairwise comparison of fundamental objectives within turnaround process according to airline operator based on literature study

| Objectives | Turnaround time | Reliability | Cost | Safety | Comfort level | Environmental impacts |
|---|---|---|---|---|---|---|
| **Turnaround time** | Equally important | Equally important | Slightly more important | Equally important | More important | More important |
| **Reliability** | Equally important | Equally important | Slightly more important | Equally important | More important | More important |
| **Cost** | Slightly less important | Slightly less important | Equally important | Slightly less important | Slightly more important | Slightly more important |
| **Safety** | Equally important | Equally important | Slightly more important | Equally important | More important | More important |
| **Comfort level** | Less important | Less important | Slightly less important | Less important | Equally important | Equally important |
| **Environmental impacts** | Less important | Less important | Slightly less important | Less important | Equally important | Equally important |

Now the qualitative ranking in table (4.20) is translated into comparison matrix using power series rating scale with base a=2 as could be seen in table (D.21).

Table 4-21: Reciprocal comparison matrix according to airline based on literature study

| Objectives | Turnaround time | Reliability | Cost | Safety | Comfort level | Environmental impacts |
|---|---|---|---|---|---|---|
| **Turnaround time** | 1 | 1 | 2 | 1 | 4 | 4 |
| **Reliability** | 1 | 1 | 2 | 1 | 4 | 4 |
| **Cost** | 1/2 | 1/2 | 1 | 1/2 | 2 | 2 |
| **Safety** | 1 | 1 | 2 | 1 | 4 | 4 |
| **Comfort level** | 1/4 | 1/4 | 1/2 | 1/4 | 1 | 1 |
| **Environmental impacts** | 1/4 | 1/4 | 1/2 | 1/4 | 1 | 1 |

The largest eigenvalue of the reciprocal matrix given in table (4.21) is 6 and its corresponding normalized eigenvector is $v = (0.25, 0.25, 0.125, 0.25, 0.0625, 0.0625)$.Thus the components of vector (v) become the weight factors of the following objectives respectively; turnaround time, reliability, cost, safety, comfort level, and environmental impacts. The consistency ratio of the reciprocal matrix given in table (4.21) equals 0 which is less than 0.1, from which it could be concluded that the consistency of the weight factors is satisfactory.

- **Airport operator**

The objectives of airport operator stated in table (4.9) are the same as airline operator. Therefore, it could be concluded that all fundamental objectives within turnaround process are important from airport operator's perspective. Except comfort level which could be considered less important compared to other fundamental objectives within turnaround process.

After reviewing the scores given by the airport operator to fundamental objectives of airport outbound traffic in table (4.12), it was decided to consider turnaround time, reliability, and safety the most important fundamental objectives within turnaround process, although safety has a low score by airport in table (4.12). The cost and environmental impacts are considered slightly less important and comfort level is assumed to be significant less important compared to turnaround time, reliability, and safety. The pairwise comparison of fundamental objectives within turnaround process from the perspective of airport is given in table (4.22) and the reciprocal matrix is given table (4.23).

**Table 4-22: Pairwise comparison of fundamental objectives within turnaround process according to airport operator based on literature study**

| Objectives | Turnaround time | Reliability | Cost | Safety | Comfort level | Environmental impacts |
|---|---|---|---|---|---|---|
| **Turnaround time** | Equally important | Equally important | Slightly more important | Equally important | Significant more important | Slightly more important |
| **Reliability** | Equally important | Equally important | Slightly more important | Equally important | Significant more important | Slightly more important |
| **Cost** | Slightly less important | Slightly less important | Equally important | Slightly less important | More important | Equally important |
| **Safety** | Equally important | Equally important | Slightly more important | Equally important | Significant more important | Slightly more important |
| **Comfort level** | Significant less important | Significant less important | Less important | Significant less important | Equally important | Less important |
| **Environmental impacts** | Slightly less important | Slightly less important | Equally important | Slightly less important | More important | Equally important |

Table 4-23: Reciprocal comparison matrix according to airport operator based on literature study

| Objectives | Turnaround time | Reliability | Cost | Safety | Comfort level | Environmental impacts |
|---|---|---|---|---|---|---|
| **Turnaround time** | 1 | 1 | 2 | 1 | 8 | 2 |
| **Reliability** | 1 | 1 | 2 | 1 | 8 | 2 |
| **Cost** | 1/2 | 1/2 | 1 | 1/2 | 4 | 1 |
| **Safety** | 1 | 1 | 2 | 1 | 8 | 2 |
| **Comfort level** | 1/8 | 1/8 | 1/4 | 1/8 | 1 | 1/4 |
| **Environmental impacts** | 1/2 | 1/2 | 1 | 1/2 | 4 | 1 |

The largest eigenvalue of the reciprocal matrix given in table (4.23) is 6 and its corresponding normalized eigenvector is $v = (0.2424, 0.2424, 0.1212, 0.2424, 0.030, 0.1212)$.Thus the components of vector (v) become the weight factors of the following objectives respectively; turnaround time, reliability, cost, safety, comfort level, and environmental impacts. The consistency ratio of the reciprocal matrix given in table (4.23) equals 0 which is less than 0.1, from which it could be concluded that the consistency of the weight factors is satisfactory.

### 4.4.2 Weight Factors of Relevant Stakeholders to the Airport

The AHP as defined in section (3.3) will be used to determine the weight factors of relevant stakeholders which determine their importance relative to the firm. First the pairwise comparison of the relevant stakeholders will be performed which is based on the following aforementioned criteria (see table (4.24)):

- $\frac{Mixed\ blessing}{Supportive} = more\ important = a^2 = 4$
- $\frac{Mixed\ blessing}{Nonsupportive} = slightly\ more\ important = a^1 = 2$
- $\frac{Nonsupportive}{Supportive} = slightly\ more\ important = a^1 = 2$
- $\frac{Nonsupportive}{NonSupportive} = \frac{supportive}{Supportive} = \frac{Mixed\ blessing}{Mixed\ blessing} = equally\ important = a^0 = 1$
- $\frac{supportive}{Mixed\ blessing} = less\ important = a^{-2} = \frac{1}{4}$
- $\frac{Nonsupportive}{Mixed\ blessing} = slightly\ less\ important = a^{-1} = \frac{1}{2}$
- $\frac{supportive}{NonSupportive} = slightly\ less\ important = a^{-1} = \frac{1}{2}$

Table 4-24: Pairwise comparison of relevant stakeholders within turnaround process

| Relevant stakeholders | National government | Air Traffic Control | Passengers | Airline operator | Airport operator |
|---|---|---|---|---|---|
| **National government** | Equally important | Equally important | Equally important | More important | More important |
| **Air Traffic Control** | Equally important | Equally important | Equally important | More important | More important |

| | | | | | |
|---|---|---|---|---|---|
| **Passengers** | Equally important | Equally important | Equally important | More important | More important |
| **Airline Operator** | Less important | Less important | Less important | Equally important | Equally important |
| **Airport Operator** | Less important | Less important | Less important | Equally important | Equally important |

Now the qualitative ranking in table (4.24) is translated into comparison matrix using power series rating scale with base a=2 as could be seen in table (4.25).

Table 4-25: Reciprocal comparison matrix of relevant stakeholders within turnaround process

| Relevant stakeholders | National government | Air Traffic Control | Passengers | Airline operator | Airport operator |
|---|---|---|---|---|---|
| **National government** | 1 | 1 | 1 | 4 | 4 |
| **Air Traffic Control** | 1 | 1 | 1 | 4 | 4 |
| **Passengers** | 1 | 1 | 1 | 4 | 4 |
| **Airline Operator** | 1/4 | 1/4 | 1/4 | 1 | 1 |
| **Airport Operator** | 1/4 | 1/4 | 1/4 | 1 | 1 |

The largest eigenvalue of the reciprocal matrix given in table (4.25) is 5 and its corresponding normalized eigenvector is $v = (0.2857, 0.2857, 0.2857, 0.0714, 0.0714)$.Thus the components of vector (v) become the weight factors of the following relevant stakeholders respectively; national government, air traffic control, passengers, airline operator and airport operator. The consistency ratio of the reciprocal matrix given in table (4.25) equals 0 which is less than 0.1, from which it could be concluded that the consistency of the weight factors is satisfactory.

### 4.4.3 Determine the Objectives Weight Factors for all Relevant Stakeholders

The objectives weight factors for all relevant stakeholders within turnaround process can be determined, by multiplying the objectives weight factors according to each relevant stakeholder which are summarized in table (4.26) as a matrix, by the weight factors of the relevant stakeholders which are summarized in table (4.27) as a vector. This results in the objectives weight factors for all relevant stakeholders within turnaround process, see table (4.28).

Table 4-26 Summary of objectives weight factors according to each relevant stakeholders within turnaround process

| Relevant stakeholders | Turnaround time | Reliability | Cost | Safety | Comfort level | Environmental impacts |
|---|---|---|---|---|---|---|
| **National government** | 0.1111 | 0.1111 | 0.0555 | 0.4444 | 0.0555 | 0.2222 |
| **Air Traffic** | 0.1739 | 0.3478 | 0.0434 | 0.3478 | 0.0434 | 0.0434 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Control | | | | | | |
| Passengers | 0.1428 | 0.2857 | 0.0714 | 0.2857 | 0.1428 | 0.0714 |
| Airline operator | 0.25 | 0.25 | 0.125 | 0.25 | 0.0625 | 0.0625 |
| Airport operator | 0.2424 | 0.2424 | 0.1212 | 0.2424 | 0.030 | 0.1212 |

Table 4-27: Weight factors determining the importance of relevant stakeholders

| Relevant stakeholders | National government | Air Traffic Control | Passengers | Airline operator | Airport operator |
|---|---|---|---|---|---|
| Weight factors | 0.2857 | 0.2857 | 0.2857 | 0.0714 | 0.0714 |

Table 4-28: Objectives weight factors according to relevant stakeholders within turnaround process

| Objectives | Turnaround time | Reliability | Cost | Safety | Comfort level | Environmental impacts |
|---|---|---|---|---|---|---|
| Weight factors of objectives according to all relevant stakeholders within turnaround process | 0.2857*0.1111 +0.2857*0.1739 +0.2857*0.1428 +0.0714*0.25 +0.0714*0.2424 =0.1573 | 0.2857*0.1111 +0.2857*0.3478 +0.2857*0.2857 +0.0714*0.25 +0.0714*0.2424 =0.2478 | 0.2857*0.0555 +0.2857*0.0434 +0.2857*0.0714 +0.0714*0.125 +0.0714*0.1212 =0.0662 | 0.2857*0.4444 +0.2857*0.3478 +0.2857*0.2857 +0.0714*0.25 +0.0714*0.2424 =0.3431 | 0.2857*0.0555 +0.2857*0.0434 +0.2857*0.1428 +0.0714*0.0625 +0.0714*0.030 =0.0756 | 0.2857*0.2222 +0.2857*0.0434 +0.2857*0.0714 +0.0714*0.0625 +0.0714*0.1212 =0.1093 |

## 4.5 Formulate Set of Attributes

As aforementioned, in this research cost, safety, environmental impacts, and comfort level will be considered constant in the value model of the turnaround process. Therefore, no attributes will be defined for those objectives. While for turnaround time and reliability, they will be defined such that they can be obtained from data received from (KQ) which will be explained in the next chapter. Turnaround time and reliability will be each represented by one single attribute which will be defined in the next chapter.

## 4.6 Determine Attributes Weight Factors

Turnaround time and reliability will be represented by one single attributes, therefore there is no need to determine attributes weight factors in this research.

## 4.7 Combine All Into One Model

The value model for the turnaround process can be expressed as in equation (4.1).

$$\Delta V = \lambda_C \frac{C_1}{C_0} + \lambda_T \frac{T_1}{T_0} + \lambda_S \frac{S_1}{S_0} + \lambda_{En} \frac{En_1}{En_0} + \lambda_{Cl} \frac{Cl_1}{Cl_0} + \lambda_R \frac{R_1}{R_0} \tag{4.1}$$

$$\Delta V = 0.0662 \frac{C_1}{C_0} + 0.1573 \frac{T_1}{T_0} + 0.3431 \frac{S_1}{S_0} + 0.1093 \frac{En_1}{En_0} + 0.0756 \frac{Cl_1}{Cl_0} + 0.2478 \frac{R_1}{R_0} \tag{4.2}$$

In equations (4.1) and (4.2), C represents cost, T represents turnaround time, S represents safety, En represents environmental impacts, Cl represents comfort level, and R represents Reliability.

Now the performance of alternative strategies of turnaround sub processes can be evaluated using equation (4.2), based on added value from the perspective of relevant stakeholders. Due to unavailability of data, it will be assumed that cost, comfort level, safety, and environmental impacts are constant. Only turnaround time and reliability will be considered. The feasible ranges of the attributes belonging to turnaround time and reliability will be introduced in the next chapter, since those depend on the received data.

## 4.8 Summary

In this chapter, the relevant stakeholders within turnaround process are determined using the method defined in section (3.1). These relevant stakeholders are national government, air traffic control, passengers, airport operator, and airline operator. The fundamental objectives within turnaround process are formulated using the method defined in section (3.2). These fundamental objectives are: turnaround time, reliability, cost, safety, comfort level, and environmental impacts. The weight factors of these fundamental objectives for all relevant stakeholders within turnaround process are presented in table (4.26).

Table 4-26: Objectives weight factors of all relevant stakeholders within turnaround process

| Objectives | Turnaround time | Reliability | Cost | Safety | Comfort level | Environmental impacts |
|---|---|---|---|---|---|---|
| **Weight factors** | 0.1573 | 0.2478 | 0.0662 | 0.3431 | 0.0756 | 0.1093 |

Equation (4.3) represents the value model of the turnaround process with which the performance of alternative strategies relative to current strategy can be evaluated, from the perspective of relevant stakeholders. However, in this research due to unavailability of data, cost, safety, comfort level, and environmental impacts will be assumed constant in the value model of the turnaround process. Only turnaround time and reliability will be taken into consideration in the value model of the turnaround process.

$$\Delta V = 0.0662 \frac{C_1}{C_0} + 0.1573 \frac{T_1}{T_0} + 0.3431 \frac{S_1}{S_0} + 0.1093 \frac{En_1}{En_0} + 0.0756 \frac{Cl_1}{Cl_0} + 0.2478 \frac{R_1}{R_0} \tag{4.3}$$

In equation (4.3), C represents cost; T represents turnaround time; S represents safety; En represents environmental impacts; and R represents reliability.

The current performance of turnaround sub processes and the alternative strategies as well as their performance, will be defined and evaluated in the next chapter, using data received from (KQ).

# 5 Kenya Airways (KQ) practical Case Study

In this chapter, the turnaround time and the reliability of the current states of turnaround sub processes on the critical path will be determined using data received from (KQ), and subsequently of the alternatives. Thereafter, these alternatives will be evaluated using the value model defined in chapter (4).

This chapter is broken up into five main sections. Section (5.1), deals with describing how data is gathered, processed and filtered in order to ensure that data is valid for performing the calculations. Section (5.2) presents the types of turnaround process and the turnaround sub processes on the critical path which will be considered in the calculations in this research. Section (5.3) presents the average duration and the standard deviation of these turnaround sub processes. The average duration is the attribute of average turnaround time and standard deviation is the attribute of the reliability. Section (5.4) introduces the alternative strategies implemented in turnaround process. Section (5.4) deals with the evaluation of these strategies using the value model of the turnaround process. Finally, a brief summary of the main findings in this chapter is provided in section (5.5).

## 1.1 Data Gathering and Process

Data received from (KQ) is gathered based on three steps as visualized in figure (5.1) namely, observation, registration process, and data storage. The turnaround sub processes are first observed by a turnaround coordinator who carries a Portable Digital Assistant (PDA) on which he/she registers the time stamps of the start time and the end time of a set of turnaround sub processes. These time stamps are then automatically transmitted into the Kenya Airways Flight Turnaround Application (FTA) database. The turnaround sub processes which are monitored a by turnaround coordinator are outlined and briefly described in table (5.1).

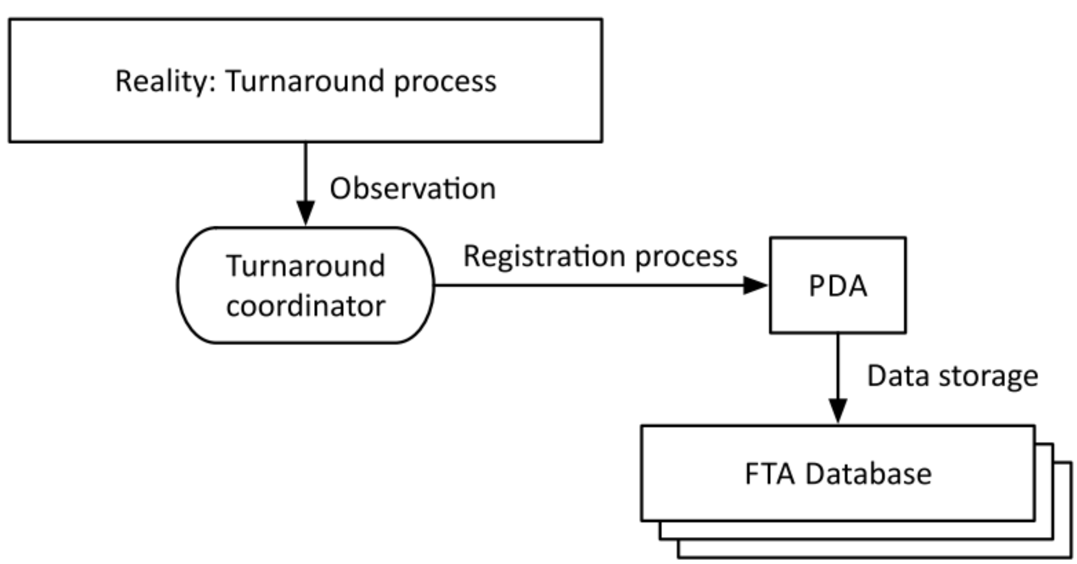


Figure 5-1: Data gathering process (O'Callaghan, 2012)

Table 5-1: Turnaround activities monitored by turnaround coordinators at (KQ) (O'Callaghan, 2012)

| Activity | Description |
|---|---|
| **On-chocks** | Position of wheel chocks at nose wheel |
| **Cabin crew onboard** | Arrival of cabin crew onboard of the aircraft |
| **Cockpit crew onboard** | Arrival of cockpit crew onboard of the aircraft |
| **Catering** | Execution of catering sub process |
| **Cabin cleaning** | Cleaning the aircraft cabin |
| **Boarding clearance** | Turnaround coordinator gives clearance for boarding |
| **Boarding** | Boarding of passengers onto the aircraft |
| **Fueling** | Fueling of the aircraft |
| **Offloading** | Offloading of baggage and cargo |
| **Loading** | Loading of baggage and cargo |
| **Engineering** | Performing engineering activities while the aircraft is on the ramp (line maintenance) |
| **Spray cans** | Disinfecting the cabin |
| **Passengers doors closed** | Closing the aircraft doors after all passengers have boarded |

Since gathered data is based on measurements and collection of human (turnaround coordinator) and equipment (PDA) respectively, it should be taken into account that the collected data might contain errors (O'Callaghan, 2012); (Jacob, Bhasi & Gopikakumari, 2003). These errors are either due to human, process or instrument (O'Callaghan, 2012). An example of a human error is when a turnaround coordinator thinks that the boarding process has finished and registers the finishing time. Due to a misunderstanding, there are still more passengers boarding onto the aircraft. An example of a process error is when a turnaround coordinator does not exactly know what the start or the finish of a process is. For instance; the start of boarding process could be defined as the first passenger entering the aircraft but it could also be defined as when the boarding clearing process is given (O'Callaghan, 2012). An instrument error could be that equipment (PDA) is not performing optimally, the clocks might not have been set at correct time, or the error could occur when the information is transmitted from the PDA's to FTA database (O'Callaghan, 2012).

During data analysis, the outliers could be attributed to these errors which are filtered out. In order to ensure that gathered data is valid, all turnaround processes of Boeing 737-300 which are recorded from first January until first July of 2012 will be analyzed. This accounts of nearly 1000 turnarounds which is assumed to be large enough to average out the errors. The information contained in raw data from FTA database is described in appendix (C).

## 1.2 Selection of Turnaround Sub Processes

According to O'Callaghan (2012), a distinction could be made of four types of turnarounds performed at (KQ) namely: originator turnarounds, terminator turnarounds, quick turnarounds, and ordinary turnarounds (see figure (5.2)). The incoming and outgoing arrows in figure (5.2) represent the inbound and the outbound flight respectively.

- **Originator turnarounds** are turnarounds when aircraft has parked and its scheduled subsequent flight is after a significant amount of time.
- **Terminator turnarounds** are turnarounds when aircraft has arrived from a flight and parks for a significant amount of time at an aircraft parking stand.
- **Quick turnarounds** are turnarounds when no slack is built into the turnaround plan (O'Callaghan, 2012). Here all activities need to be performed as quickly as possible.
- **Ordinary Turnarounds** are turnarounds when there is more available time to perform the activities compared to quick turnarounds.

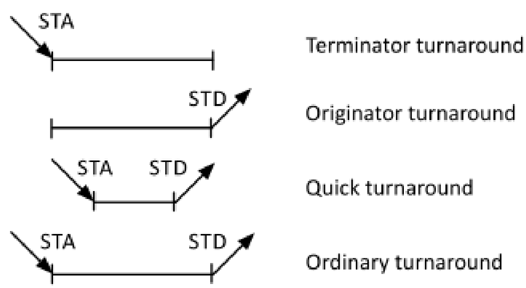


**Figure 5-2: Types of turnarounds performed at (KQ) (O'Callaghan, 2012)**

Logically the delays are expected to occur more in quick and ordinary turnarounds, since they have less available time for their turnarounds to be performed in compare with terminator and originator turnarounds. In order to test the triumph of the strategies implemented in performing the turnaround activities, there performance should be analyzed within turnarounds which cause most of delays. Therefore, as in previous research (O'Callaghan, 2012), only the quick and the normal turnarounds will be taken into the consideration in this research. However on gathered data it cannot be seen whether a turnaround belongs to a quick or normal turnaround.

As can be seen in table (5.1), there is a number of turnaround sub processes monitored by (KQ). However, to be able to stay within the time constraint of the research, it was decided to focus only on turnaround sub processes which have high potential in reducing the turnaround time and improving its on-time performance. The critical path analysis is the method used in selecting these turnaround sub processes which is defined as the longest sequence of direct dependent activities that takes the greatest time to complete (IATA, 2007). If any of these activities on the critical path is delayed, the whole process is delayed, only if one or more activities following the delayed activity are completed earlier such that the entire process is completed on time (Beelaerts van Blokland et al., 2008, p. 4).

As can be seen on figure (2.1), there are several parallel paths within turnaround process. However, according to the study performed by Beelaerst van Blokland et al. (2008), the following turnaround sub processes; passengers boarding and disembark, catering, cabin cleaning and security check take the longest time for turnaround process to be completed for both narrow body and wide body aircraft. This study is based on statistical data analysis of turnarounds of Boeing 737-800 and Boeing 747-400 Combi. Therefore, it was decided to focus only on these turnaround sub processes including aircraft fueling. The reason why aircraft fueling is included because usually, fueling takes place when the passengers have disembarked the aircraft and the incoming passengers are waiting to board onto the aircraft due to safety regulations (O'Callaghan, 2012). Therefore, it could be concluded that the completeness of the passenger and cabin flow depends on fueling. Subsequently, it was decided in this research to focus on all the activities in passenger and cabin flow including fueling as visualized in figure (5.3).

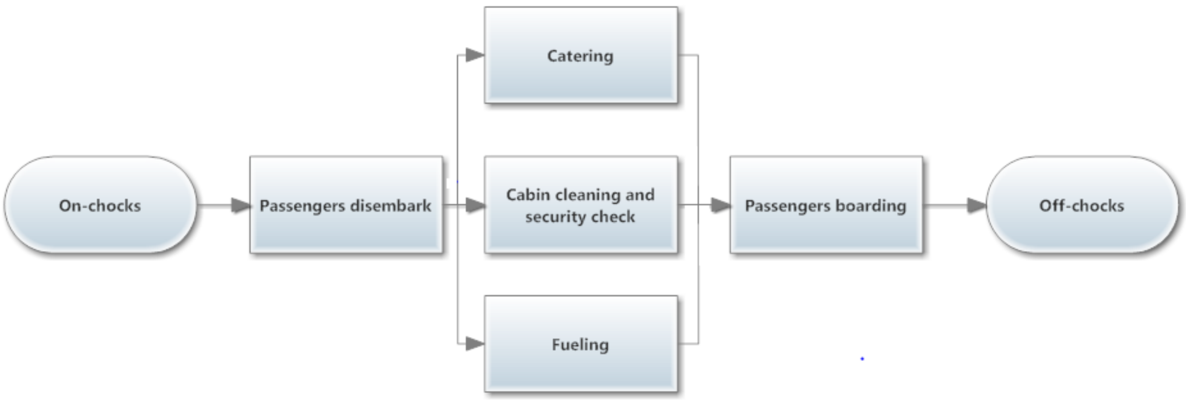


Figure 5-3: Passenger cabin flow including fueling

## 1.3 Current States of Turnaround Sub processes

In order to evaluate the current strategy used in performing the turnaround process at (KQ), the external factors which affect duration of turnaround sub processes should be extracted. These external factors were already defined in the research of (O'Callaghan, 2012) and they are:

- Type of aircraft
- Type of parking bay
- Busyness at the airport
- Length of outbound flight
- Amount of passengers on outbound flight
- Amount of bags on outbound flight
- Amount of passengers on inbound flight
- Amount of bags on inbound flight
- Inbound delay

Unfortunately, the amounts of passengers and of bags on inbound flight as well as inbound delay are not available on data. Therefore, it will be assumed in this research that there influence on the performance of the current strategy is negligible.

To extract the effect of type of aircraft on duration of the selected turnaround sub processes, it was decided to only analyze the available data of Boing 737-300 and for turnarounds which take place at (JKIA). The same approach could be used for other types of aircraft and turnarounds at other airports.

There are three types of parking bays at (JKIA) namely, local parking bays, domestic parking bays and remote parking bays. The local parking bays are located close to the terminal and they are equipped with passengers' bridges (O'Callaghan, 2012). The domestic parking bays are also located close to the terminal; however they are not equipped with passengers' bridges and due to relatively small distances between the terminal and the domestic parking bays, passengers walk sometimes from aircraft to the terminal and vice versa (O'Callaghan, 2012). The remote parking bays are located relatively far from the terminal and here buses are required to bring the passenger from aircraft to the terminal and vice versa (O'Callaghan, 2012).

For the airport busyness, the date and the start time of turnaround sub processes will be used to determine the influence of this external factor on duration of a turnaround activity. Based on the analysis a decision could be made whether to extract this effect out of data. The effect of start time and of date on duration of a sub process reflects the influence of airport busyness on an hourly basis throughout the day and on a monthly basis throughout the seasons respectively.

To determine the influence of the length of outbound flight on duration of the selected turnaround sub processes, the available destinations on data from (JKIA) will be expressed in term of distances in nautical miles. Thereafter, it will be plotted against duration of the selected turnaround sub processes. Based on the analysis, a decision could be made whether to extract the influence of this external factor (length of outbound flight) on duration of the selected turnaround sub processes.

By using the amount of passengers on outbound flight which is available on data, the effect of this external factor on duration of the selected turnaround sub processes could be determined. Based on the analysis, a decision could be made whether to extract this external effect out of data. For the amount of bags, this external factor has no potential influence on the selected turnaround sub processes. It might have a potential influence on duration of fueling sub process; however it is assumed that this effect is covered in the amount of passengers on outbound flight.

There is another external factor which has potential influence on fueling sub process which is the amount of fuel left on the inbound flight. However, this is not available on data and therefore, this external effect will be assumed negligible.

Using the available data of (KQ), the average duration and the reliability of the selected turnaround sub processes will be presented in the following order: passengers disembark, cabin grooming, catering, fueling and passengers boarding.

### 1.3.1 Passengers Disembark

The duration of disembark is the time between the end time of on-chocks and the start time of catering or cabin grooming depending on which of these two latest activities starts first. According to previous research (O'Callaghan, 2012), the duration of disembark could be approximately determined by equation (5.1), since the start time of catering and cabin grooming at (KQ) correlates about 91%.

$$dur_{disembark} = \frac{(T_{start-catering} + T_{start-cabin\ grooming})}{2} - T_{end-onchocks} \qquad (5.1)$$

As aforementioned, in order to determine the performance of the current strategy used in disembarking the passengers, the influence of the external factors should first be extracted out of data. The external factors that have potential influence on duration of disembarks are; type of parking bay and airport busyness. While the outbound characteristics have no potential influence on duration of disembarks since this turnaround sub process belongs to inbound flight. According to analysis of previous research (O'Callaghan, 2012); type of parking bay is the only external factor which affects duration of disembarks. In this research it was decided to analyze also the effect of airport busyness on duration of disembark since this external factor is defined differently than the research of (O'Callaghan, 2012).

In this analysis, first the influence of type of parking bay will extracted out of data by analyzing duration of disembarks belonging to each parking bay separately. Thereafter, the effect of airport busyness on duration of disembarks will be analyzed belonging to each type of parking bay. By doing so, the effect of airport busyness on each type of parking bay could be determined.

#### *1.3.1.1 Remote Parking Bay*

After focusing only on disembark activities which take place at remote parking bays, the effect of airport busyness on duration of disembarks could be analyzed. Figures (5.4) and (5.5) show the effect of date and of start time on duration of disembarks respectively. From both figures, it could be seen that the effect of airport busyness could be assumed negligible since the correlation in both figures are weak. This is indicated by the low value of $R^2$ which is less than 10%. It is assumed if the correlation between an external factor and duration of a sub process is less than 10 % then this external factor has relatively no relationship with duration of a sub process and therefore, no influence.

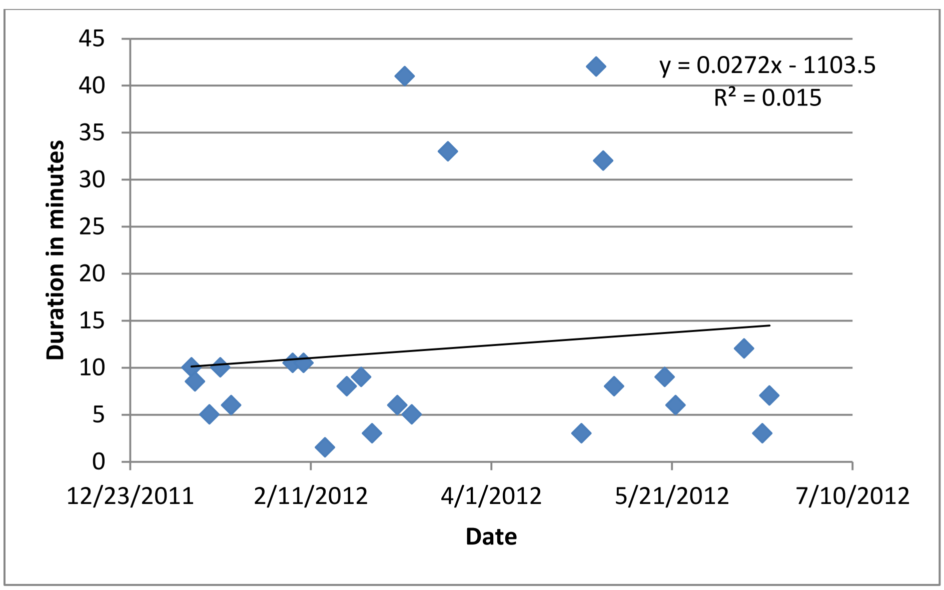


Figure 5-4: Effect of date on duration of disembarks at remote parking bay

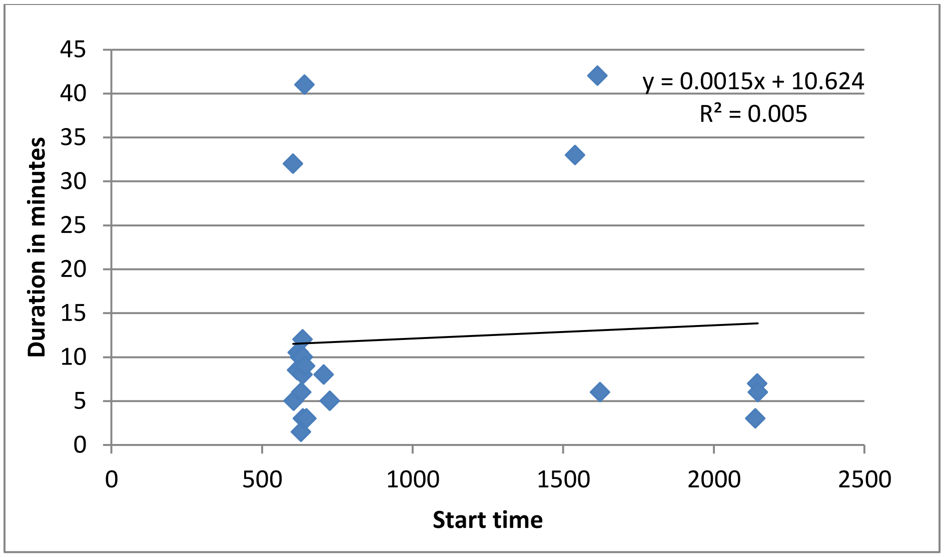


Figure 5-5: Effect of start time on duration of disembarks at remote parking bay

Now the current performance of disembark could be determined since the external factors are analyzed. The relative frequency distribution of disembark could be visualized in figure (5.6). From this figure, it could be seen that the duration of disembarks varies from 2 minutes to 42 minutes and the most frequent duration is 9 minutes which accounts for 15% of the sample. The average duration of disembark is 12.04 minutes and the standard deviation is 11.87 minutes.

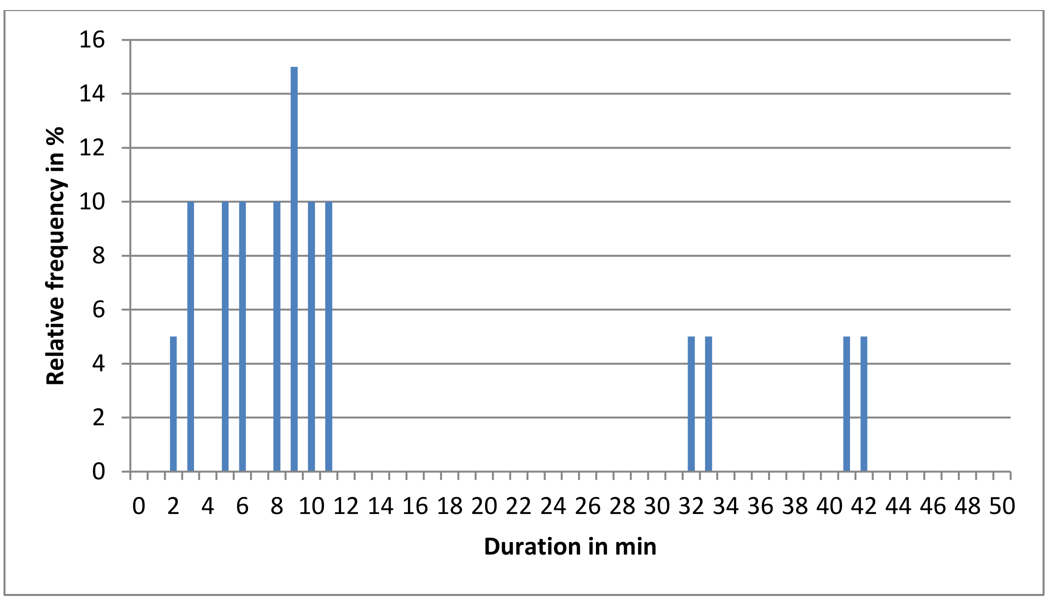


Figure 5-6: Relative frequency distribution of duration of disembarks at remote parking bay

#### *1.3.1.2 Local Parking Bay*

Figures (5.7) and (5.8) show the effect of date and of start time on duration of disembarks at local parking bays respectively. From both figures it could be observed that the effect of airport busyness is negligible since the correlation in both figure are weak. This is indicated by the low value of $R^2$ which is less than 10%.

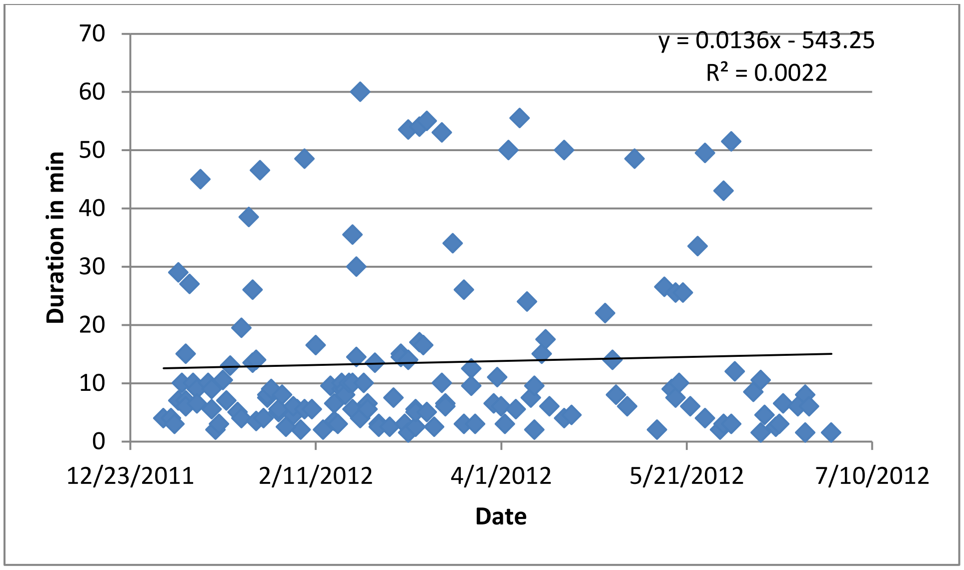


Figure 5-7: Effect of date on duration of disembarks at local parking bays

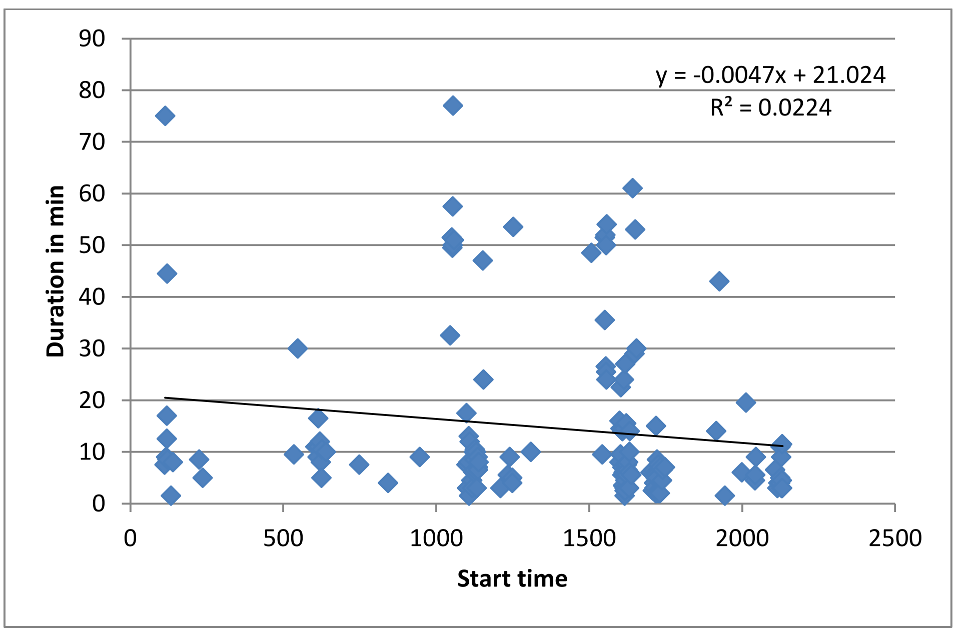


Figure 5-8: Effect of start time on duration of disembarks at local parking bay

Now that the external factors are extracted, the current performance of disembark at local parking bays could be determined. Figure (5.9) displays the relative frequency distribution of duration of disembarks at local parking bays. As could be seen from this figure, the duration of disembarks varies from 2 to 77 minutes and the most frequent duration is 3 minutes. This accounts for 10% of the sample. The average duration and the standard deviation of disembark at local parking bays are 14. 04 minutes and16.37 minutes respectively.

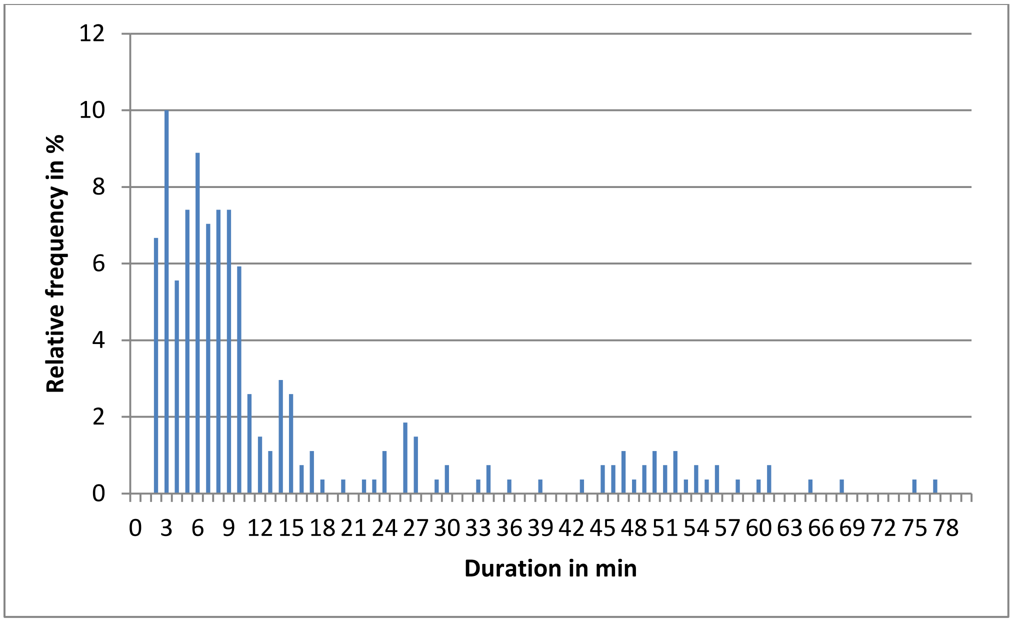


Figure 5-9: Relative frequency distribution of disembarks at local parking bays

#### *1.3.1.3 Domestic Parking Bay*

Figures (5.10) and (5.11) show the effect of date and of start time on duration of disembarks at domestic parking bays respectively. From both figures it could be observed that the effect of airport busyness is negligible since the correlation in both figure are weak. This is indicated by the low value of $R^2$ which is less than 10%.

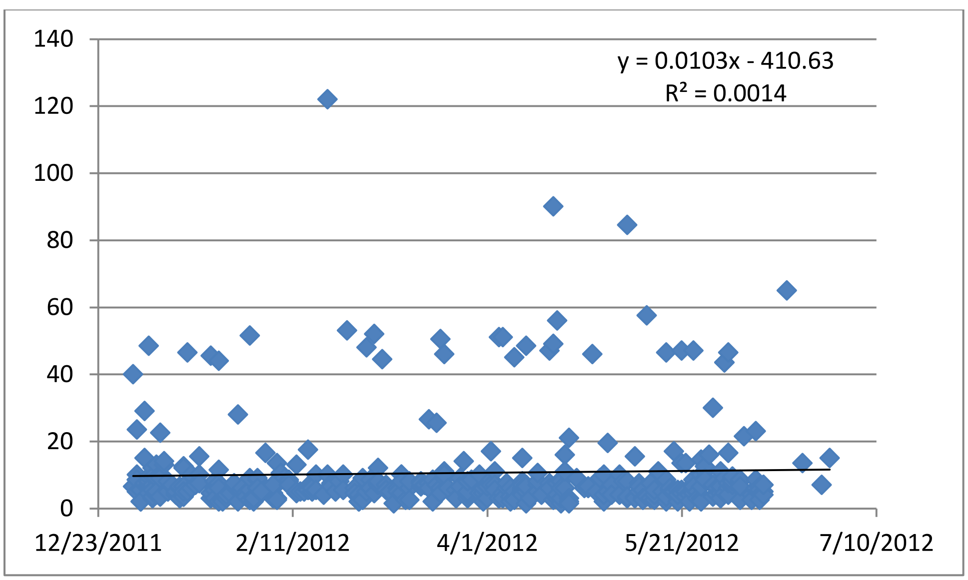


Figure 5-10: Effect of date on duration of disembarks at domestic parking bays

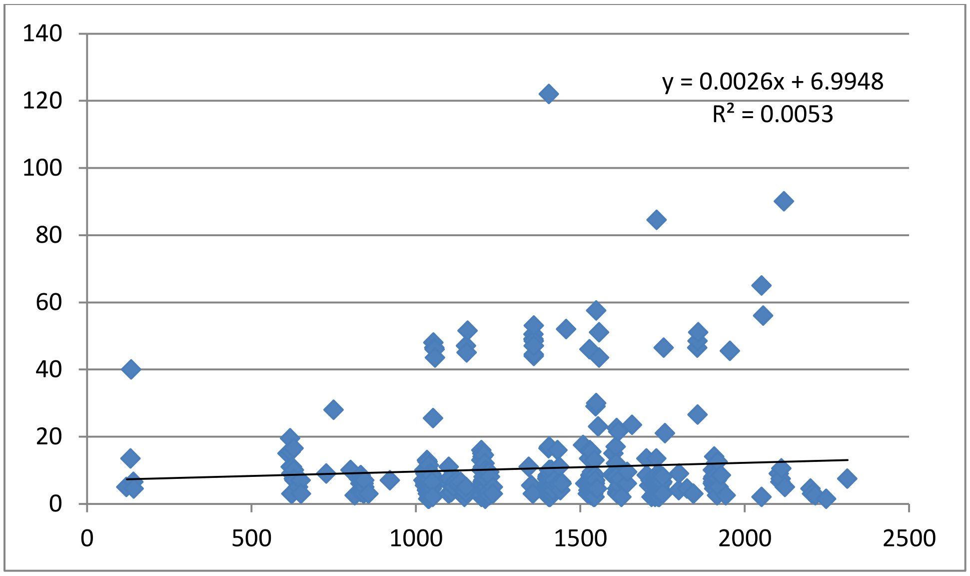


Figure 5-11: Effect of start time on duration of disembarks at domestic parking bays

Now that the external factors are extracted, the current performance of disembark at domestic parking bays could be determined. Figure (5.12) displays the relative frequency distribution of duration of disembark s at domestic parking bays. As could be seen from this figure, the duration of disembarks varies from 1.5 to 122 minutes and the most frequent duration is 6 minutes which accounts for about 14.5% of the sample. The average duration of disembarks at local parking bays is 10.6 minutes and the standard deviation is 13.95 minutes.

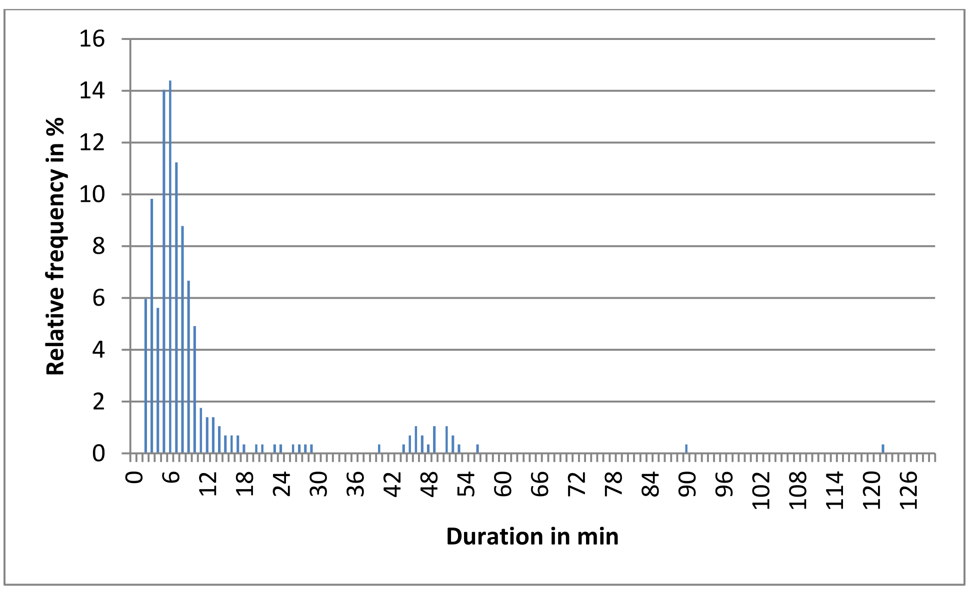


Figure 5-12: Relative frequency distribution of duration of disembarks at domestic parking bays

Figure (5.13) summarizes the performance of the current strategy implemented in disembarking the passengers by (KQ) at different parking bays at (JKIA). In this figure, the average turnaround time is partly indicated by the average duration of disembark and the reliability is indicated by the standard deviation.

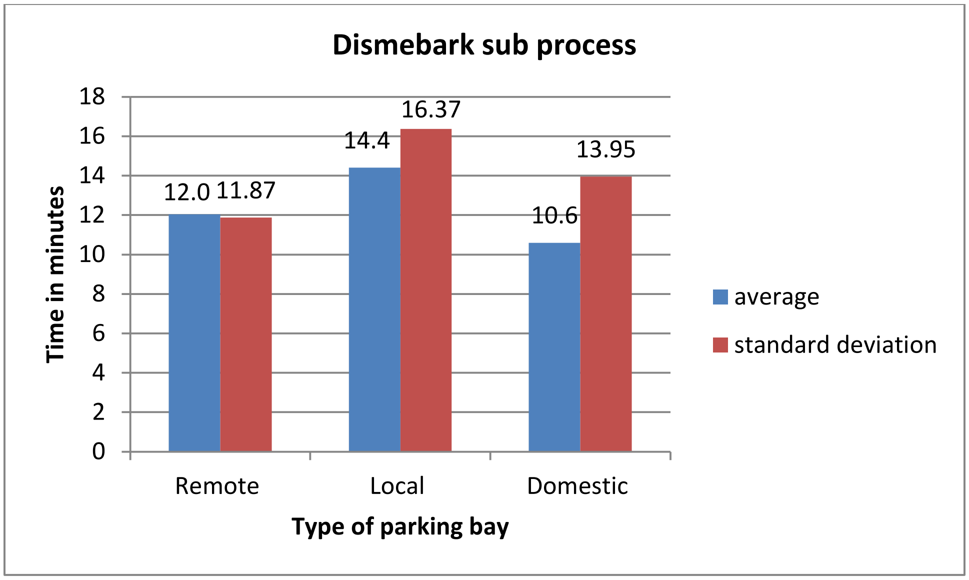


Figure 5-13: Current performance of disembark sub process at each type of parking bay

### 1.3.2 Cabin Grooming

Since cabin grooming is related to both inbound and outbound flights, the effect of all external factors should be analyzed. According to previous research (O'Callaghan, 2012), the only external factor which affects cabin grooming is the type of parking bay. However, as aforementioned, the airport busyness in this research is defined differently than the research of (O'Callaghan, 2012). As well as during analysis of the external factors, first the influence of type of parking bay is extracted and then the remaining external factors are analyzed. This approach is different than the approach used by O'Callaghan (2012) on which the external factors are analyzed without first extracting the effect of type of parking bay. Therefore, it is decided to analyze all the available external factors on KQ's data for each type of parking bay in the following order; airport busyness, length of outbound flight, and the amount of passengers of outbound flight.

#### *1.3.2.1 Remote Parking Bay*

Figure (5.14) shows the influence of date on duration of cabin grooming at remote parking bays. As could be seen from this figure, the durations of cabin grooming decrease from January to June. However, since the correlation which is indicated by $R^2$ is less than 10%, it will be assumed that the influence of date is insignificant. Therefore, this external factor will not be extracted out of data. The effect of start time on duration of cabin grooming at remote parking bays is visualized on figure (5.15). As could be seen from this figure, the effect of start time on durations of cabin grooming is significant. This is indicated by relatively medium correlation which is about 18%. To extract the influence of this external factor, it was decided to focus only on data which took place between 5:00 and 10:00 AM.

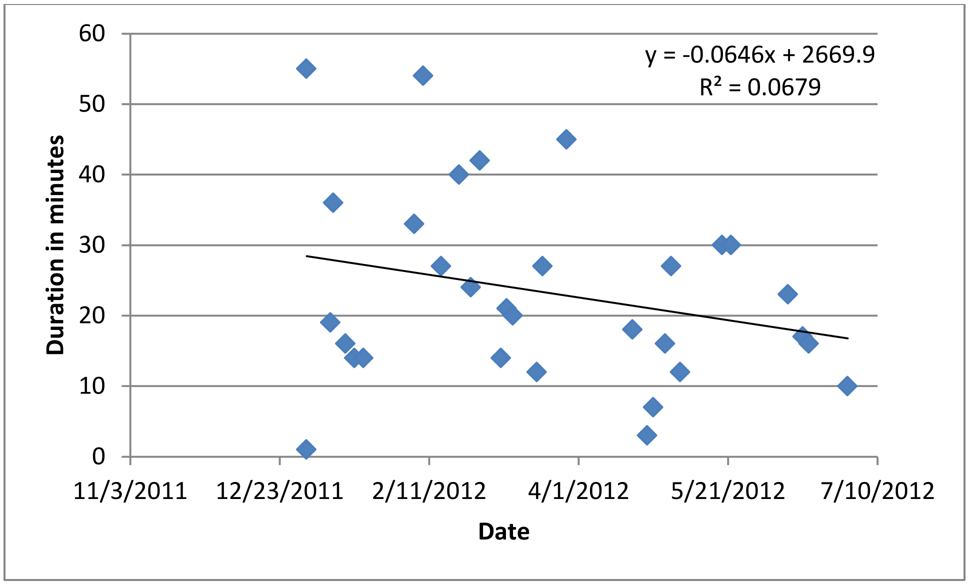


Figure 5-14: Effect of date on duration of cabin grooming at remote parking bays

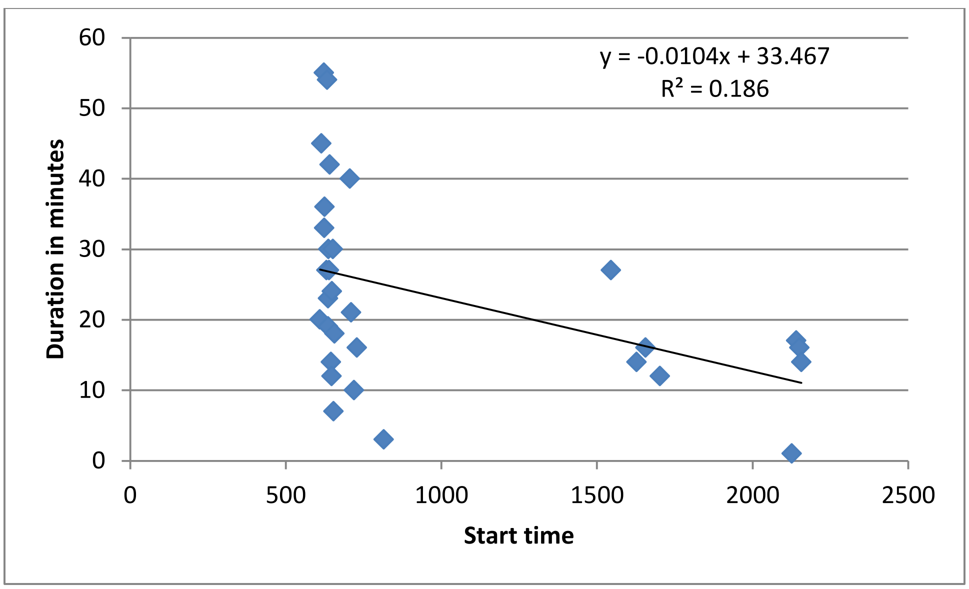


Figure 5-15: Effect of start time on duration of cabin grooming at remote parking bays

The influence of flight length of outbound flight on duration of cabin grooming at remote parking bays is visualized in figure (5.16). As could be seen from this figure, the influence of flight length which is expressed in term of distance in nautical miles on duration of cabin grooming at remote parking bays is insignificant. This is indicated by the weak correlation which is less than 10%. Therefore, this external factor will not be extracted out of data considering cabin grooming at remote parking bays.

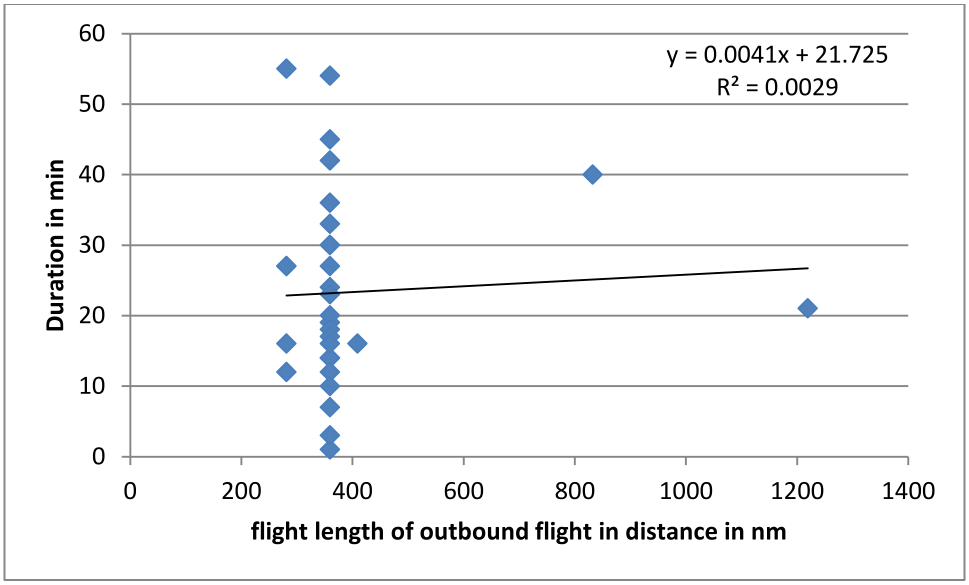


**Figure 5-16: Effect of flight length on duration of cabin grooming at remote parking bays**

The influence of amount of passengers on duration of cabin grooming at remote parking bays is visualized on figure (5.17). From this figure, it could be seen that the influence of this external factor is insignificant since the correlation is less than 10%. Therefore, this external factor will not be extracted out of data for cabin grooming at remote parking bays.

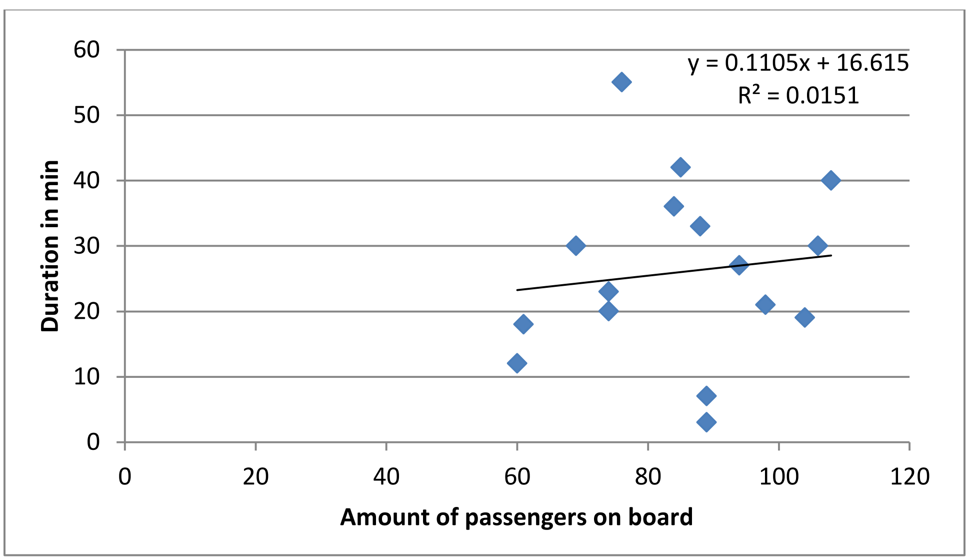


**Figure 5-17: Effect of amount of passengers on duration of cabin grooming at remote parking bays**

Now that influence of the external factors is analyzed and the effect of start time is extracted, the current performance based on duration of cabin grooming at remote parking bays could be determined. Figure (5.18) displays the relative frequency distribution of duration of cabin grooming at remote parking bays. From this figure, it could be seen that the duration of cabin grooming at remote parking bays varies from 3 to 55 minutes and the most frequent duration is 30 minutes. This accounts for 12.5% of the sample. The average duration is 26 minutes and the standard deviation is 13.52 minutes.

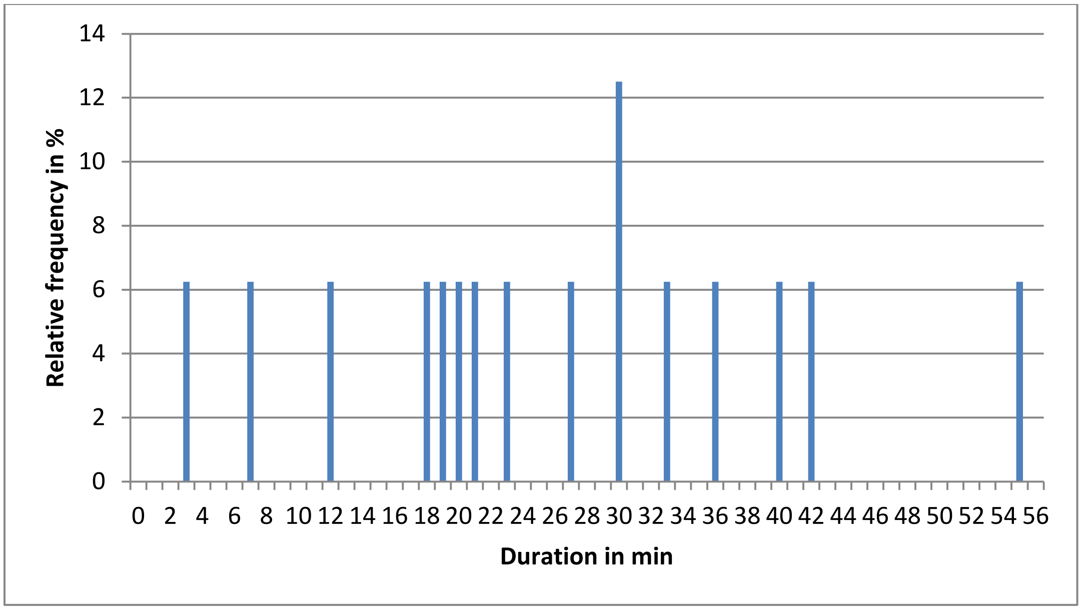


Figure 5-18: Relative frequency distribution of duration of cabin grooming at remote parking bays

### *1.3.2.2 Local parking bay*

Figure (5.19) and (5.20) visualize the influence of date and of start time on duration of cabin grooming at local parking bays respectively. As could be seen from both figures, there is no significant influence of date and of start time on duration of cabin grooming respectively. This is indicated by the weak correlation which is less in than 10% in both figures. Therefore, it will be assumed that airport busyness has no effect on duration of cabin grooming at local parking bays.

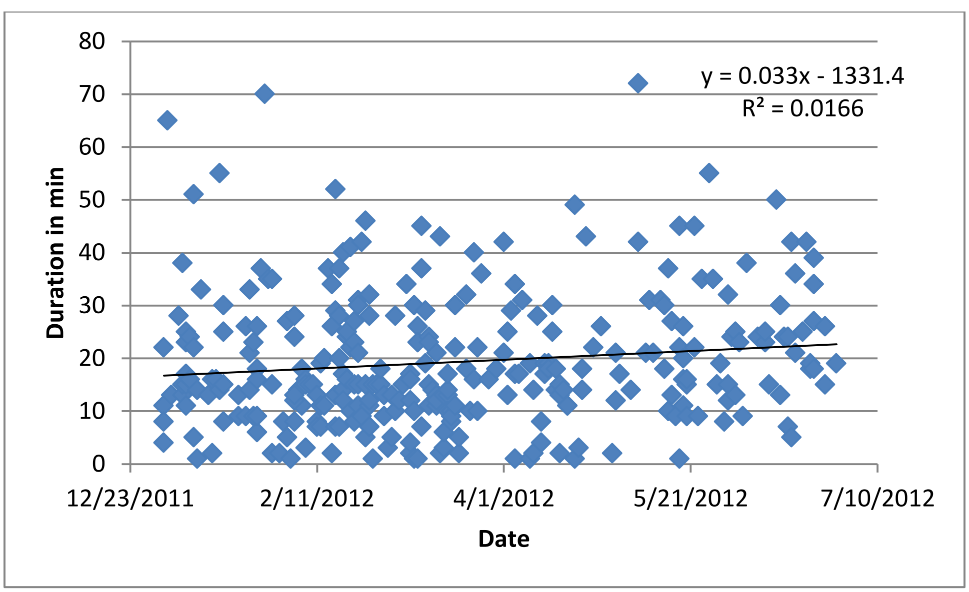


Figure 5-19: Effect of date on duration of cabin grooming at local parking bays

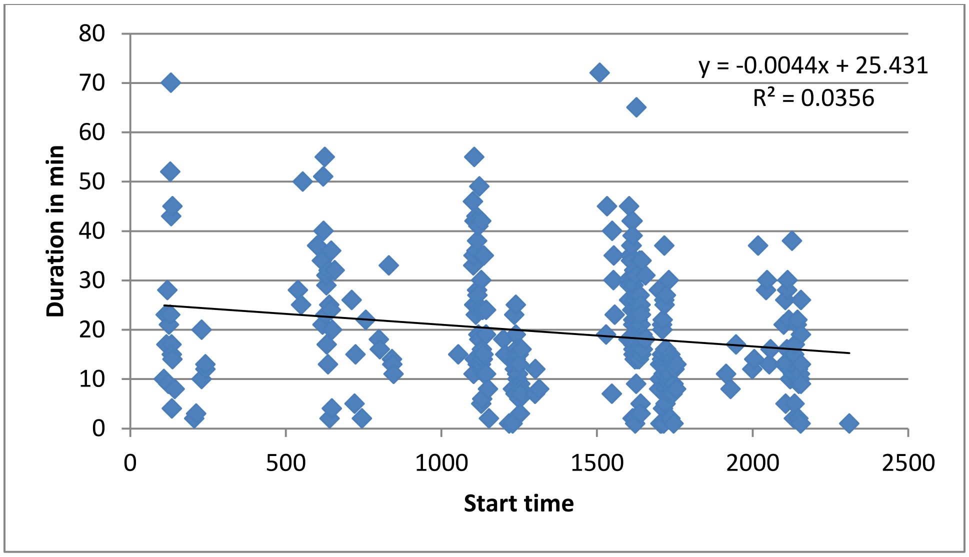


Figure 5-20: Effect of start time on duration of cabin grooming at local parking bays

The influence of flight length of outbound flight on duration of cabin grooming at local parking bays is displayed on figure (5.21). Due to weak correlation which is less than 10%, it will be assumed that this external has no effect on duration of cabin grooming at local parking bays.

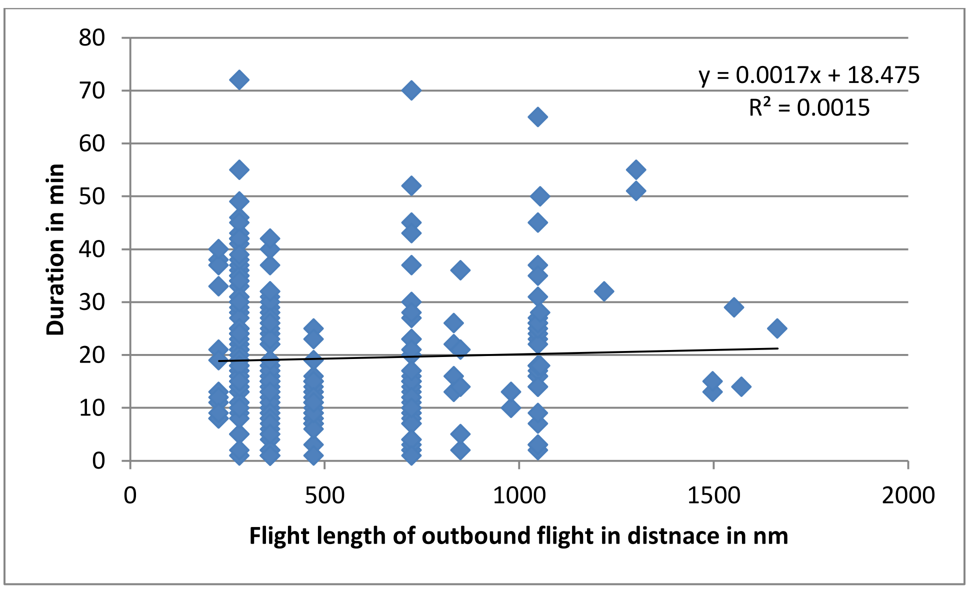


Figure 5-21: Effect of flight length on duration of cabin grooming at local parking bays

Figure (5.22) visualizes the influence of amount of passengers on outbound flight on duration of cabin grooming at local parking bays. As could be seen on this figure, there is no significant effect of this external factor on duration of cabin grooming due to weak correlation which is less than 10%. Therefore, it will be assumed that the amount of passengers on outbound flight has no influence on duration of cabin grooming at local parking bays.

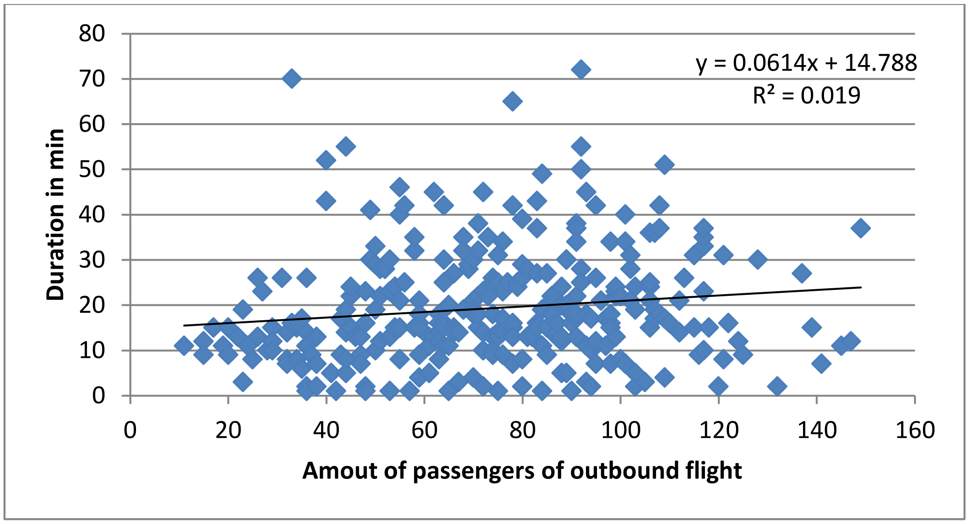


Figure 5-22: Effect of amount of passengers of outbound flight on duration of cabin grooming at local parking bays

Now that the external factors are analyzed, the current performance of cabin grooming at local parking bays based on duration will be determined. Figure (5.23) visualizes relative frequency distribution of cabin grooming at local parking bays. From this figure, it could be seen that duration of cabin grooming varies from 1 to 72 minutes and that the most frequent duration is 15 minutes. This accounts for about 7% of the sample. The average duration of cabin grooming at local parking bays is 19.31 min and the standard deviation is 12.62 minutes.

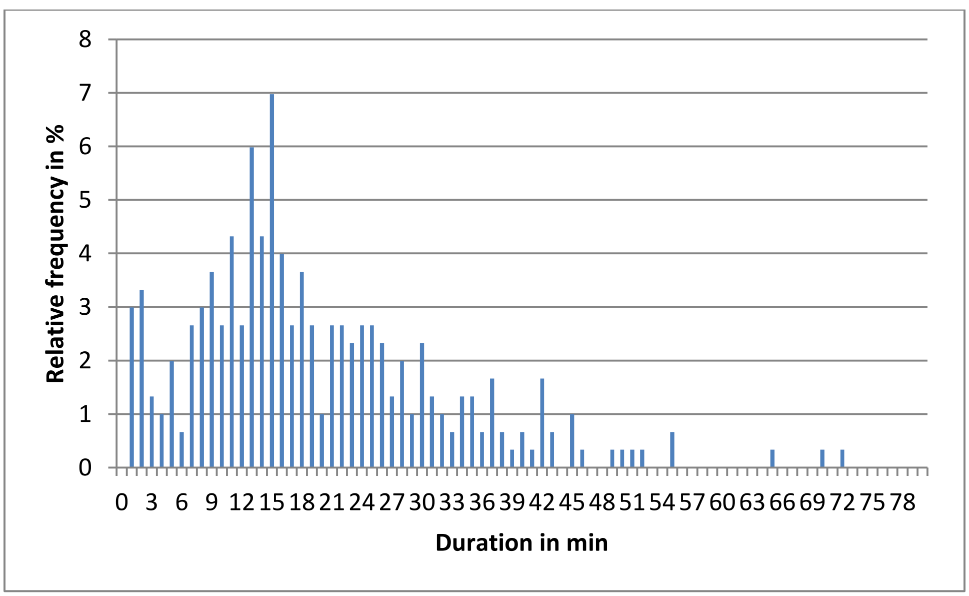


Figure 5-23: Relative frequency distribution of duration of cabin grooming at local parking bays

### *1.3.2.3 Domestic Parking Bay*

Figures (5.24) and (5.25) display the influence of date and of start time on duration of cabin grooming at domestic parking bays respectively. Due to weak correlation which is less than 10% as could be seen on both figures, it could be assumed that airport busyness has no external factors on duration of cabin grooming at domestic parking bays.

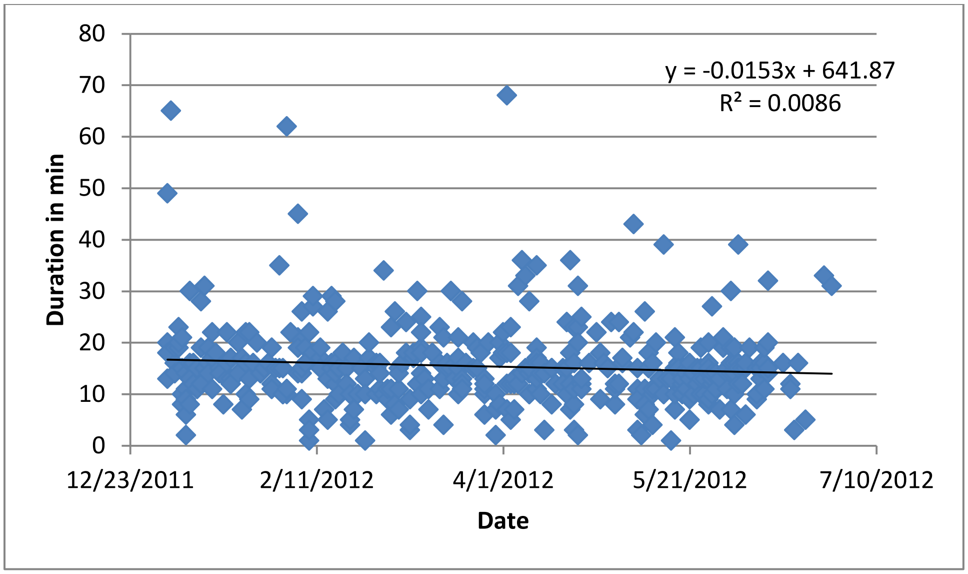


Figure 5-24: Effect of date on duration of cabin grooming at domestic parking bays

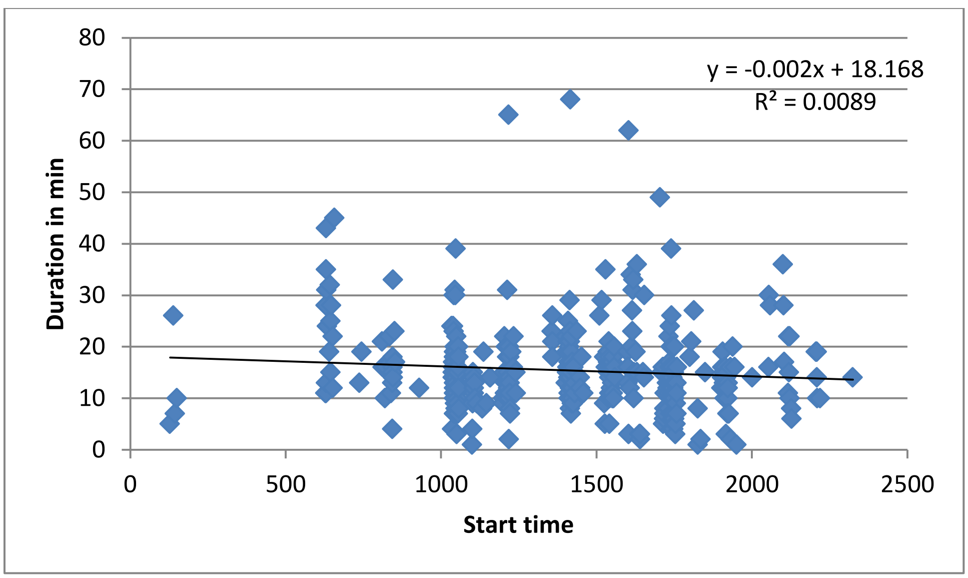


Figure 5-25: Effect of start time on duration of cabin grooming at domestic parking bays

The influence of flight length of outbound flight on duration of cabin grooming at domestic parking bays could be visualized in figure (5.26). Due to weak correlation which is less than 10% the effect of this external factor on duration of cabin grooming is insignificant. Therefore, it will be assumed that the flight length of outbound flight has no effect on duration of cabin grooming at domestic parking bays.

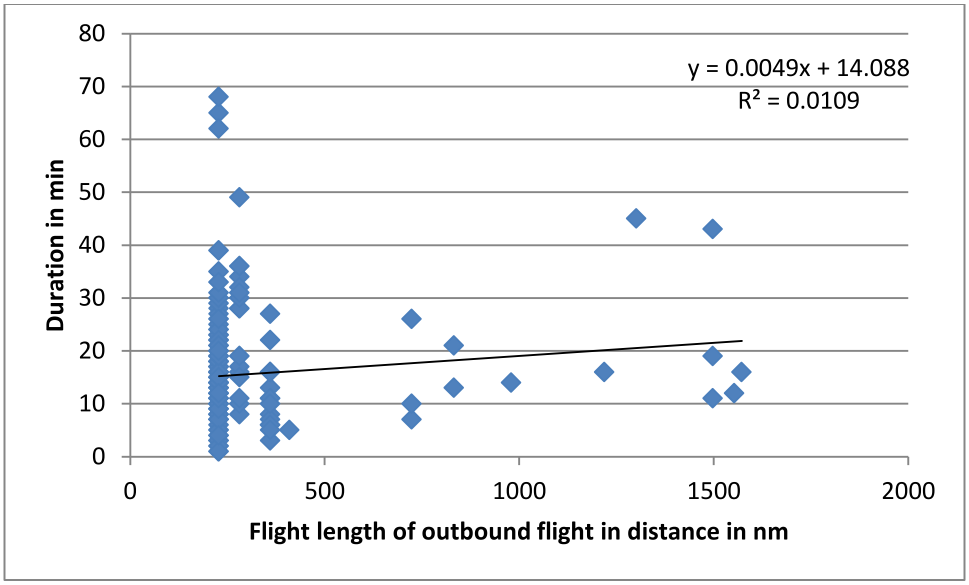


Figure 5-26: Effect of flight length of outbound flight on duration of cabin grooming at domestic parking bays

Figure (5.27) displays the effect of amount of passengers on outbound flight on duration of cabin grooming at domestic parking bays. From this figure, it could be seen that the correlation is extremely weak. This concludes that the amount of passengers on outbound flight has no influence on duration of cabin grooming at domestic parking bays.

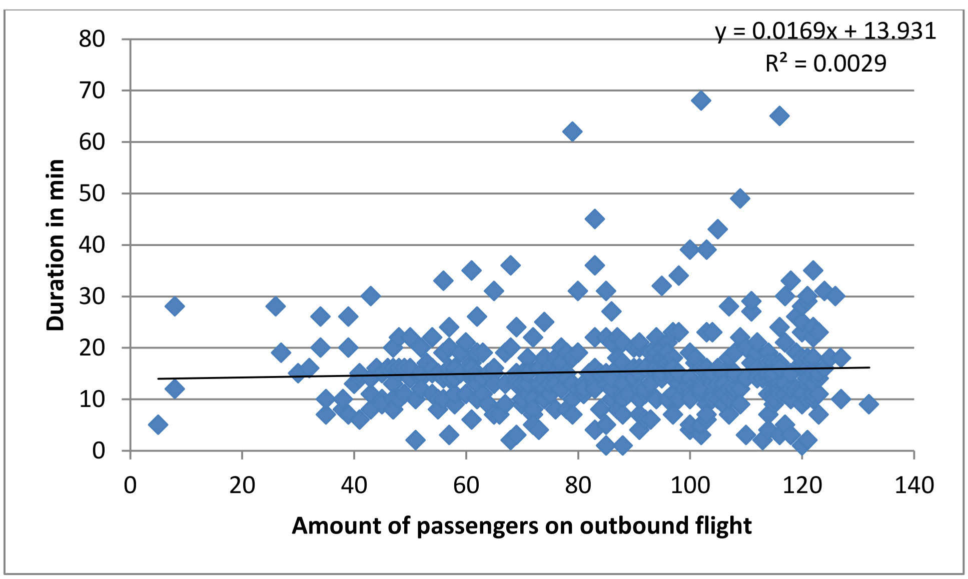


Figure 5-27: Effect of amount of passengers on outbound flight on duration of cabin grooming at domestic parking bays

Now that the external factors are analyzed, the current performance of cabin grooming at domestic parking bays based on duration will be determined. Figure (5.28) visualizes relative frequency distribution of cabin grooming at domestic parking bays. From this figure, it could be seen that duration of cabin grooming varies from 1 to 68 minutes and that the most frequent duration is 15 minutes. This accounts for about 12% of the sample. The average duration of cabin grooming at domestic parking bays is 15.4 min and the standard deviation is 8.17 minutes.

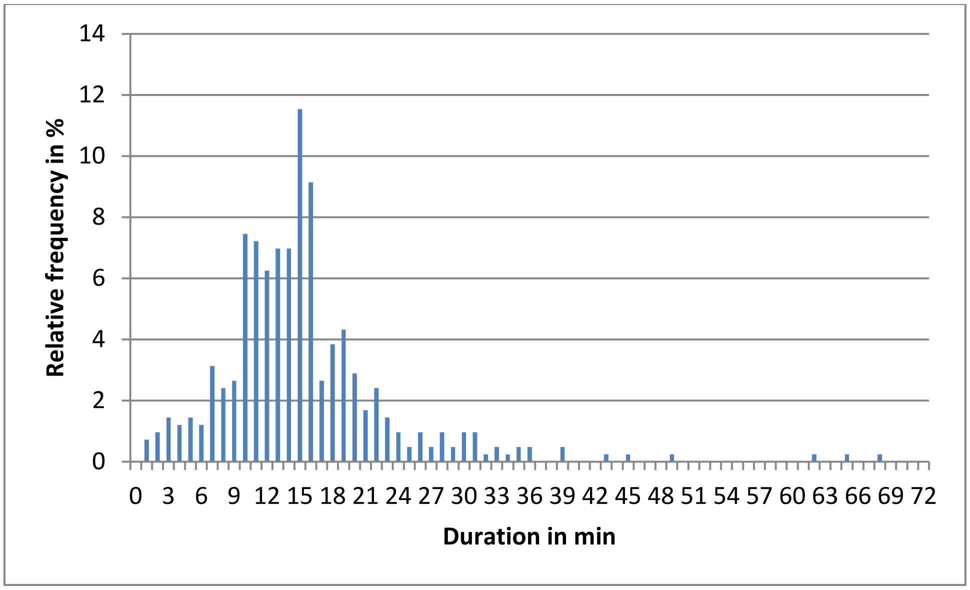


Figure 5-28: Relative frequency distribution of duration of cabin grooming at domestic parking bays

Figure (5.29) summarizes the performance of the current strategy used in performing cabin grooming at different parking bays at (JKIA). In this figure, the average turnaround time is partly indicated by the average duration and the reliability is indicated by the standard deviation.

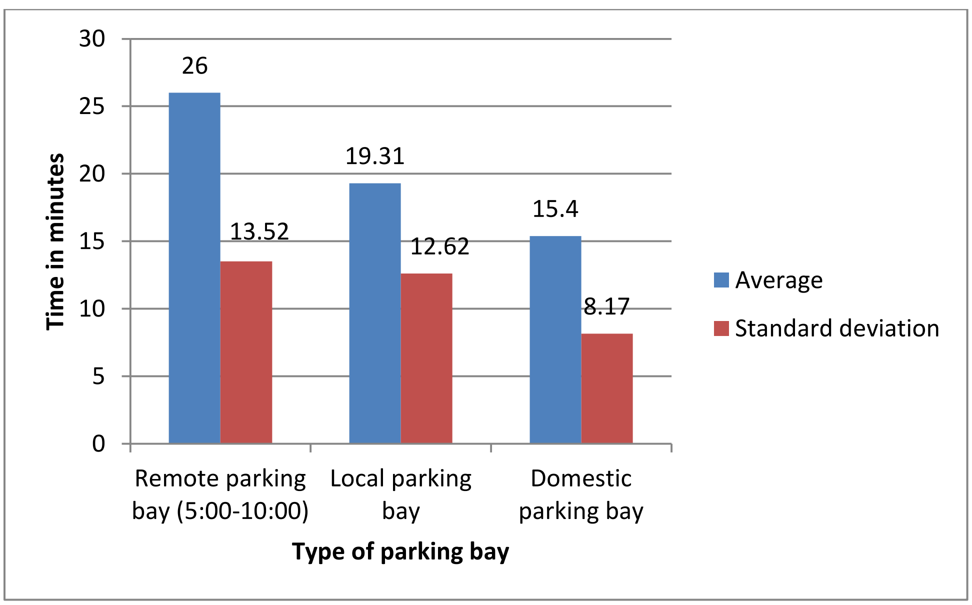


Figure 5-29: Current performance of cabin grooming at different types of parking bays at (JKIA)

### 1.3.3 Catering

As cabin grooming, catering is related to inbound and outbound flight. Therefore, all the available external factors on data should be analyzed at each type of parking bay.

#### *1.3.3.1 Remote Parking Bay*

As could be seen on figures (5.30) and (5.31), the effect of date and of start time on duration of catering at remote parking bays is insignificant respectively. This is indicated by the weak correlation which is less than 10% in both figures. Therefore, it is assumed that airport busyness has no influence on duration of catering at remote parking bays.

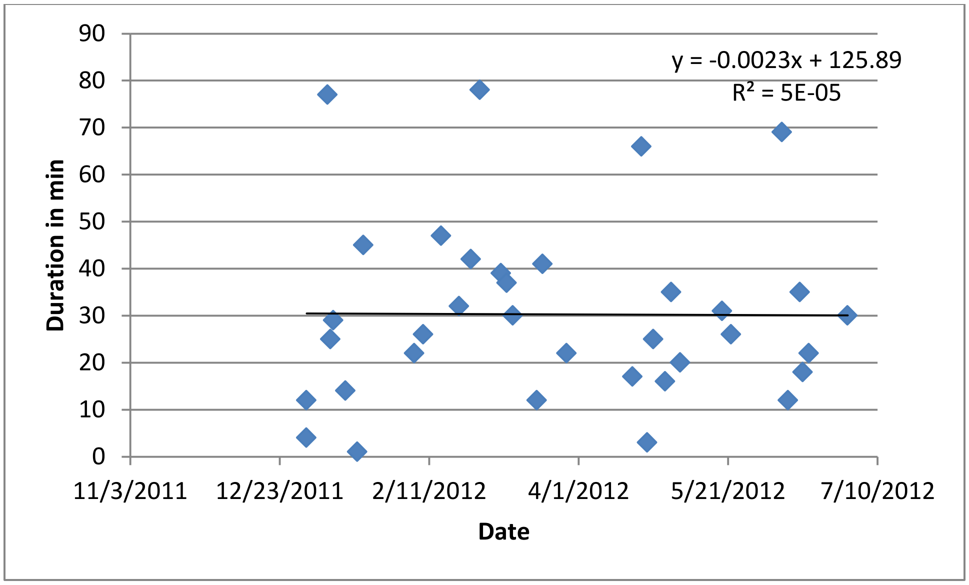


Figure 5-30: Effect of date on duration of catering at remote parking bays

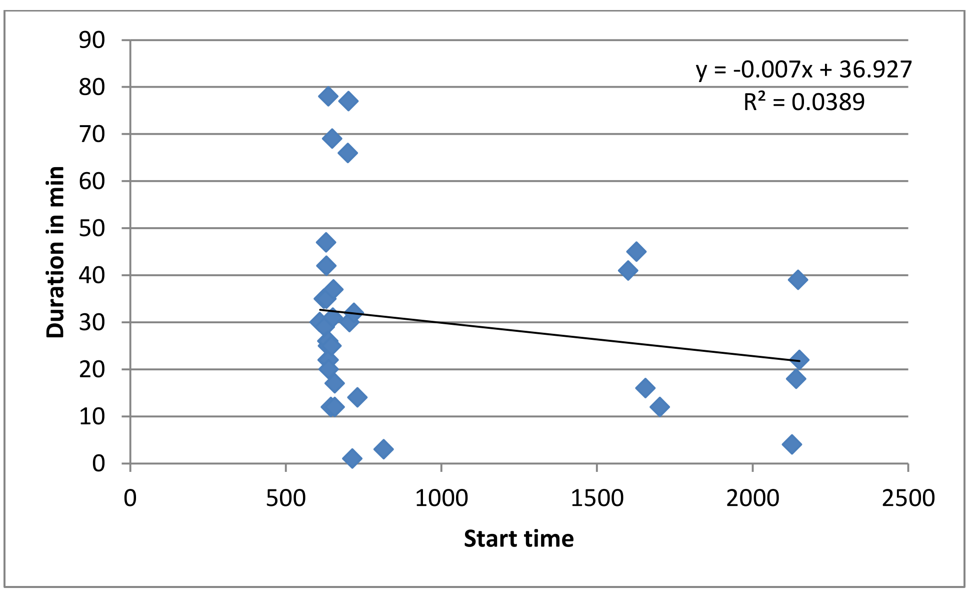


Figure 5-31: Effect of start time on duration of catering at remote parking bays

Figure (5.32) visualizes the effect of flight length of outbound flight on duration of catering at remote parking bays. Due to weak correlation which is less than 10%, it is assumed that flight length of outbound flight has no influence on catering at remote parking bays.

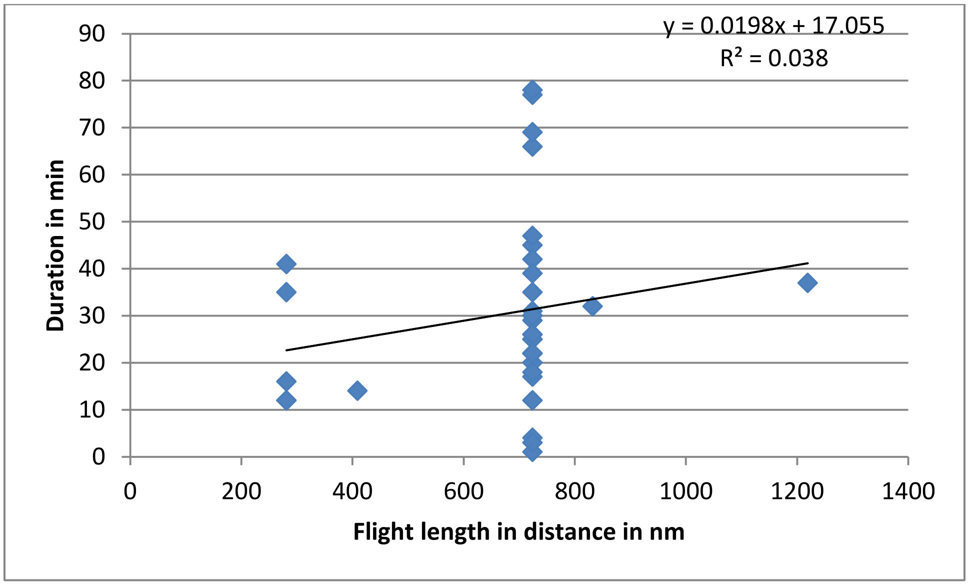


Figure 5-32: Effect of flight length of outbound flight on duration of catering at remote parking bays

As could be seen on figure (5.33), the effect of amount passengers on outbound flight on duration of catering at remote parking bays is insignificant. The reasoning behind this is that as the number of passengers on outbound flight increases, the duration of catering increases and decreases as well. This is also indicated by relatively weak correlation which is less than 10%. Therefore, it is assumed that amount of passengers on outbound flight has no influence on catering at remote parking bays.

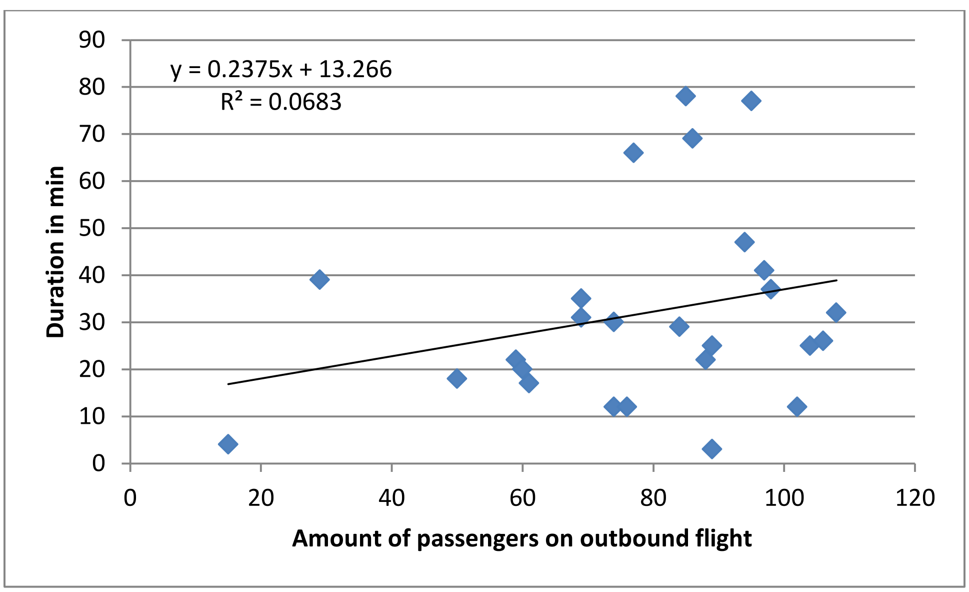


Figure 5-33: Effect of amount passengers on outbound flight on duration of catering at remote parking bays

Now that the external factors are analyzed, the current performance of catering based on duration at remote parking bays could be determined. Figure (5.34), visualizes relative frequency distribution of catering at remote parking bays. As could be seen on this figure, duration of catering varies from 1 to 78 minutes and the most frequent durations are 12 and 22 minutes which each accounts for about 8.5% of the sample. The average duration is 30.28 minutes and the standard deviation is 19.28 minutes.

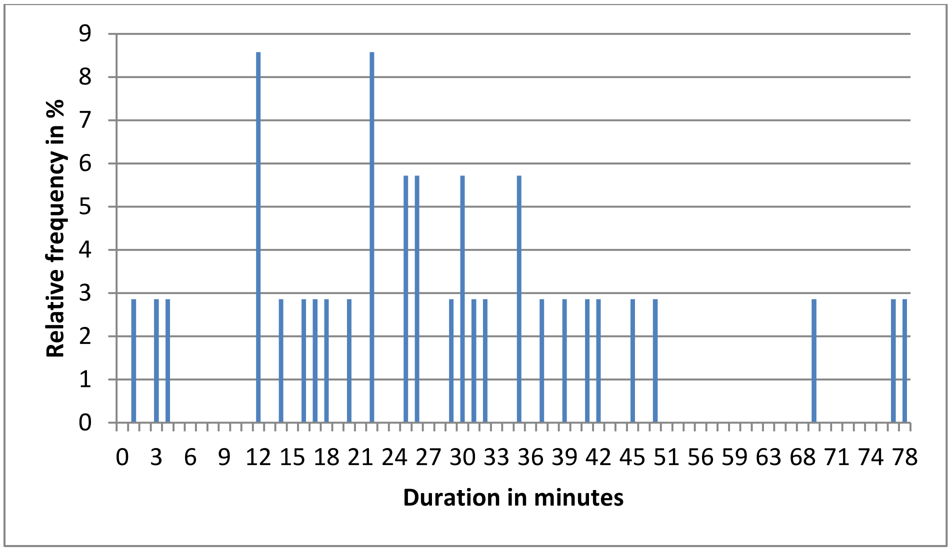


Figure 5-34: Relative frequency distribution of catering at remote parking bays

### 1.3.3.2 Local Parking Bay

As could be seen on figures (5.35) and (5.36), the effect of date and of start time on duration of catering at local parking bays is insignificant respectively. This is indicated by the weak correlation which is less than 10% in both figures. Therefore it is assumed that airport busyness has no influence on duration of catering at local parking bays.

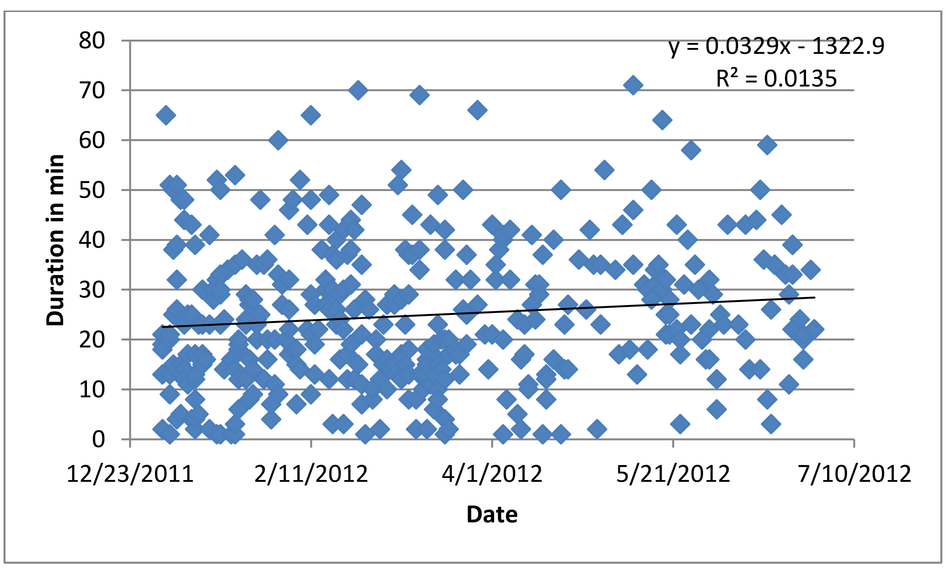


Figure 5-35: Effect of date on duration of catering at local parking bays

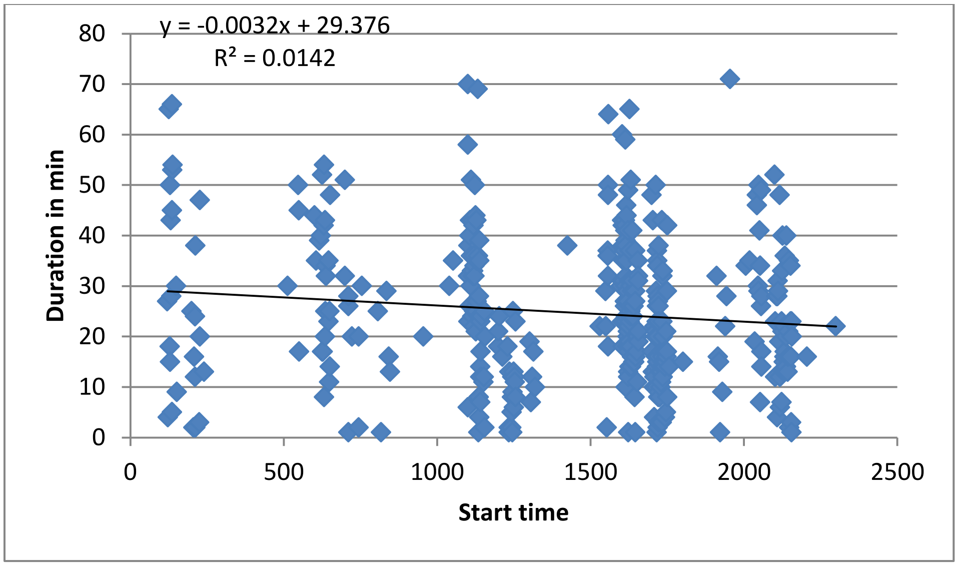


Figure 5-36: Effect of start time on duration of catering at local parking bays

Figure (5.37) visualizes the effect of flight length of outbound flight on duration of catering at local parking bays. Due to weak correlation which is less than 10%, it is assumed that flight length of outbound flight has no influence on catering at local parking bays.

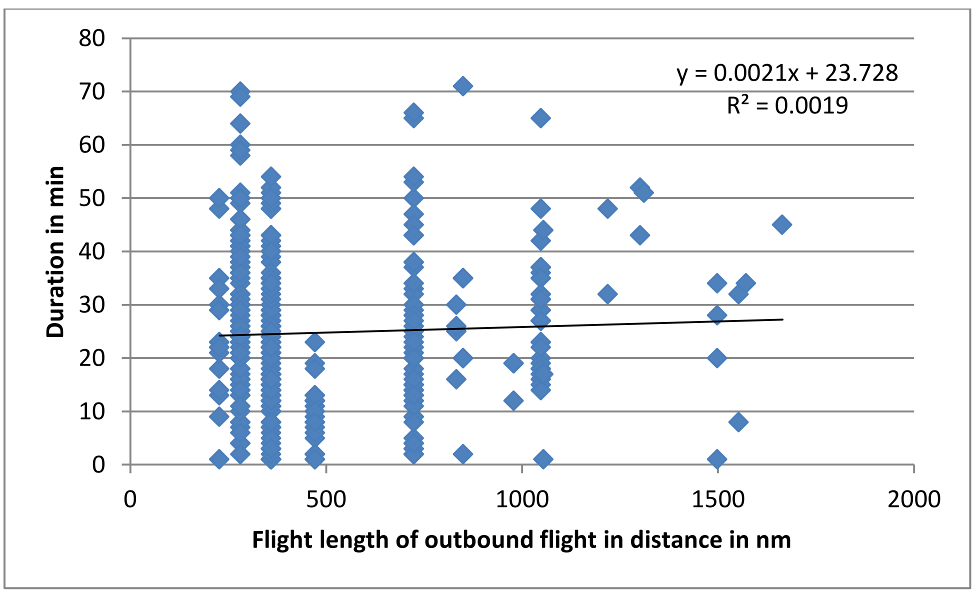


Figure 5-37: Effect of flight length of outbound flight on duration of catering at local parking bays

As could be seen on figure (5.38), the effect of amount passengers on outbound flight on duration of catering at local parking bays is insignificant. The reasoning behind this is that as the number of passengers on outbound flight increases the duration of catering increases and decreases as well. This is also indicated by the weak correlation which is less than 10%. Therefore, it is assumed that amount of passengers on outbound flight has no influence on catering at remote parking bays.

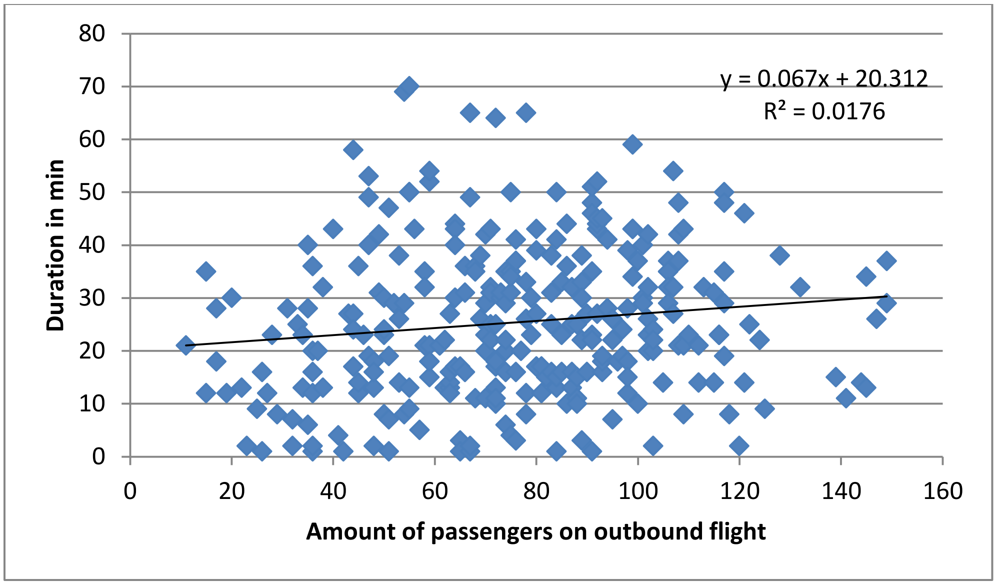


Figure 5-38: Effect of amount of passengers on outbound flight on duration of catering at local parking bays

Now that the external factors are analyzed, the current performance of catering based on duration at local parking bays could be determined. Figure (5.39), visualizes relative frequency distribution of catering at local parking bays. As could be seen from this figure, duration of catering varies from 1 to 71 minutes and the most frequent duration is 23 minutes. This accounts for about 4.3% of the sample. The average duration is 24.8 minutes and the standard deviation is 14.4 minutes.

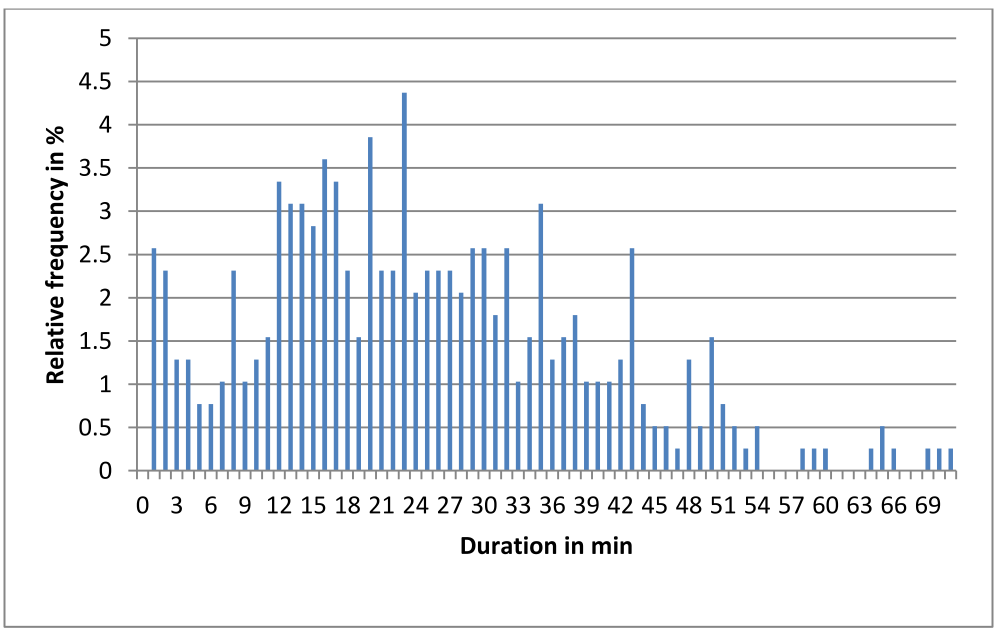


Figure 5-39: Relative frequency distribution of catering at local parking bays

#### 1.3.3.3 Domestic Parking Bay

As could be seen on figures (5.40) and (5.41), the effect of date and of start time on duration of catering at domestic parking bays is insignificant respectively. This is indicated by the significant weak correlation which is less than 10% in both figures. Therefore, it is concluded that airport busyness has no influence on duration of catering at domestic parking bays.

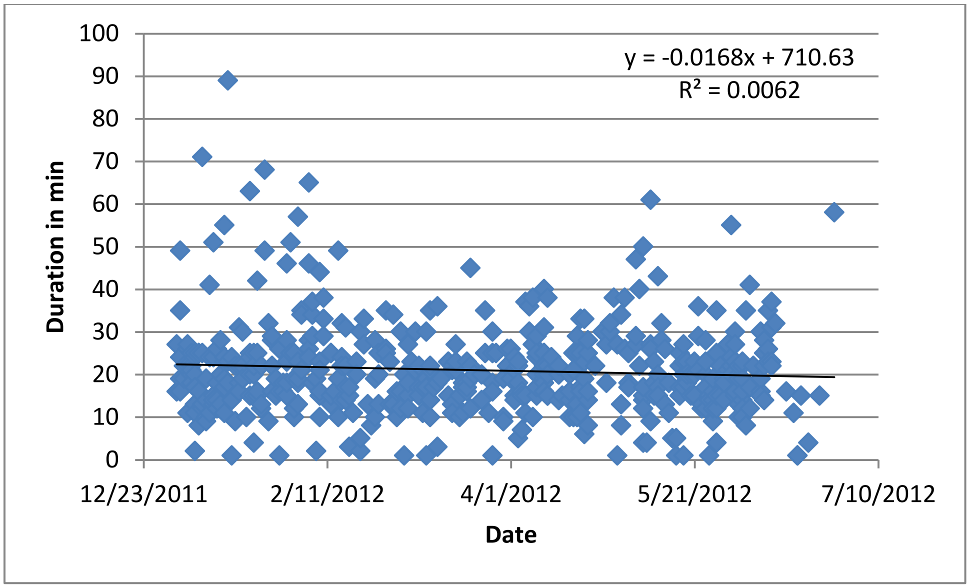


Figure 5-40: Effect of date on duration of catering at domestic parking bays

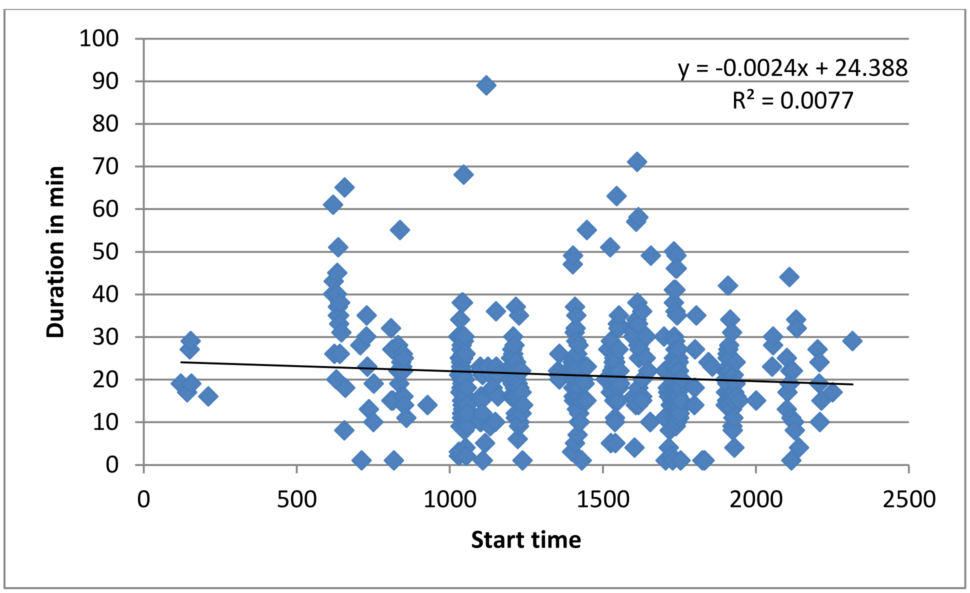


Figure 5-41: Effect of start time on duration of catering at domestic parking bays

Figure (5.42) visualizes the effect of flight length of outbound flight on duration of catering at domestic parking bays. Due to weak correlation which is less than 10%, it is assumed that flight length of outbound flight has no influence on catering at domestic parking bays.

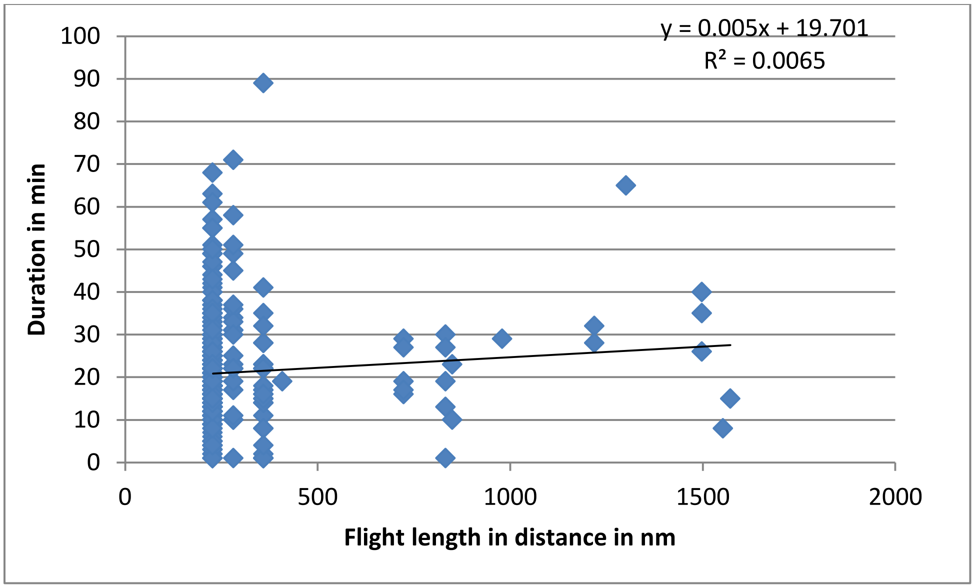


Figure 5-42: Effect of flight length of outbound flight on duration of catering at domestic parking bays

As could be seen on figure (5.43), the effect of amount passengers on outbound flight on duration of catering at domestic parking bays is insignificant. This is clearly indicated by the weak correlation which is less than 10%. Therefore, it is assumed that amount of passengers on outbound flight has no influence on catering at domestic parking bays.

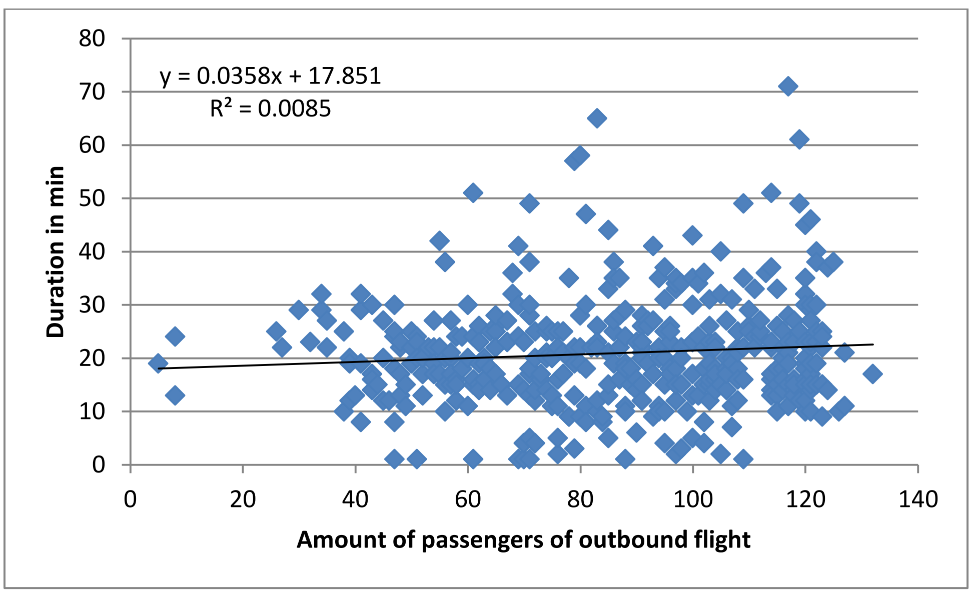


Figure 5-43: Effect of amount of passengers on outbound flight on duration of catering at domestic parking bays

Now that the external factors are analyzed, the current performance of catering based on duration at domestic parking bays could be determined. Figure (5.44), visualizes relative frequency distribution of catering at domestic parking bays. As could be seen on this figure, duration of catering varies from 1 to

89 minutes and the most frequent duration is 15 minutes. This accounts for about 7.1% of the sample. The average duration is 21.07 minutes and the standard deviation is 10.97 minutes.

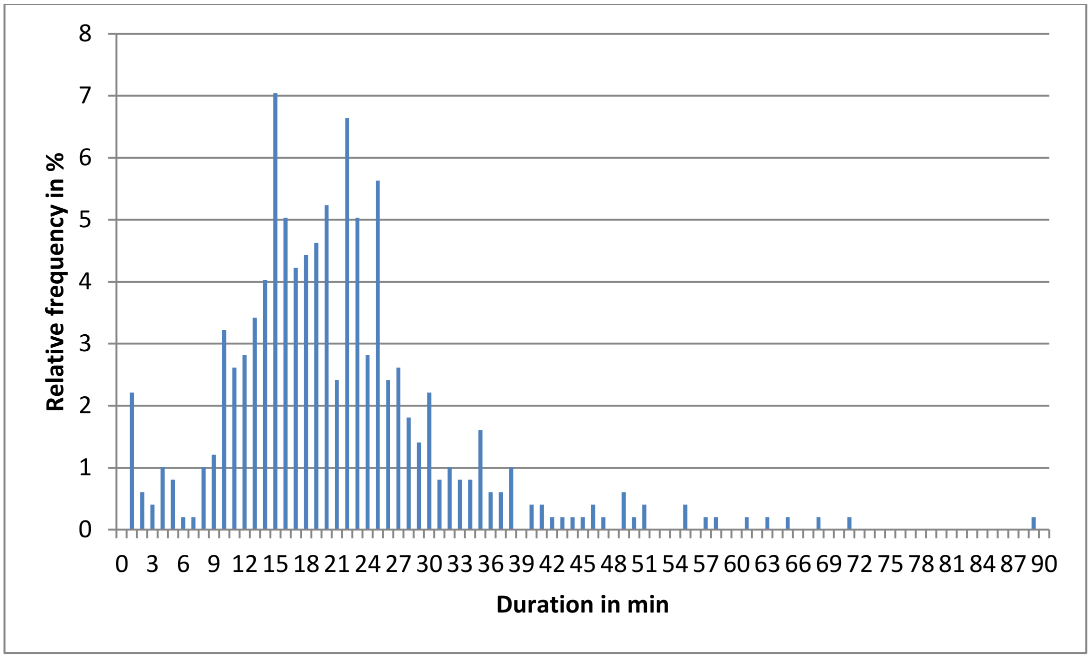


Figure 5-44: Relative frequency distribution of catering at domestic parking bays

Figure (5.45) summarizes the performance of the current strategy used in performing catering at different parking bays at (JKIA). In this figure, the average turnaround time is partly indicated by the average duration of cabin grooming and the reliability is indicated by the standard deviation.

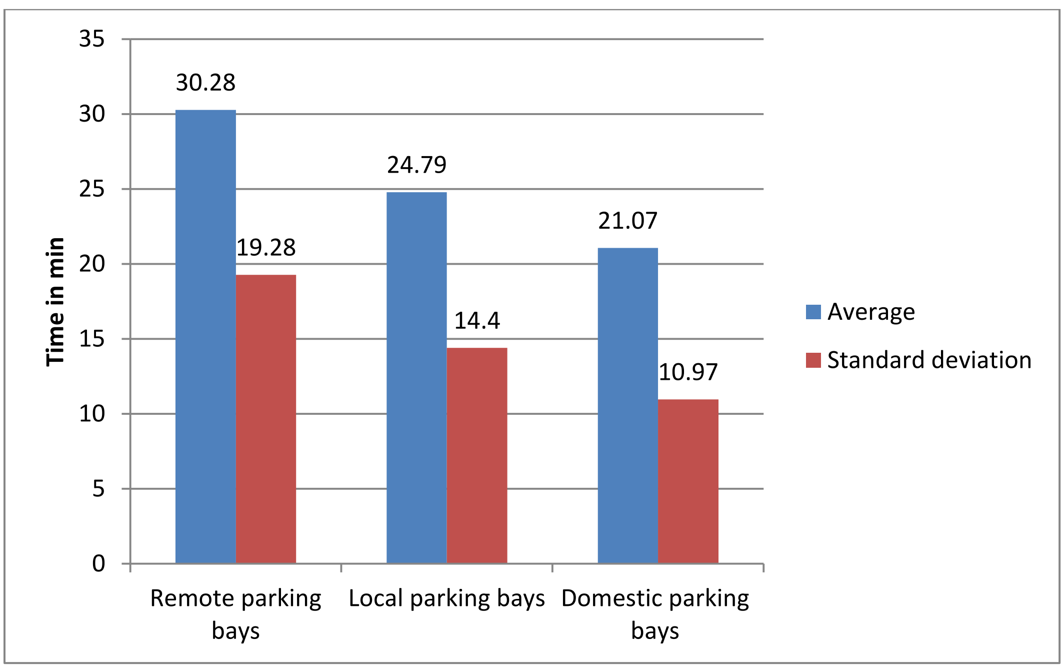


Figure 5-45: Current performance of catering at different types of parking bays at (JKIA)

### 1.3.4 Fueling

The available external factors on data which have potential influence on duration of fueling are airport busyness, flight length of outbound flight, and the amount of passengers on outbound flight. The effect of these external factors on duration of fueling will be analyzed at each type of parking bay at (JKIA).

#### *1.3.4.1 Remote Parking Bay*

As could be seen on figures (5.46) and (5.47), the effect of date and of start time on duration of fueling at remote parking bays is insignificant respectively. This is indicated by the weak correlation which is less than 10% in both figures. Therefore, it is assumed that airport busyness has no influence on duration of catering at remote parking bays.

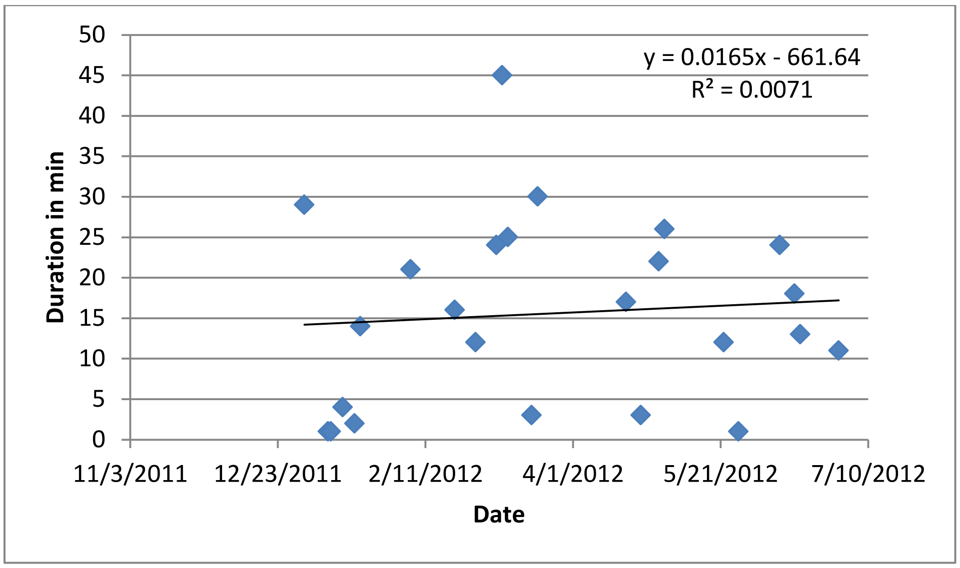


Figure 5-46: Effect of date on duration of fueling at remote parking bays

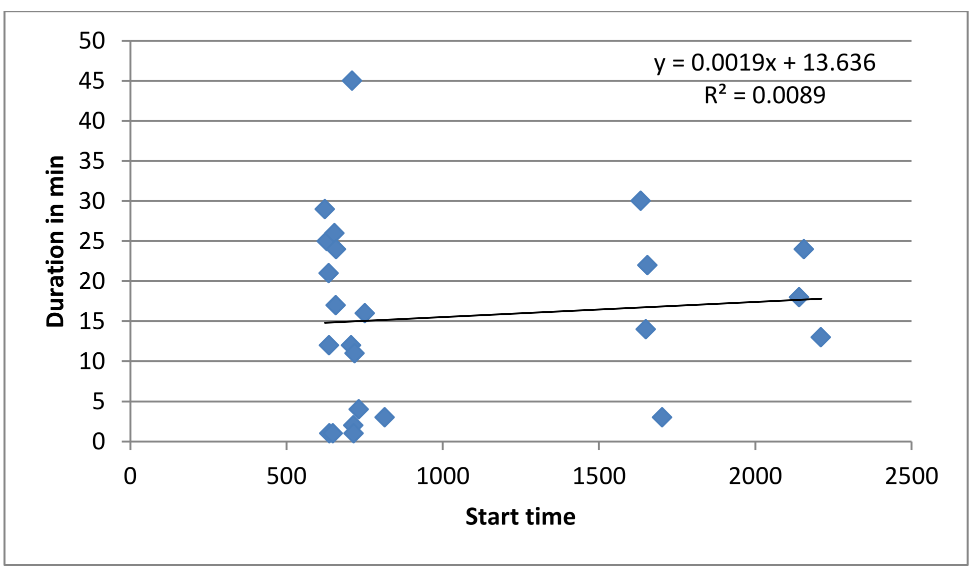


Figure 5-47: Effect of start time on duration of fueling at remote parking bays

Figure (5.48) visualizes the effect of flight length of outbound flight on duration of fueling at remote parking bays. Due to relatively medium correlation which about 17%, it is assumed that flight length of outbound flight has an influence on duration of fueling. To extract this influence, it was decided to only focus on data from 0 until 1000 nm, because as could be seen on figure (5.48), the sudden increase in data is from 1200 nm. Furthermore for data between 0 and 1000 nm, there is no indication of a relationship between flight length of outbound flight and duration of fueling as could be seen on figure (5.47). Therefore, it is assumed that flight length of outbound flight has no influence on duration of fueling at remote parking bays for destinations with distance less than 1000 nm from (JKIA).

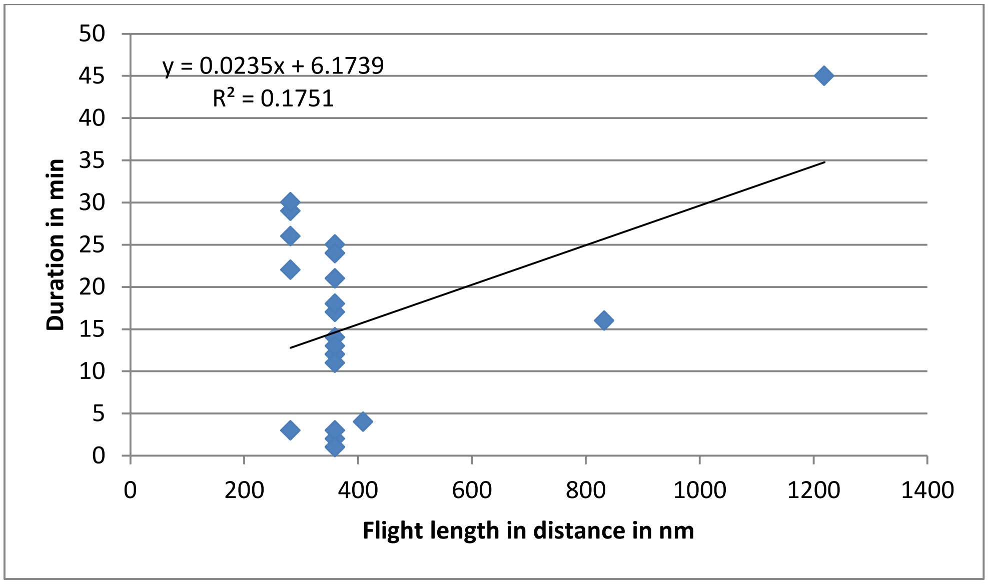


Figure 5-48: Effect of flight length of outbound flight on duration of fueling at remote parking bays

As could be seen on figure (5.49), the effect of amount passengers on outbound flight on duration of fueling at remote parking bays is insignificant. The reasoning behind this is that as the number of passengers on outbound flight increases the duration of fueling increases and decreases as well. This is also indicated by relatively weak correlation which is less than 10%. Therefore, it is assumed that amount of passengers on outbound flight has no influence on duration of fueling at remote parking bays.

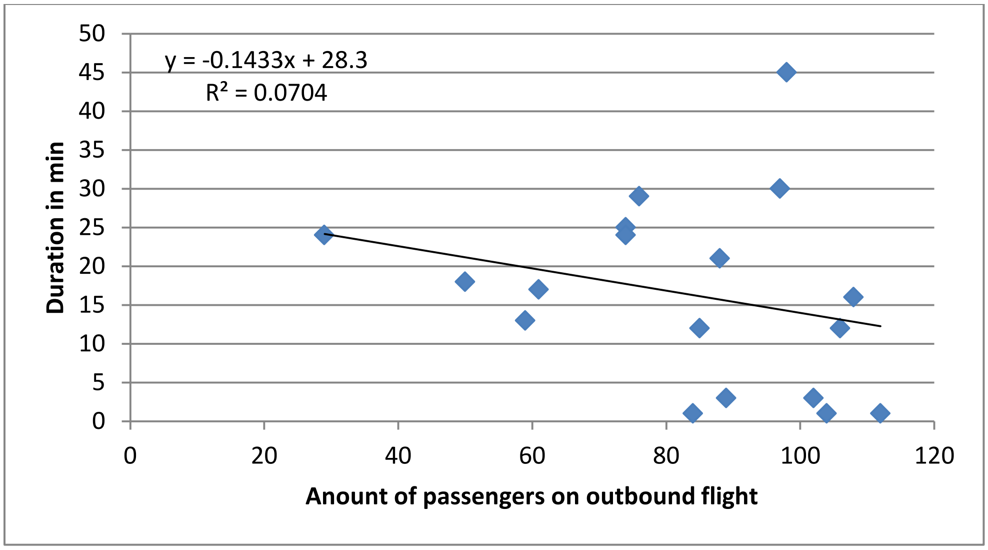


Figure 5-49: Effect of amount of passengers on outbound flight on duration of fueling at remote parking bays

Now that the external factors are analyzed, the current performance of fueling based on duration at remote parking bays could be determined. Figure (5.50), visualizes relative frequency distribution of fueling at remote parking bays. As could be seen on this figure, duration of fueling varies from 1 to 30 minutes and the most frequent duration is 1min. This accounts for about 13% of the sample. The average duration is 14.3 minutes and the standard deviation is 9.76 minutes.

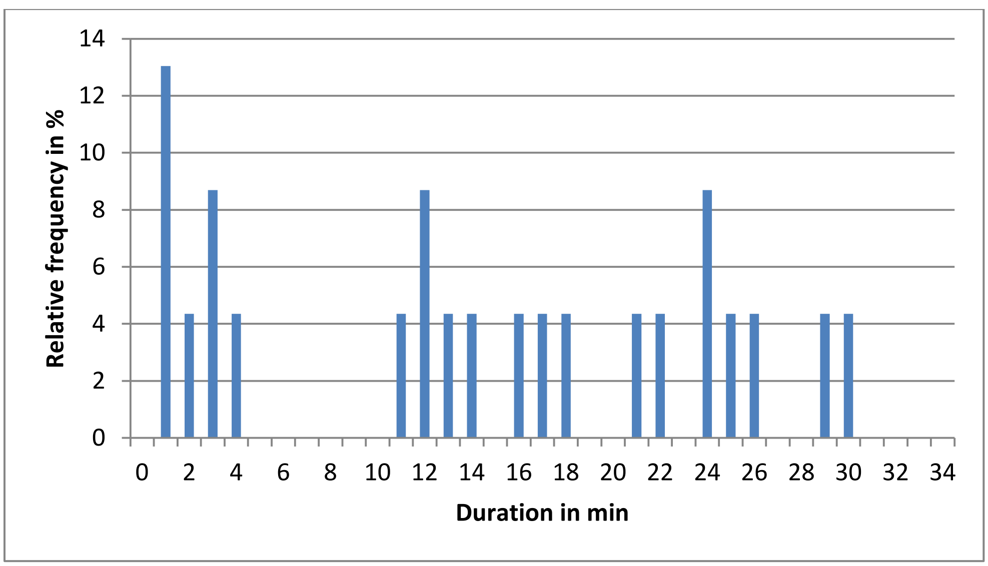


Figure 5-50: Relative frequency distribution of duration of fueling at remote parking bays

### *1.3.4.2 Local Parking Bay*

As could be seen on figures (5.51) and (5.52), the effect of date and of start time on duration of fueling at local parking bays is insignificant respectively. This is indicated by the weak correlation which is less than 10% in both figures. Therefore it is assumed that airport busyness has no influence on duration of fueling at local parking bays.

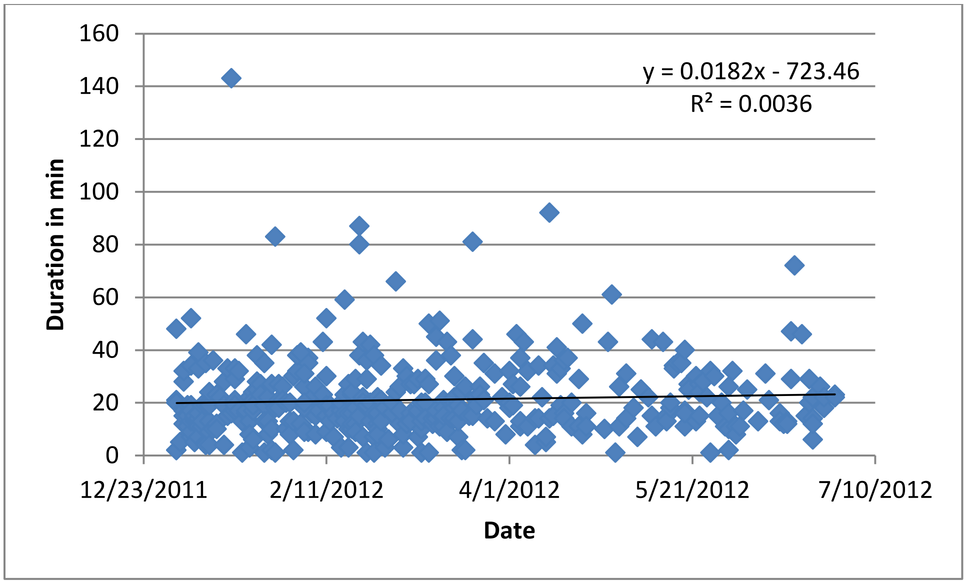


Figure 5-51: Effect of date on duration of fueling at local parking bays

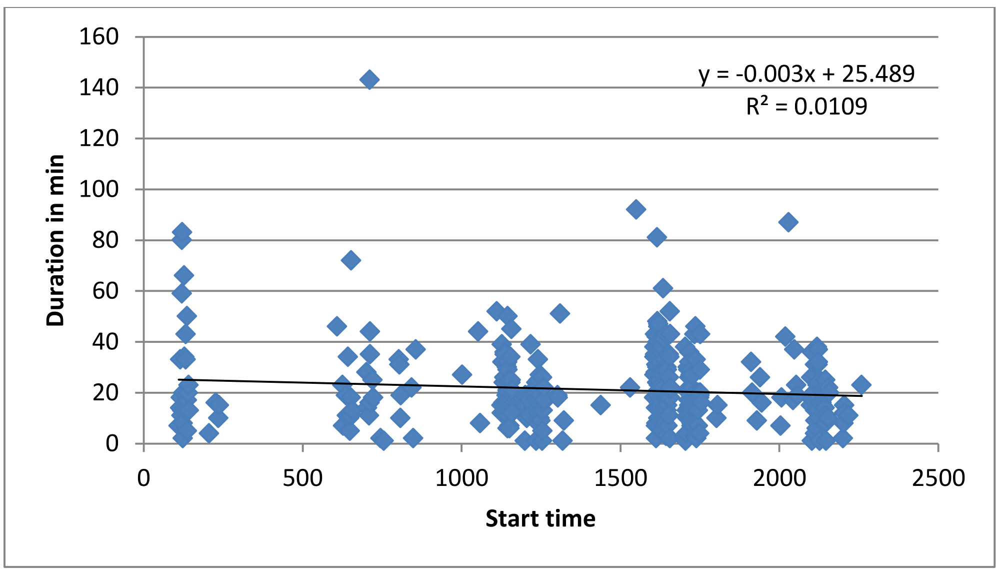


Figure 5-52: Effect of start time on duration of fueling at local parking bays

Figure (5.53) visualizes the effect of flight length of outbound flight on duration of fueling at local parking bays. Due to weak correlation which is less than 10%, it is assumed that flight length of outbound flight has no influence on duration of fueling at local parking bays.

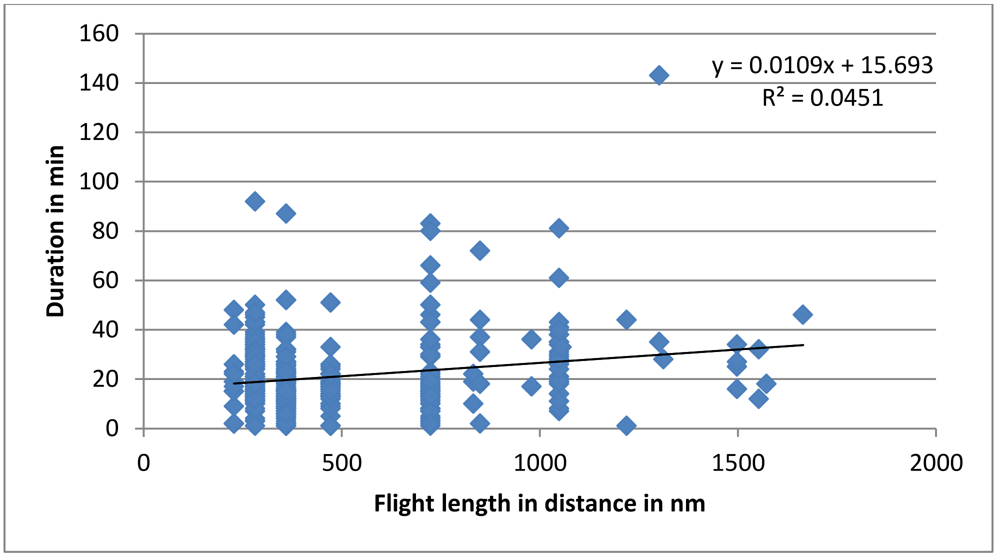


Figure 5-53: Effect of flight length of outbound flight on duration of fueling at local parking bays

As could be seen on figure (5.54), the effect of amount passengers on outbound flight on duration of fueling at local parking bays is insignificant. The reasoning behind this is that as the number of passengers on outbound flight increases the duration of catering increases and decreases as well. This is also indicated by the weak correlation which is less than 10%. Therefore, it is assumed that amount of passengers on outbound flight has no influence on fueling at local parking bays.

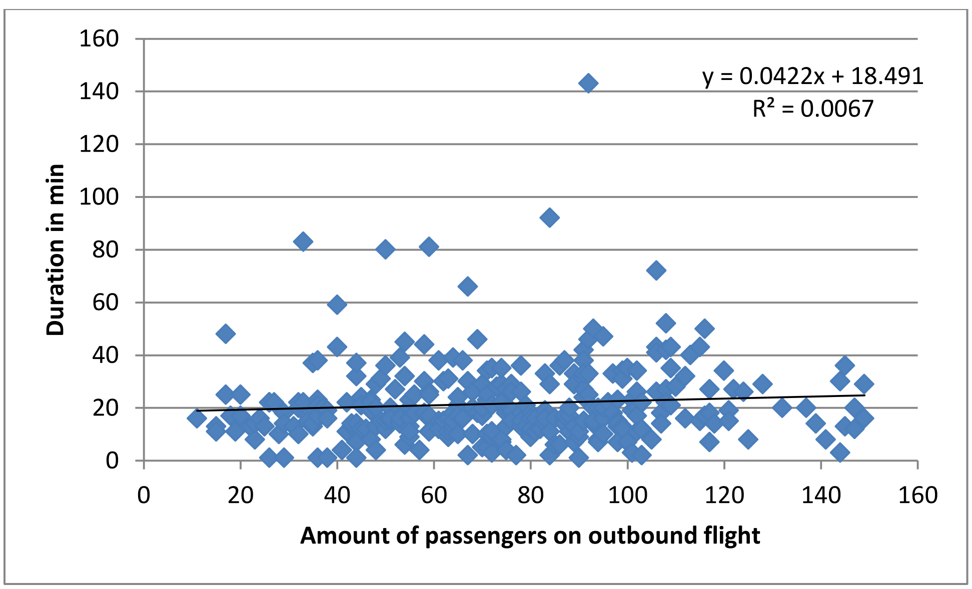


Figure 5-54: Effect of amount of passengers on outbound flight on duration of fueling at local parking bays

Now that the external factors are analyzed, the current performance of fueling based on duration at local parking bays could be determined. Figure (5.55), visualizes relative frequency distribution of fueling at local parking bays. As could be seen on this figure, duration of fueling varies from 1 to 143 minutes and the most frequent duration is 13 minutes. This accounts for about 6.11% of the sample. The average duration is 20.2 minutes and the standard deviation is 14.85 minutes.

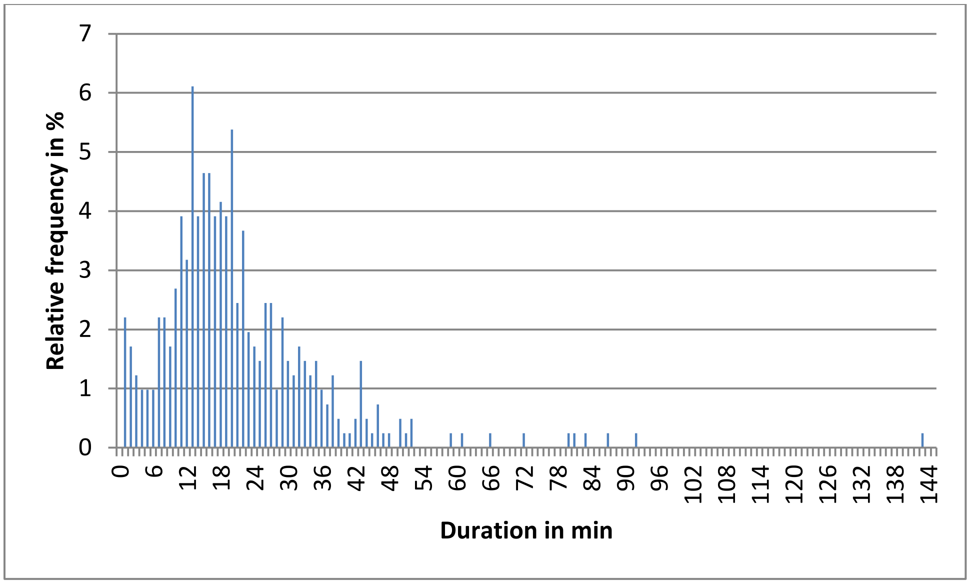


Figure 5-55: Relative frequency distribution of duration of fueling at local parking bays

#### *1.3.4.3 Domestic Parking Bay*

As could be seen on figures (5.56) and (5.57), the effect of date and of start time on duration of fueling at domestic parking bays is insignificant respectively. This is indicated by the weak correlation which is less than 10% in both figures. Therefore, it is assumed that airport busyness has no influence on duration of fueling at domestic parking bays.

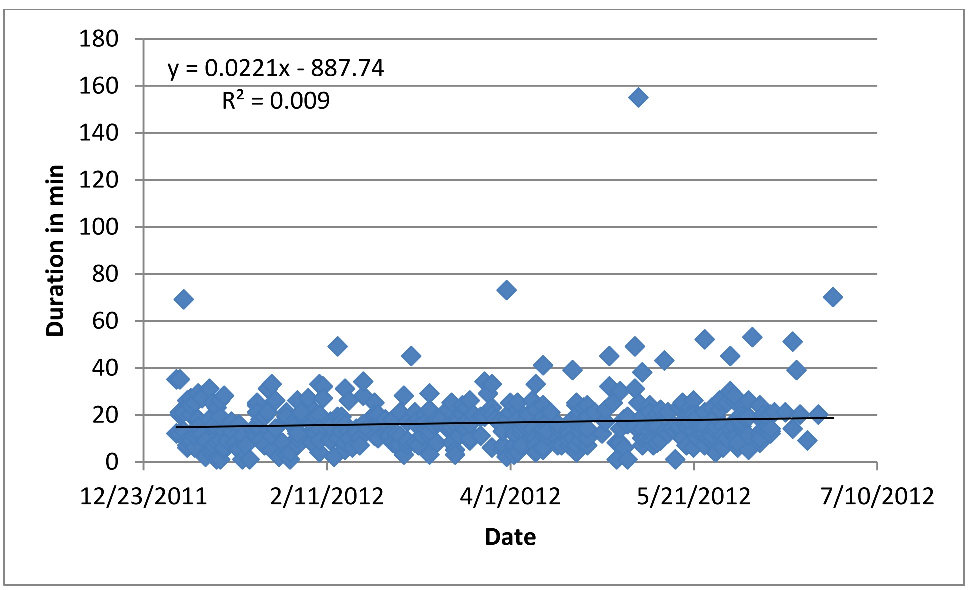


Figure 5-56: Effect of date on duration of fueling at domestic parking bays

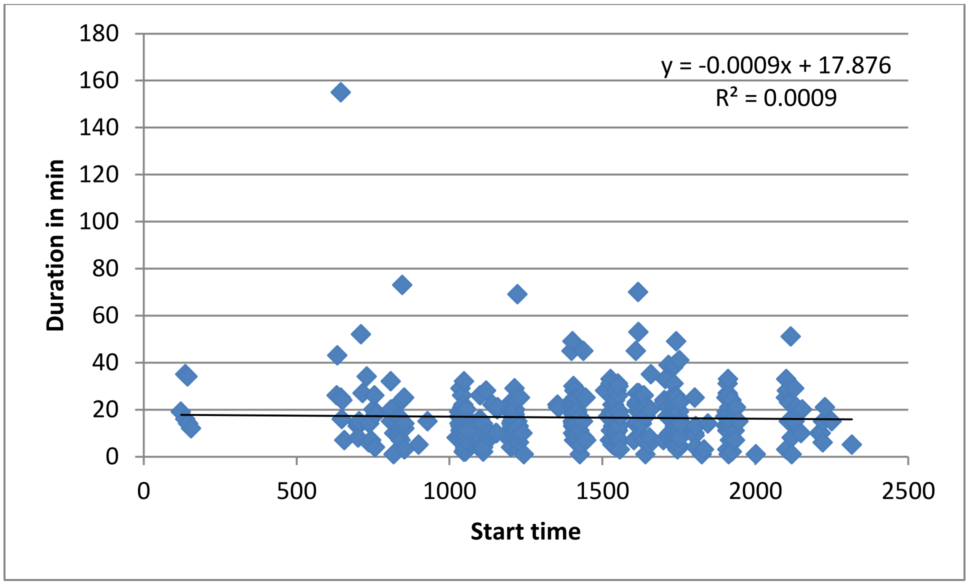


Figure 5-57: Effect of start time on duration of fueling at domestic parking bays

Figure (5.58) visualizes the effect of flight length of outbound flight on duration of fueling at domestic parking bays. Due to weak correlation which is less than 10%, it is assumed that flight length of outbound flight has no influence on duration of fueling at domestic parking bays.

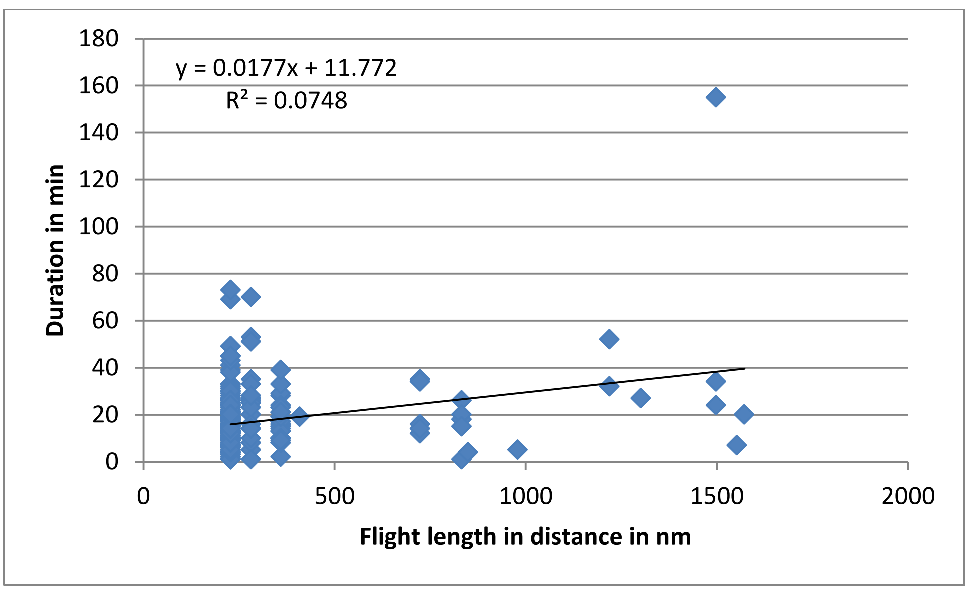


Figure 5-58: Effect of flight length of outbound flight on duration of fueling at domestic parking bays

As could be seen on figure (5.59), the effect of amount passengers on outbound flight on duration of fueling at domestic parking bays is insignificant. This is indicated by the weak correlation which is less than 10%. Therefore, it is assumed that amount of passengers on outbound flight has no influence on fueling at domestic parking bays.

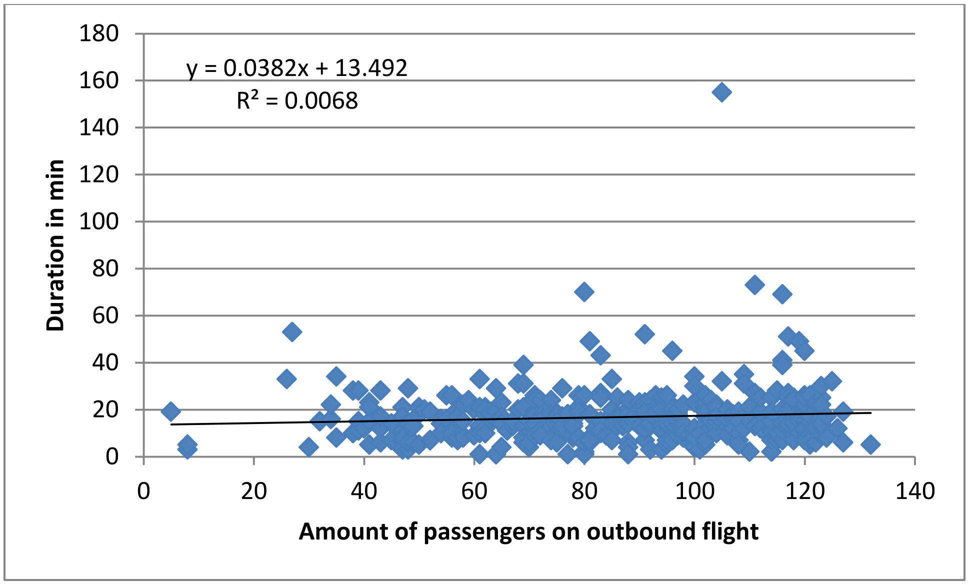


Figure 5-59: Effect of amount of passengers on outbound flight on duration of fueling at domestic parking bays

Now that the external factors are analyzed, the current performance of fueling based on duration at domestic parking bays could be determined. Figure (5.60), visualizes relative frequency distribution of fueling at domestic parking bays. As could be seen on this figure, duration of fueling varies from 1 to 73 minutes and the most frequent duration is 14 minutes. This accounts for about 6.6% of the sample. The average duration is 16.31 minutes and the standard deviation is 9.83minutes.

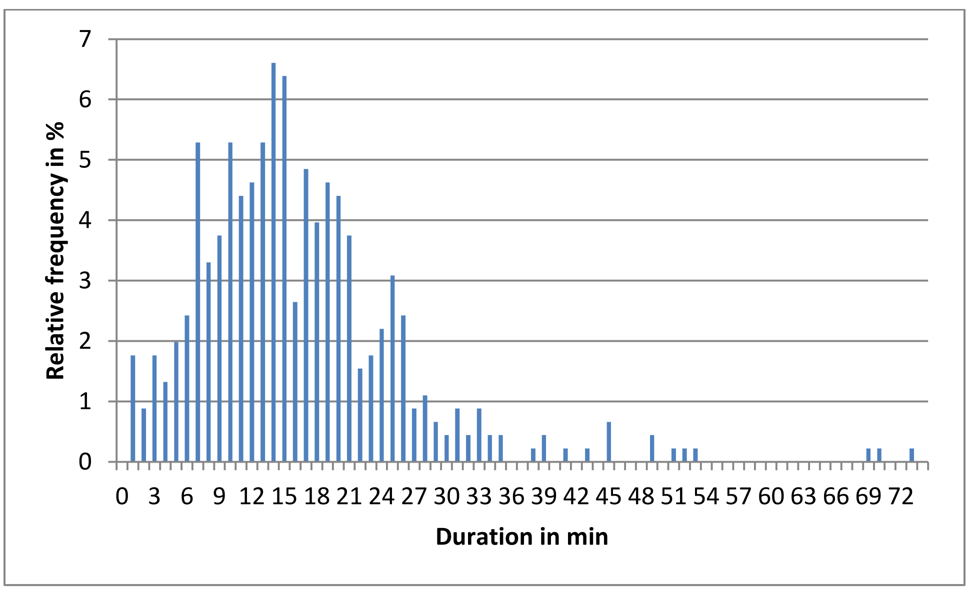


Figure 5-60: Relative frequency distribution of duration of fueling at domestic parking bays

Figure (5.61) summarizes the performance of the current strategy used in performing fueling at different parking bays at (JKIA). In this figure, the average turnaround time is indicated by the average duration and the reliability is indicated by the standard deviation.

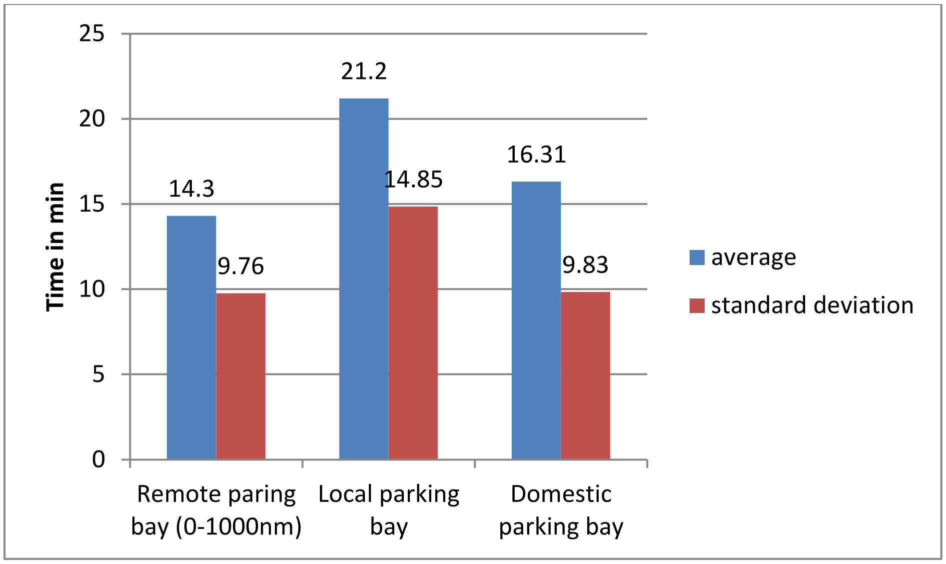


Figure 5-61: Current performance of fueling at different types of parking bays at (JKIA)

### 1.3.5 Boarding

The available external factors on data which have potential influence on duration of boarding are airport busyness and amount of passengers on outbound flight.

#### *1.3.5.1 Remote Parking Bay*

Figures (5.62) and (5.63) visualize the effect of date and of start time on duration of boarding at remote parking bays respectively. The effect of date on duration of boarding at remote parking bays is insignificant. This is indicated by the weak correlation which is less than 10% as could be seen on figure (5.62). However, the effect of start time on duration of boarding at remote parking bays is significant which is indicated by relatively medium correlation which about 17%. To extract the effect of start time, it was decided to focus only on data between 5:00 and 10:00 AM.

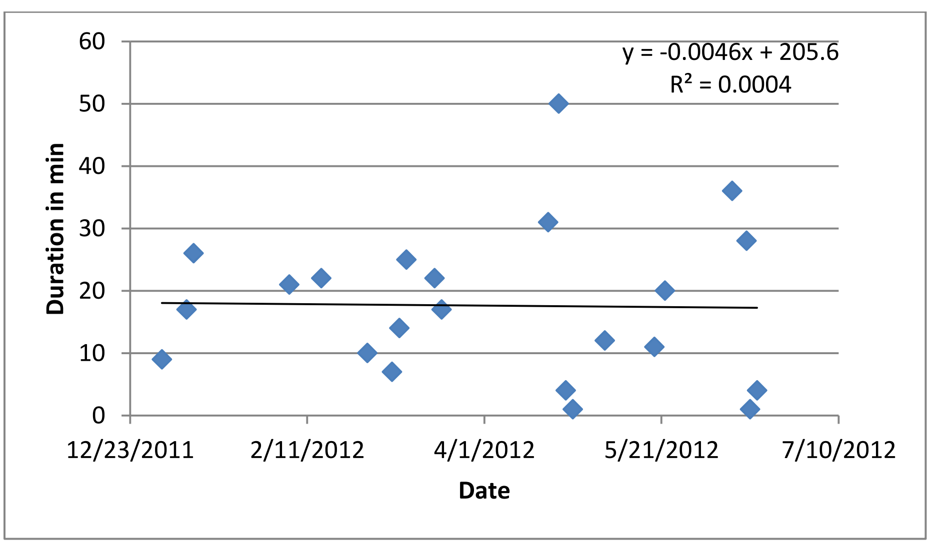


Figure 5-62: Effect of date on duration of boarding at remote parking bays

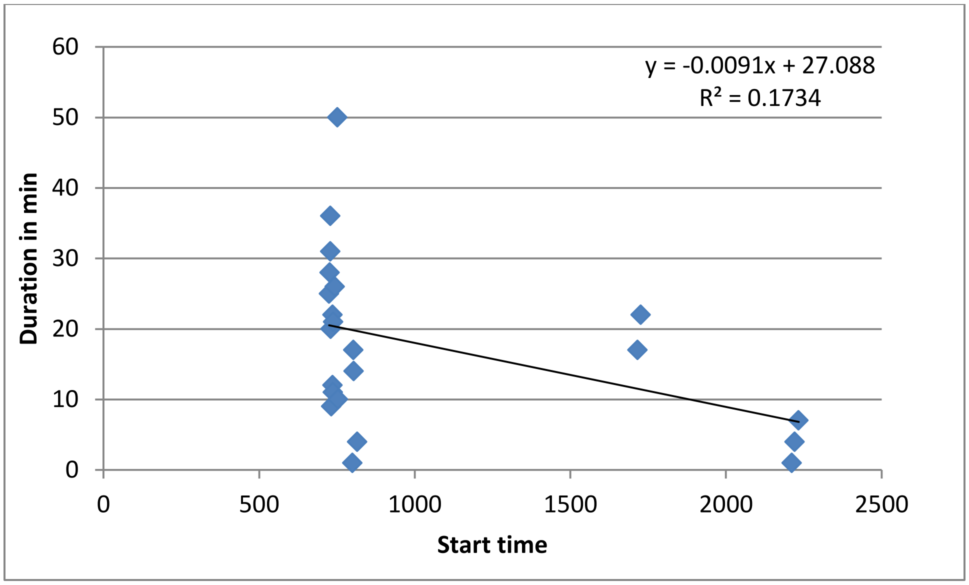


Figure 5-63: Effect of start time on duration of boarding at remote parking bays

As could be seen on figure (5.64), the effect of amount passengers on outbound flight on duration of boarding at remote parking bays is insignificant. This is indicated by the weak correlation which is less than 10%. Therefore, it is assumed that amount of passengers on outbound flight has no influence on fueling at domestic parking bays.

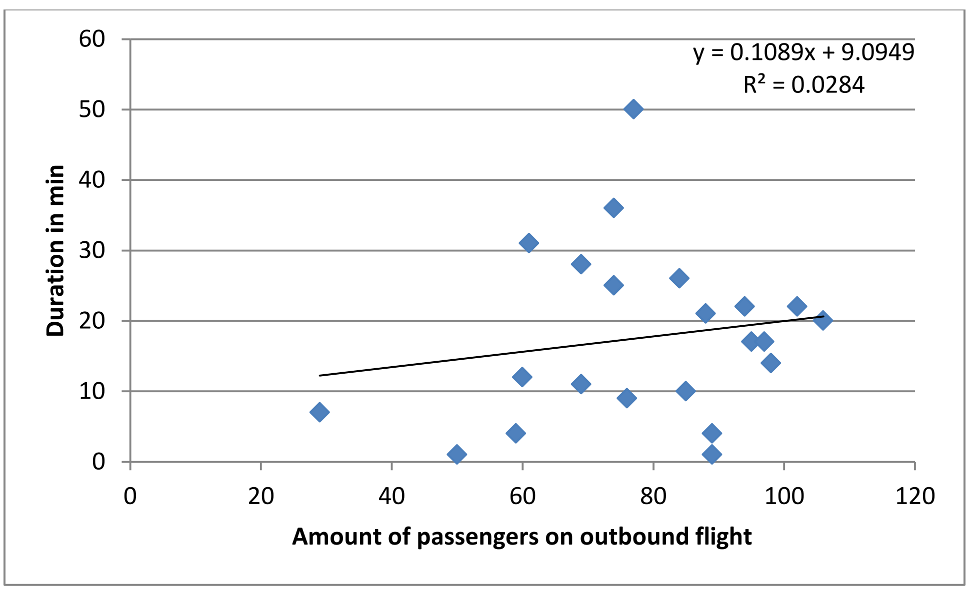


Figure 5-64: Effect of amount of passengers on outbound flight on duration of boarding at remote parking bays

Now that the external factors are analyzed, the current performance of boarding based on duration at remote parking bays could be determined. Figure (5.65), visualizes relative frequency distribution of boarding at remote parking bays. As could be seen on this figure, duration of boarding varies from 1 to 50 minutes and each observed duration has occurred once in the sample. The average duration is 19.82 minutes and the standard deviation is 12.33 minutes.

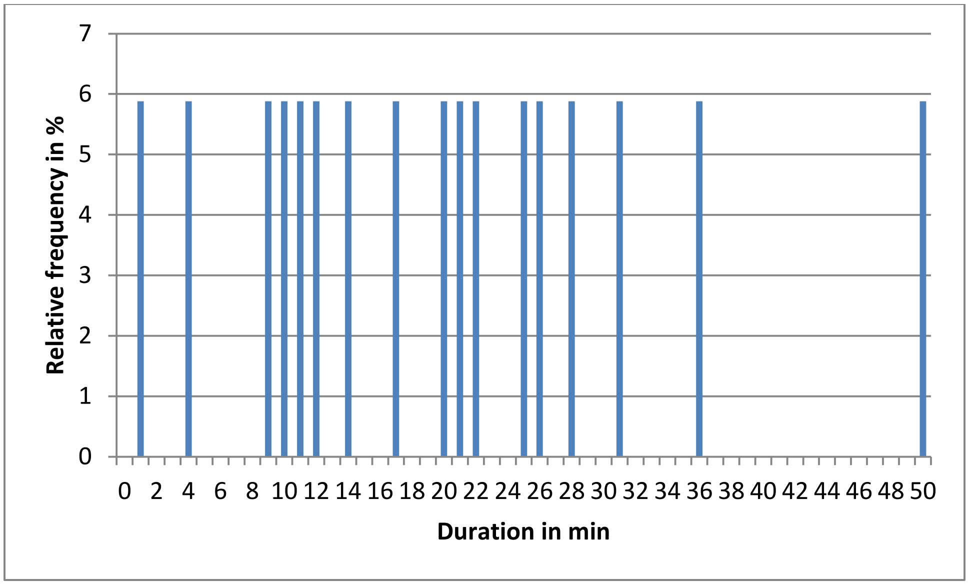


Figure 5-65: Relative frequency distribution of duration of boarding at remote parking bays

#### *1.3.5.2 Local Parking Bay*

As could be seen on figures (5.66) and (5.67), the effect of date and of start time on duration of boarding at local parking bays is insignificant respectively. This is indicated by the weak correlation which is less than 10% in both figures. Therefore, it is assumed that airport busyness has no influence on duration of boarding at local parking bays.

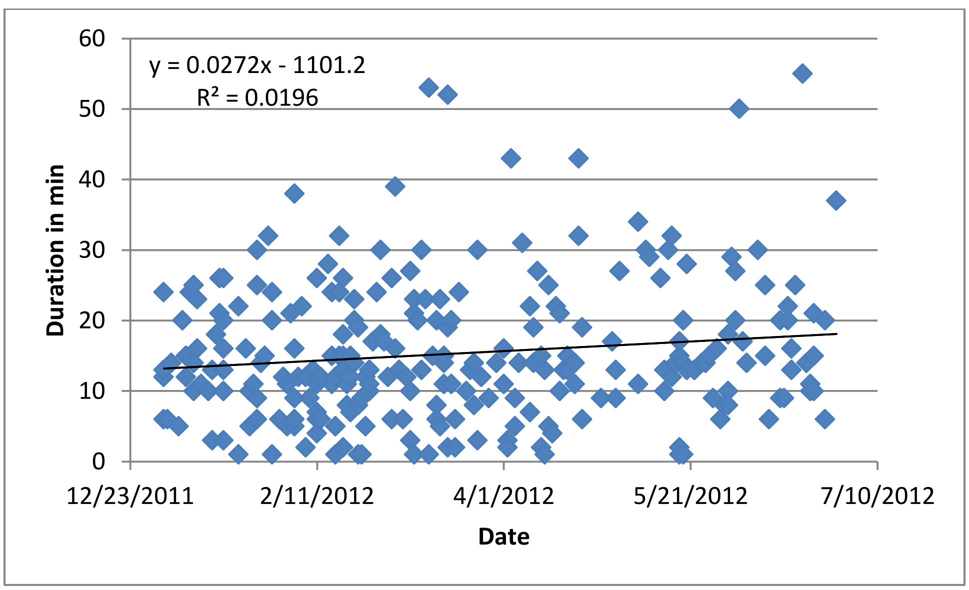


Figure 5-66: Effect of date on duration of boarding at local parking bays

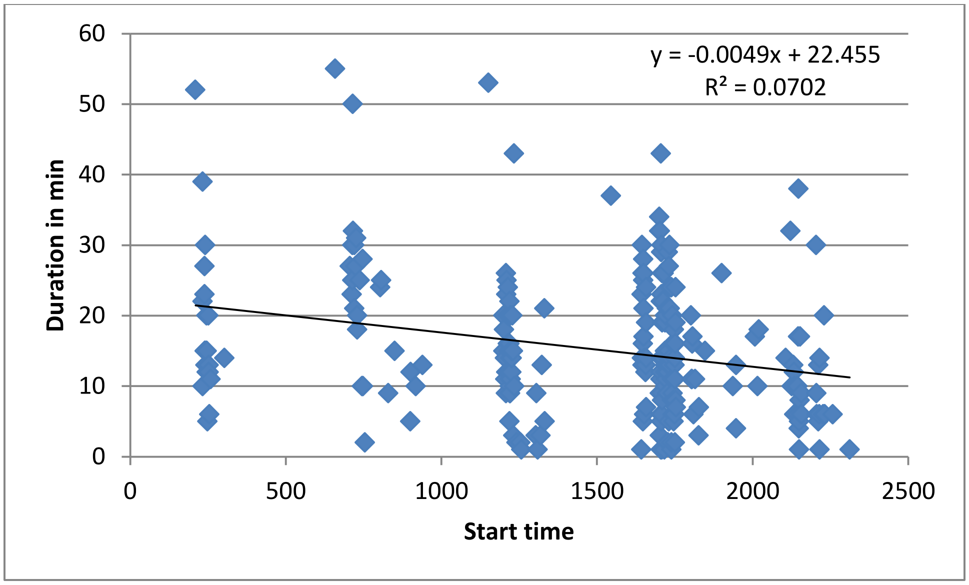


Figure 5-67: Effect of start time on duration of boarding at local parking bays

As could be seen on figure (5.68), the effect of amount passengers on outbound flight on duration of boarding at local parking bays is insignificant. This is indicated by the relatively weak correlation which is less than 10%. Therefore, it is assumed that amount of passengers on outbound flight has no influence on boarding at local parking bays.

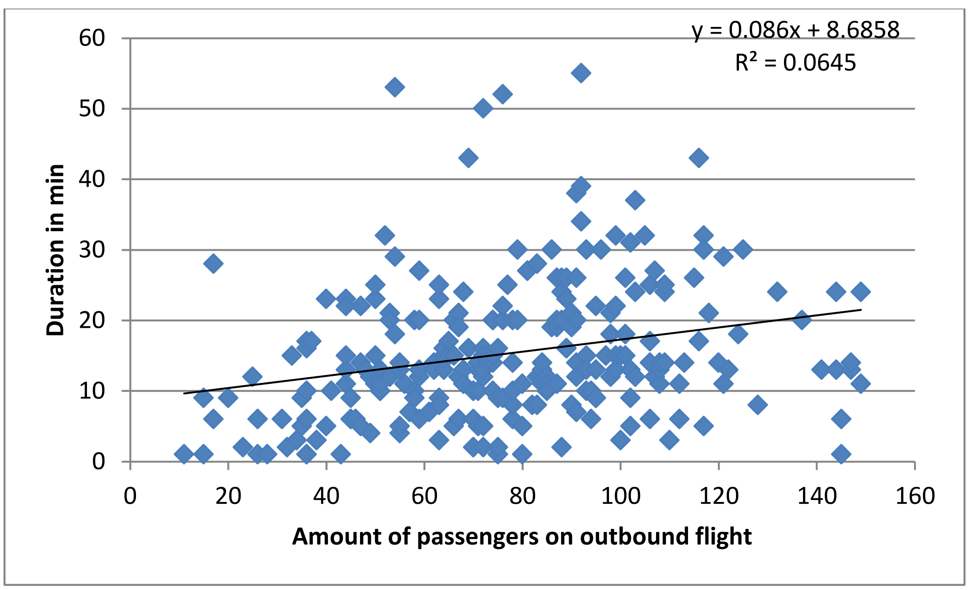


Figure 5-68: Effect of amount of passengers on outbound flight on duration of boarding at local parking bays

Now that the external factors are analyzed, the current performance of boarding based on duration at local parking bays could be determined. Figure (5.69), visualizes relative frequency distribution of boarding at local parking bays. As could be seen on this figure, duration of boarding varies from 1 to 55 minutes and the most frequent duration is 13 minutes. This accounts for about 8% of the sample. The average duration is 15.33 minutes and the standard deviation is 9.75 minutes.

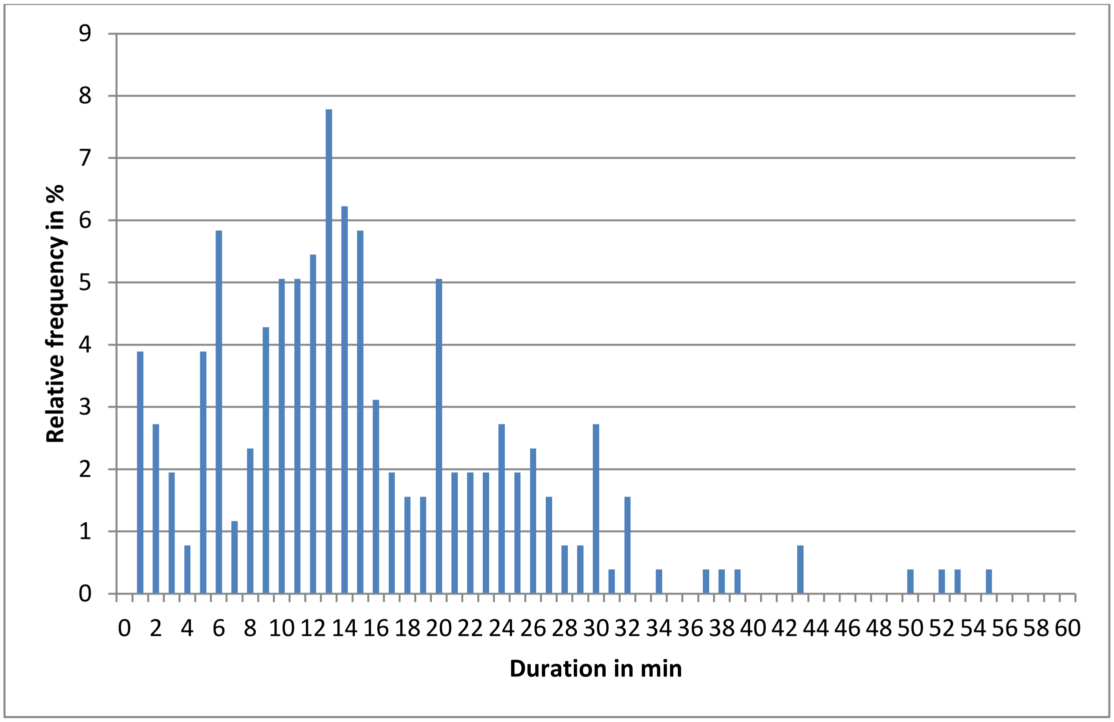


Figure 5-69: Relative frequency distribution of duration of boarding at local parking bays

#### *1.3.5.3 Domestic Parking Bay*

As could be seen on figures (5.70) and (5.71), the effect of date and of start time on duration of boarding at domestic parking bays is insignificant respectively. This is indicated by the weak correlation which is less than 10% in both figures. Therefore, it is assumed that airport busyness has no influence on duration of boarding at domestic parking bays.

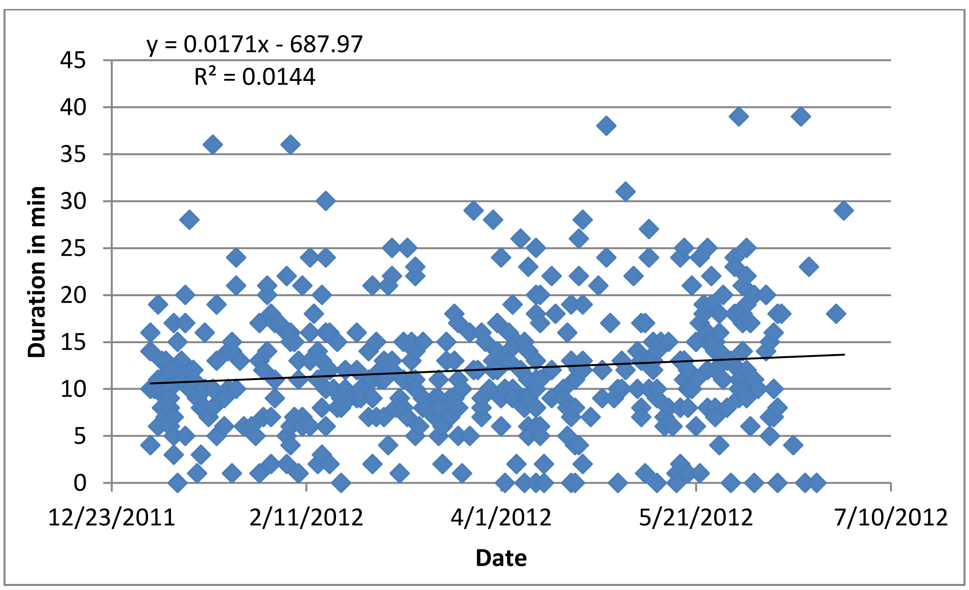


Figure 5-70: Effect of date on duration of boarding at domestic parking bays

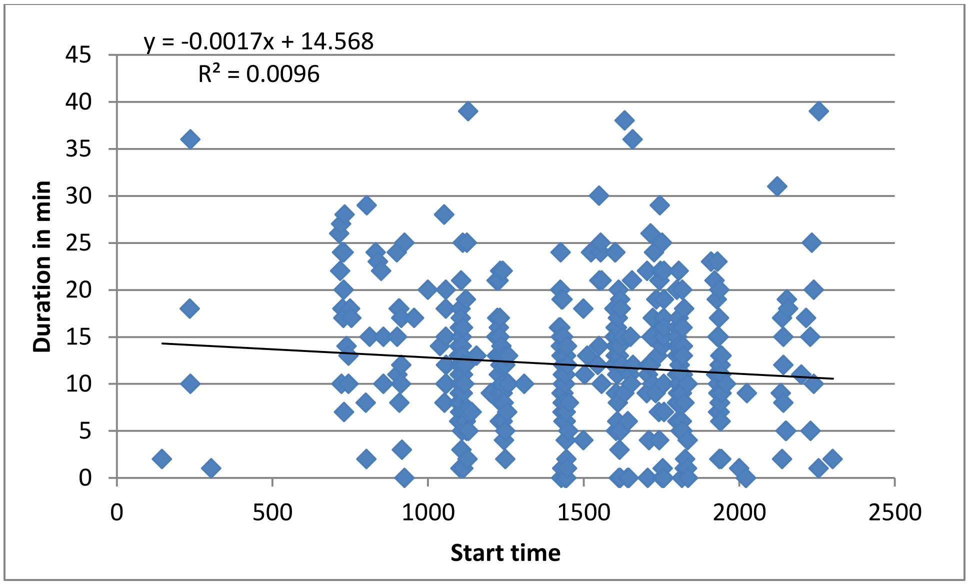


Figure 5-71: Effect of start time on duration of boarding at domestic parking bays

As could be seen on figure (5.72), the effect of amount passengers on outbound flight on duration of boarding at domestic parking bays is insignificant. This is indicated by the weak correlation which is less than 10%. Therefore, it is assumed that amount of passengers on outbound flight has no influence on boarding at domestic parking bays.

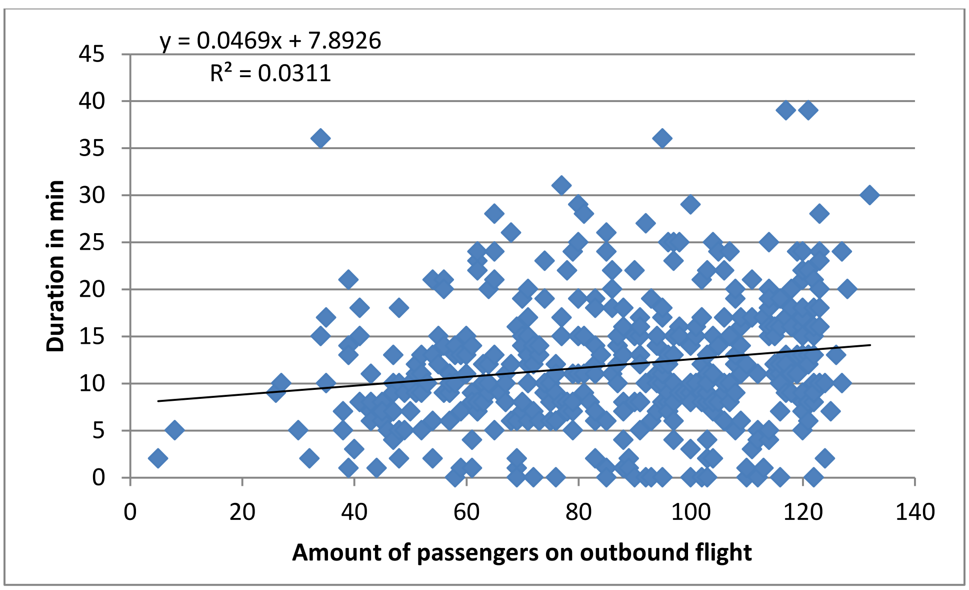


Figure 5-72: Effect of amount of passengers on outbound fight on duration of boarding at domestic parking bays

Now that the external factors are analyzed, the current performance of boarding based on duration at domestic parking bays could be determined. Figure (5.73), visualizes relative frequency distribution of boarding at domestic parking bays. As could be seen from this figure, duration of boarding varies from 1 to 39 minutes and the most frequent duration is 8 minutes. This accounts for about 8.5% of the sample. The average duration is 12.52 minutes and the standard deviation is 6.69 minutes.

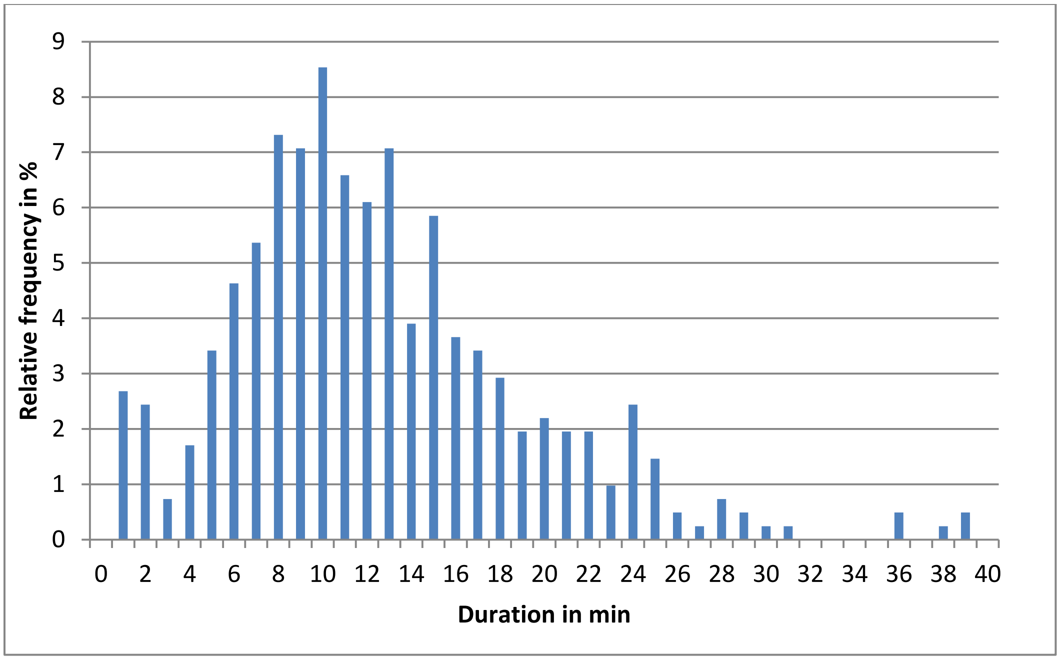


Figure 5-73: Relative frequency distribution of duration of boarding at domestic parking bays

Figure (5.74) summarizes the performance of the current strategy used in performing boarding at different parking bays at (JKIA). In this figure, the average turnaround time is partly indicated by the average duration and the reliability is indicated by the standard deviation.

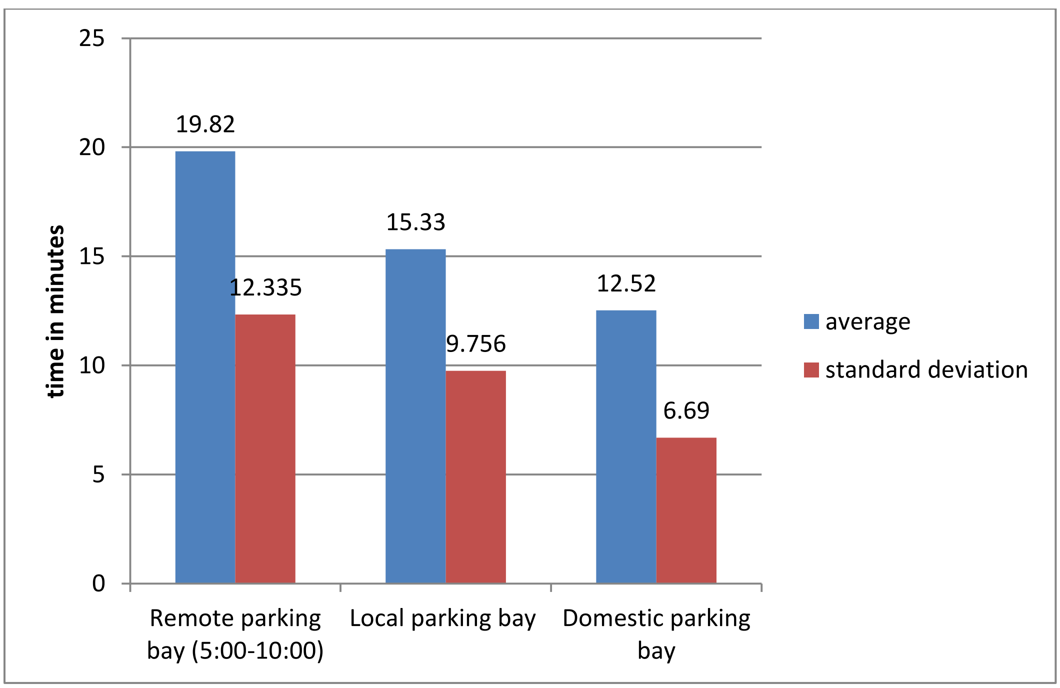


Figure 5-74: Current performance of boarding at different types of parking bays at (JKIA)

The current performance of turnaround sub processes at different parking bays at (JKIA) is summarized in figure (5.75).

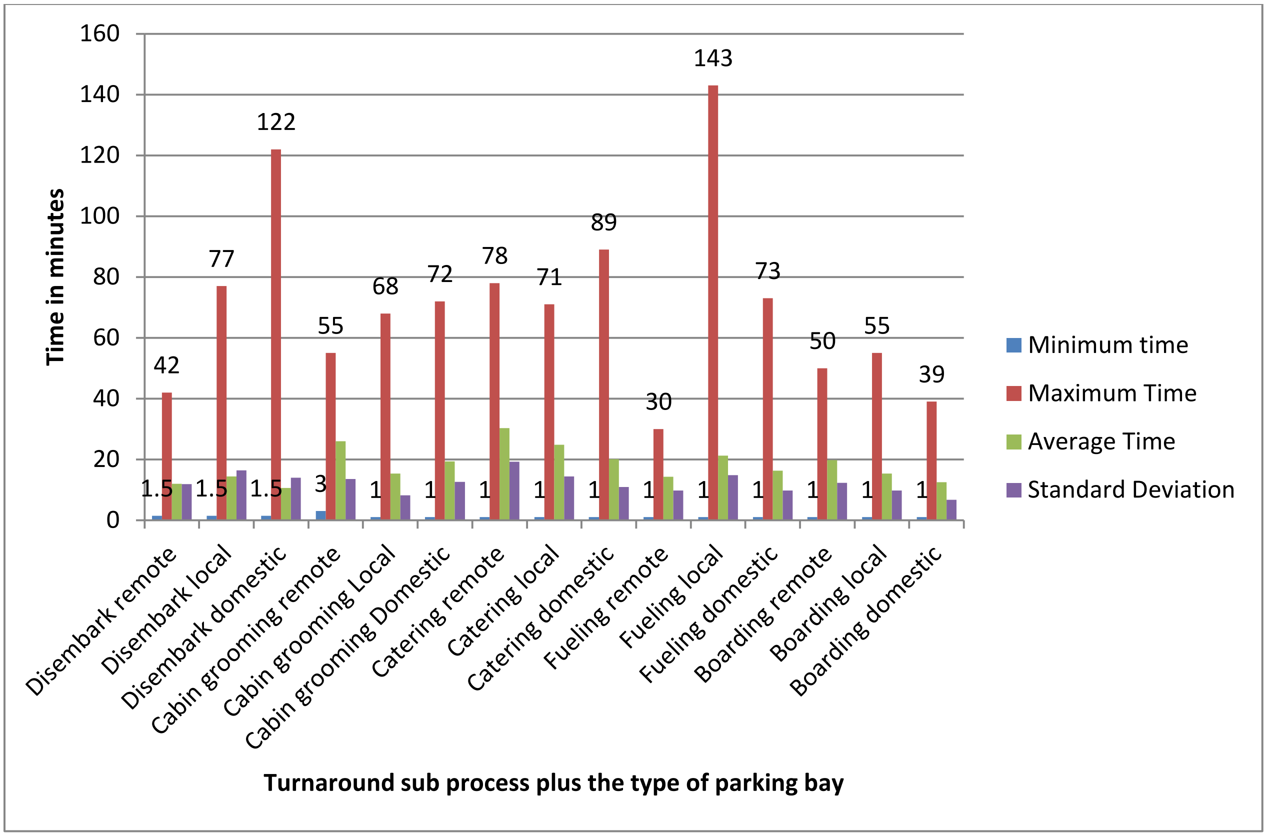


Figure 5-75: Summary of current performance of turnaround sub processes of (KQ) at (JKIA)

Now that the average duration and the reliability of the current state of the selected turnaround sub processes have been determined, the alternatives and their performance will be identified in next section.

## 1.4 Identification of Alternatives within Turnaround Process

In this section, the results of two alternatives which are implemented in improving the performance of turnaround process will be described namely, theory of constraints and lean production system.

### 1.4.1 Theory of Constraints

Theory of constraints was implemented by Beelaerts van Blokland et al. (2008) to reduce the turnaround time of narrow and wide body aircraft (Boeing 737-800 and Boeing 747-400 Combi respectively) for KLM at SAA. Since data analysis of Boeing 737-300 is used during this research, only the results of Boeing 737-800 will be considered.

The proposed solutions for Boeing 737-800 by Beelaerts van Blokland et al. (2008) after the implementation of theory of constraints are stated in table (5.2). However, according to Beelaerts van Blokland et al. (2008), these solutions or improvements cannot be implemented at once at SAA due to number of reasons. The main reasons are; current layout, large investments and long development time for some of these solutions. Therefore, implementation plans have been made which show the solutions that need to be implemented in time to reduce the turnaround time of Boeing 737-800. These implementation plans are described in table (5.3) within their potential reductions on turnaround time. Notice that within each implementation plan, there is another critical path. Also these solutions haven bee proposed with taking into account environment, safety, security, and flexibility.

After analyzing the proposed solutions stated in tables (5.2) and (5.3), several assumptions are made to estimate the average duration and the reliability of the selected turnaround sub processes if theory of constraints is implemented by (KQ) at (JKIA). These assumptions are:

- The same reductions in turnaround time of Boeing 737-800 are achieved if the theory of constraints is implemented by (KQ) at (JKIA) for Boeing 737-300.
- The implementation plan 1 (see table (5.3)) is related only to cleaning and catering. Therefore, it is assumed if these solutions are implemented by (KQ) at (JKIA), then there will be 20% of reduction of average duration in catering and cleaning.
- The implementation plan 3 (see table (5.3)) is related only to boarding and disembark. Therefore, it is assumed if these solutions are implemented by (KQ) at (JKIA), then there will be 12% of reduction of average duration in boarding and disembark.
- It is assumed that the performance of fueling will remain the same even if the theory of constraints is implemented
- Figure (5.76) displays reliability in term of standard deviation with respect to average duration of the selected turnaround sub processes based on data of (KQ). As could be seen from the figure, there is a relatively medium correlation which is about 35% between reliability and average duration. The equation of the trend line in figure (5.76) will be used to estimate the reliability once the average duration is obtained.

The performance of the selected turnaround sub processes is summarized in table (5.4) if the theory of constraints is implemented by (KQ) at (JKIA).

**Table 5-2: Turnaround ground handling process design specifications for new narrow body turnaround ground handling concept for the Boeing 737-800 (Beelaerts van Blokland et al., 2008)**

| Activity | Specification |
|---|---|
| **Disembark** | -Use aircraft left front and left aft door. |
| **Boarding** | -Use aircraft left front door and left aft door.<br>-A passenger flow rate of 18 passengers/minute |
| **Catering** | -Parallel catering of front and aft galley<br>-A flow rate of 2 trolleys/minute<br>-Extra resources<br>-Put up a partition in the galleys |
| **Cabin cleaning** | -Extra resources (twice as much) |
| **Cabin check and cabin security check** | -Cabin security check by cabin crew (combined) |
| **Unloading and loading of baggage/freight** | -Continuous and smooth supply of baggage/freight<br>-A loading flow rate of 8.91 pieces/minute and unloading flow rate of 7.93 pieces/minute |

| | |
|---|---|
| | -Tail tipping prevention |
| **Fuel service** | -Fixed fuel system at the ramp<br>-A refuel flow rate of at least 1100 liters/minute<br>-Digital communication system for sending fuel note<br>-Connecting bonding cable together with placing wheel chocks<br>-Use aircraft left front and left aft door for disembark to start earlier |

**Table 5-3: Implementation plan for a new narrow body turnaround ground handling concept based on the Boeing 737-800 (Beelaerts van Blokland et al., 2008)**

| Phase | Initial critical path | Concept design turnaround specification | Turnaround time reduction |
|---|---|---|---|
| **1 (2009-2014)** | Catering service | -An extra catering truck<br>-An extra catering employee<br>-Gallery partition<br>-Four extra cabin cleaners<br>-Combining cabin security check and cabin check<br>-Fixed wall electricity | 20% |
| **2 (2014-2019)** | Unloading/loading baggage and freight | -A new baggage and freight sorting and distribution system<br>-A supporting strut | 10% |
| **3 (2019-2024)** | Cabin cleaning | -A second passenger bridge<br>-An extra passenger handler<br>-An extra boarding pass control device<br>-Automated passenger bridge system | 12% |
| **4 (2024-2029)** | Cabin cleaning | -A fixed fuel pop-up system<br>-A fixed water and toilet service pop-up system | 0% |

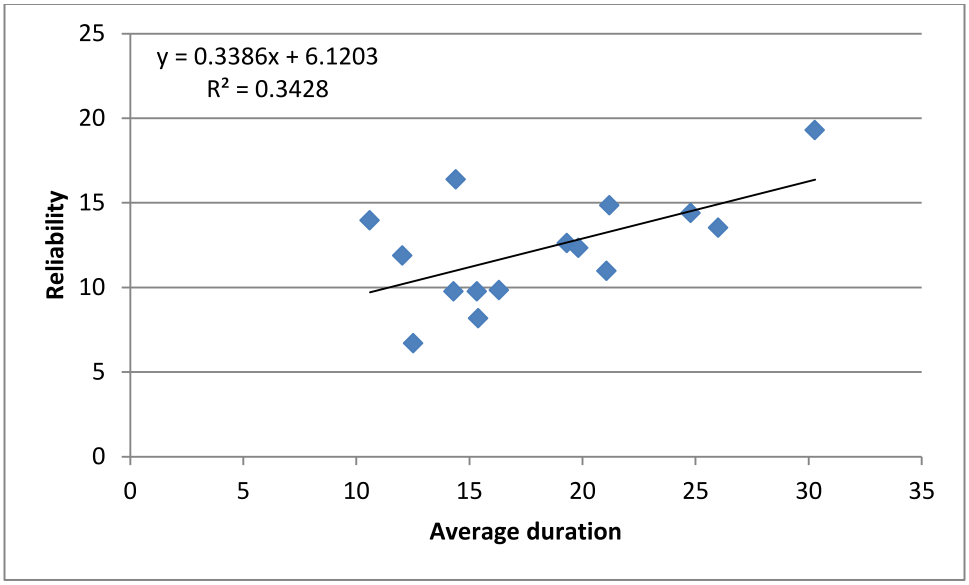


Figure 5-76: Correlation between reliability and average duration of the selected turnaround sub processes based on data of (KQ)

Table 5-4: Performance of the selected turnaround processes using theory of constraints

| Turnaround sub process | Type of parking bay | Average duration in min | Reliability in min |
|---|---|---|---|
| **Passengers Disembark** | Remote | 10.59 | 9.70 |
| | Local | 12.67 | 10.41 |
| | Domestic | 9.32 | 9.27 |
| **Cabin grooming** | Remote (5:00-10:00) | 20.8 | 13.16 |
| | Local | 15.448 | 11.35 |
| | Domestic | 12.32 | 10.29 |
| **Catering** | Remote | 24.22 | 14.32 |
| | Local | 19.83 | 12.83 |
| | Domestic | 16.85 | 11.82 |
| **Fueling** | Remote (0-1000nm) | 14.3 | 9.76 |
| | Local | 21.2 | 14.85 |
| | Domestic | 16.31 | 9.83 |
| **Passengers boarding** | Remote (5:00-10:00) | 17.44 | 12.02 |
| | Local | 13.49 | 10.68 |
| | Domestic | 11.01 | 9.85 |

### 1.4.2 Lean Production System

Lean production system was implemented by McKinsey & Company to reduce the turnaround time of Airbus A320 (Doig et al., 2003). The proposed improvements within their potential reductions of turnaround time could be seen on figure (5.77).

To estimate the average duration and the reliability of the selected turnaround sub processes if the lean production system is implemented by (KQ) at (JKIA) for Boeing 737-300, the same potential reduction in turnaround time of Airbus A20 will be assumed. While the reliability is estimated using the equation of the trend line given in figure (5.76). As could be seen on figure (5.77), there is a potential reduction of duration in unload of passengers from 6:14 to 4:38 which is about 22.15%. This potential reduction of duration will be linked to passengers disembark. The total potential reduction of duration of approval to board, waiting for first passengers to board, load passengers, and waiting for passenger information list from 29:07 to 16:00 which is about 44.54% will be linked to passengers boarding.

The performance of the selected turnaround sub processes is summarized in table (5.5) if the lean production system is implemented by (KQ) at (JKIA).

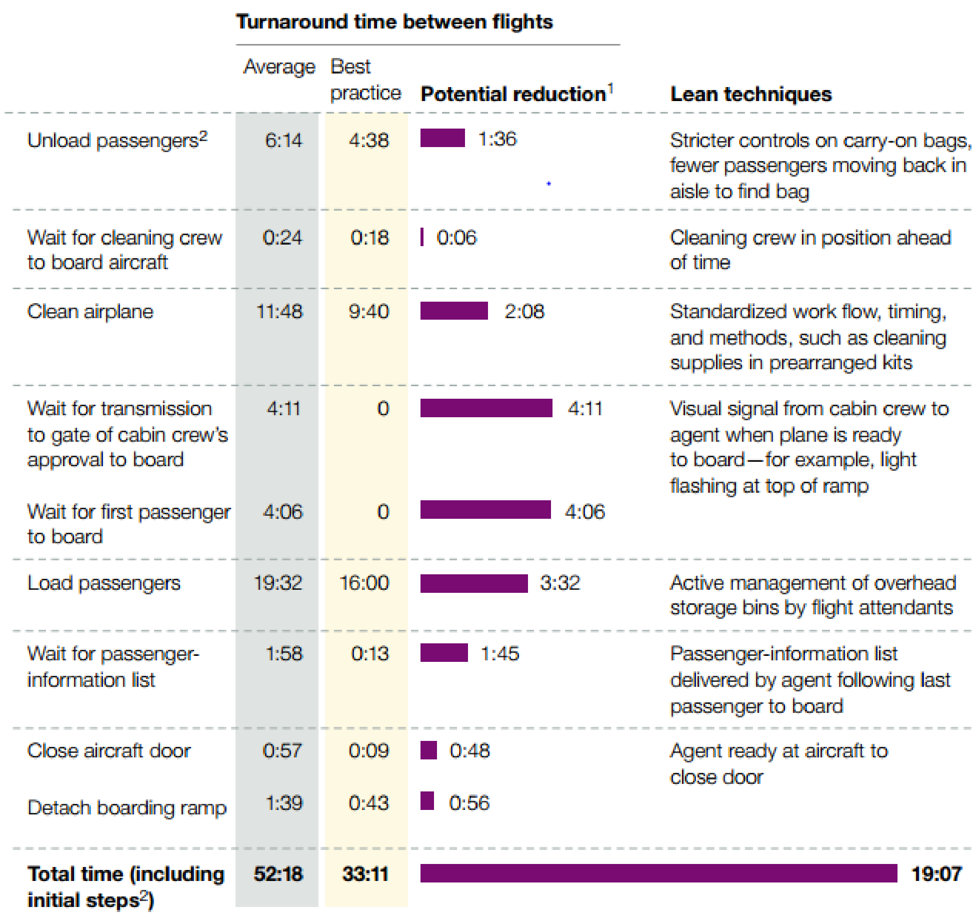


**Figure 5-77: Potential reduction in turnaround of Airbus A320 using lean techniques (Doig et al., 2003)**

**Table 5-5: Performance of the selected turnaround processes using lean production system**

| Turnaround sub process | Type of parking bay | Average duration in min | Reliability in min |
|---|---|---|---|
| **Passengers Disembark** | Remote | 9.37 | 9.29 |
| | Local | 11.21 | 9.91 |
| | Domestic | 8.25 | 8.91 |

| | | | |
|---|---|---|---|
| **Cabin grooming** | Remote (5:00-10:00) | 26 | 13.52 |
| | Local | 19.31 | 12.62 |
| | Domestic | 15.4 | 8.17 |
| **Catering** | Remote | 30.28 | 19.28 |
| | Local | 24.79 | 14.4 |
| | Domestic | 21.07 | 10.97 |
| **Fueling** | Remote (0-1000nm) | 14.3 | 9.76 |
| | Local | 21.2 | 14.85 |
| | Domestic | 16.31 | 9.83 |
| **Passengers boarding** | Remote (5:00-10:00) | 10.99 | 9.84 |
| | Local | 8.5 | 8.99 |
| | Domestic | 6.94 | 8.47 |

Now that the performances of the current states and of the alternatives of the selected turnaround sub processes are determined, they need to be evaluated in order to determine which concept adds as much value for the relevant stakeholders. This will be covered in next section.

## 1.5 Evaluation of Alternatives

In this section, the alternative strategies presented in previous section (5.4), will be evaluated using the value model defined in chapter (4) for each selected turnaround sub process at each type of parking bay at (JKIA).

The current states defined in section (5.3), will be used as a reference state in the value model. As aforementioned, it is assumed that cost, safety, environmental impacts, and comfort level are constant due to unavailability of data. During the evaluation of the alternative strategies of the selected turnaround sub processes, only the turnaround time which is expressed as average duration per a turnaround sub process on the critical path and the reliability which is expressed in term of standard deviation will be considered.

The feasible ranges of the average duration will be considered as the minimum and maximum duration of an average duration of a turnaround sub process. This is according to data of (KQ) 0 and 30.28 min respectively. While of the reliability, the minimum feasible range will be the lowest standard deviation, which is 0 min and the maximum will be the highest standard deviation, which is 19.28 min (see figure (5.75)).

By using the value model defined in chapter (4) (see equation (4.2)), the change in value of the alternative strategies namely, theory of constraints and lean production system are determined relative to the current state for the selected turnaround sub processes at different parking bays at (JKIA). The results are plotted in figure (5.78). In this figure, the green line indicates, the value of the reference state.

As could be seen on figure (5.78), the lean production system adds more value than theory of constraints for passengers disembark and boarding. However, the theory of constraints and lean production system add less value than the current strategy especially for cabin grooming and boarding at domestic parking bay (see figure (5.78). This could be explained by the fact the reliability was estimated by the equation of the trend line in figure (5.76) with a relatively medium correlation of about 35%. For the catering and cabin grooming the theory of constraints adds more value relative to lean production system and to the current state, except for cabin grooming and boarding at domestic parking bays which could be explained by the inaccurate estimation of the reliability. For fueling sub process, there is no change in value for both alternative strategies. This is because both strategies have not added any improvements on fueling sub process.

As a conclusion, it is recommended to implement lean production system in passengers disembark and boarding, and to implement theory of constraints in cabin and catering.

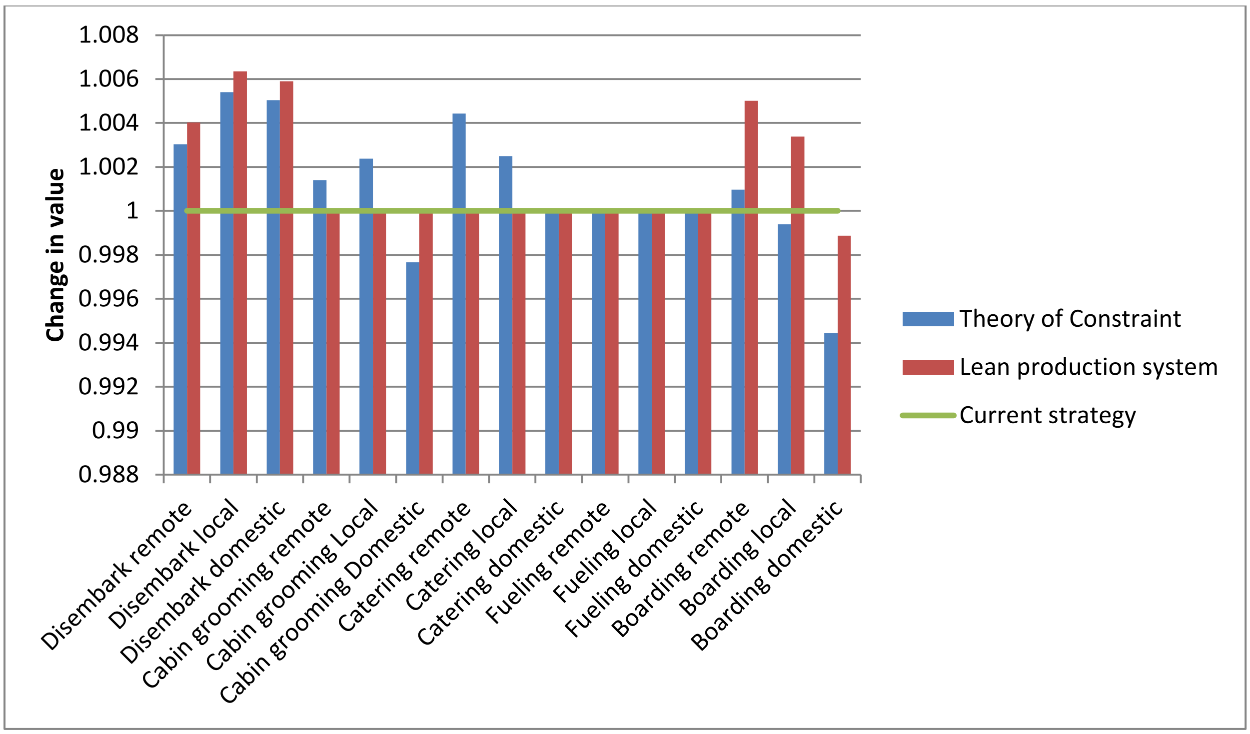


**Figure 5-78: Evaluation of alternative strategies relative to the current state using the value model defined in chapter (4)**

## 1.6 Summary

In this chapter, the current performance of average turnaround time and reliability of turnaround sub processes on critical path of (KQ) at different parking bays at (JKIA) are determined. These turnaround sub processes are: passenger disembark, cabin cleaning, catering, fueling, and passenger boarding. This performance is summarized in figure (5.75). In this figure, the average time of a turnaround sub process on the critical path denotes partially the turnaround time, because the total average time of these turnaround sub processes equals the average turnaround time. While the standard deviation denotes the reliability which is defined as on-time performance of these turnaround sub processes.

In this chapter, two alternatives which are implemented in turnaround process are defined namely, theory of constraints and lean production system. The performance of theory constraints, if it is implemented by (KQ) at different parking bays at (JKIA) of turnaround sub processes on the critical path is summarized in table (5.4). While the performance of lean production system of these turnaround sub processes is summarized in table (5.5).

By using the value model of the turnaround process defined in chapter (4), the performance of these alternatives relative to the current state is evaluated based on added value for the relevant stakeholders. The results of this evaluation are presented in figure (5.78). Based on these results, it is recommended to implement lean production system in passenger disembark and boarding, and to implement theory of constraints in cabin grooming and catering.

# 6 Conclusions and Recommendations

The conclusions of the entire research are provided in section (6.1). The recommendations and future research work are provided in section (6.2).

## 6.1 Conclusions

The main purpose of this thesis was to develop the value model of the turnaround process based on value focused-thinking, specifically, value operations methodology (VOM). With this model the alternative strategies with which the turnaround process can be performed, can be evaluated from the perspective of stakeholders. Eventually, the strategy that adds as much value for the relevant stakeholders within turnaround process can be determined. This has led to the formulation of the research question which is stated as follows:

***"How can a change in value be measured for relevant stakeholders within turnaround process when evaluating new ideas in improving its performance?"***

To answer the main research question, VOM should be implemented in developing the value model of the turnaround process. However, VOM lacked several details and required further developments. The main improvements implemented in VOM are:

- It was proposed to use a new qualitative method defined in section (3.1) to rank and classify stakeholders. This qualitative method is based on numerical method defined by Bennebroek (2012). The qualitative method allows the managers or the decision makers to incorporate their knowledge and expertise to qualitatively judge the stakeholders on potential for cooperation and for threat based on the following factors: control of resources, stakeholder power, likelihood to take opposed action, and history with the target company. This enables the ranking and classification of stakeholders to be more accurate compared to numerical method. Also, this qualitative method is easier and faster to perform, and more self-evident compared to numerical method.
- It was proposed to use a systematic approach in formulating the objectives based on the approach defined by Bennebroek (2012). Also, it was proposed in the last step of this approach to consult the relevant stakeholders, to check whether the formulated objectives are measurable and operational.
- It was proposed to use power series rating scale with base a=2 to compare the objectives in pairwise fashion in AHP (see section (3.3)). This rating scale allows for more answers than the proposed rating scale by Bennebroek (2012), which gives to the stakeholders more space to compare the objectives in pairwise fashion. Also each scale or answer in the proposed rating scale has a specific meaning. This will make it easier for the stakeholders to compare the objectives.
- It is proposed to use AHP twice to recombine different assessments from relevant stakeholders. It will be used to determine the importance of relevant stakeholders relative to their firm or to their organization, and it will be used to determine the weight factors of the formulated objectives according to each relevant stakeholder. Finally, the objective weight factors for all

relevant stakeholders are determined by multiplying vector V by matrix A. Vector V contains the weights which determine the importance of relevant stakeholders relative to the centered firm and matrix A contains the weight factors of objectives according to each relevant stakeholder. With this proposed method, the assessments of different relevant stakeholders are recombined with taking into consideration that their importance relative to the firm is not the same.

With this improved vision of VOM, the value model of the turnaround process is developed. In this value model, five relevant stakeholders are identified namely, airport operator, airline operator, air traffic control, passengers, and national government. Based on the objectives of these relevant stakeholders, the value drivers with turnaround process are identified. These value drivers are: cost, turnaround time, safety, comfort level, environmental impacts, and reliability. Based on literature review and previous MSc researches namely, Repko (2011) and Bennebroek (2012), safety is the most important value driver within turnaround process from the perspective of stakeholders.

The turnarounds performed by Kenya Airways (KQ) at Jomo Kenyatta International Airport of Boeing 737-300 from January till the end of June 2012 are used as a case study in this research. Due to unavailability of data, only the current performance of turnaround time and reliability of the turnaround sub processes on the critical path are determined (see chapter (5)). The results are presented in figure (5.75), in which average duration and standard deviation denote the turnaround time and the reliability of the turnaround sub processes on the critical path respectively. This performance is used a reference state in the value model of the turnaround process.

The performance of the turnaround time and the reliability of two alternatives namely, theory of constraints and lean production system are estimated if implemented by (KQ) at (JKIA). Using the value model of the turnaround process, the performances of these alternatives are evaluated as can be visualized in figure (6.1). Based on these results, it is recommended to implement the solutions proposed by lean production system within passengers disembark and boarding, and to implement the solutions proposed by theory of constraints within catering and cabin cleaning. The reason why lean production system and theory of constraints add less value than the current strategy for cabin grooming and boarding at domestic parking bays, because of the inaccurate estimations of the reliability at domestic parking bays. There is no change in value of fueling sub process at (JKIA). This is because both alternative strategies did not implement any improvements in fueling sub process.

Two hypotheses were stated in chapter (1) namely:

- ***The value model of the turnaround process will improve the decision making process of relevant stakeholders to decide whether an alternative strategy or a new idea is an improvement***
- ***Modifying the current strategy of the turnaround process will enhance its performance***

Both of these hypotheses are accepted. By using the value model of the turnaround process, the decision making process is improved, because if a decision is made the performance of all value drivers within turnaround process can be checked. This can be used as a feedback to the decision making process. The performance of theory of constraints and lean production system as can be seen on figure

(6.1) is better than the performance of the current strategy. This proves the second proposed hypotheses.

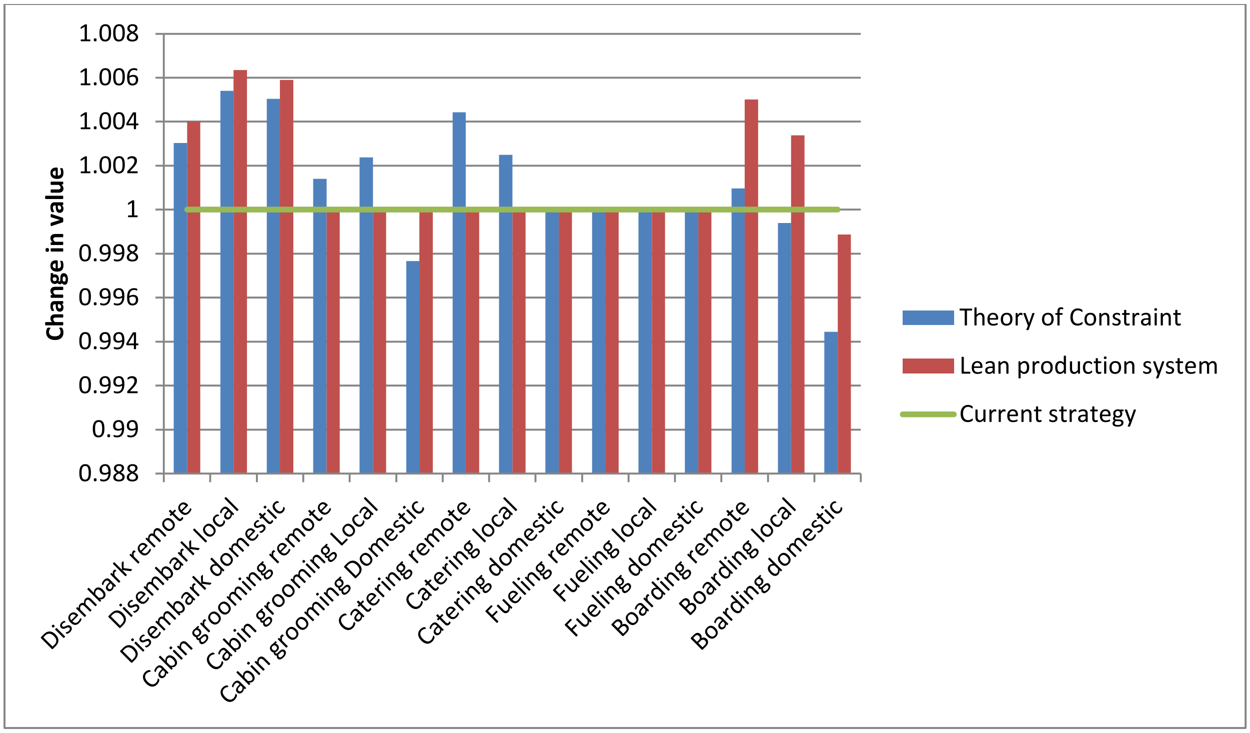


**Figure 6-1: Evaluation of the performance of alternative strategies using the value model of turnaround process**

## 6.2 Recommendations for Further Research

There are number of recommendations made during this research related to value operations methodology (VOM), value model of the turnaround process, and the turnaround process. These recommendations are described in the following subsections.

### 6.2.1 Recommendations on VOM

- The qualitative method used in ranking and classifying the stakeholders. This qualitative method is based on numerical method defined in the research of (Bennebroek, 2012) with number of modifications. However, a full validation of this method is required. Therefore, for further research, a method should be defined which enables the ranking and classification of stakeholders using Savage's approach.
- VOM assumes that objectives are linear and independent. For further research, VOM should also be able to incorporate nonlinear and dependent objectives as well.

### 6.2.2 Recommendations on Value Model of the Turnaround Process

- The value drivers of the turnaround process are determined based on literature review. For further research, it is recommended to conduct interviews with relevant stakeholders in order to compile all their objectives.

- The objectives weight factors for all relevant stakeholders within turnaround process are determined based on literature review and previous MSc researches on VOM at airport. For further research, this should be checked with relevant stakeholders.

### 6.2.3 Recommendations on the Turnaround Process

- More data should be gathered in order to estimate the current performance of safety, cost, environmental impacts, and comfort level.
- The alternative strategies should not only be implemented in turnaround process by estimating only turnaround time, but also to estimate other value drivers in order to be included in the value model for evaluation.
- In the available data of (KQ) at (JKIA), number of external factors should be included. These external factors are: amount of passengers and bags on inbound flight, inbound delay, and amount of fuel tanked during a turnaround process.
- Also in the available data of (KQ), it cannot be seen whether the performed turnaround is a normal or quick turnaround.

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# Appendix A

**Numerical method for ranking the identified stakeholders used in the research of (Bennebroek, 2012)**

This method ranks the identified stakeholders for potential of threat and cooperation and based on the ranking, an identified stakeholder is either classified as supportive, non-supportive, mixed blessings or marginal.

The ranking on both potentials is done using a list of Characteristics reproduced in table (A.1), and then the following equation is used to determine the ranking:

$$\vec{r} = \vec{s}P \quad (A.1)$$

Here, $\vec{s}$ is a vector with a dimension of eleven scalars which is equivalent to the number of characteristics listed in table (A.1) and each scalar is either equal to one or zero. It equals one when a stakeholder does have a characteristic listed in table (A.1) and it equals zero when it does not. The matrix P contains the effects of different characteristics listed in table (A.1) on potential of threat and of cooperation and it is defined as follows:

$$P = \begin{bmatrix} 1 & -1 & 1 & 0 & -1 & -1 & 1 & -1 & 1 & -1 & -1 \\ 1 & 0 & 0 & 0 & 1 & 1 & -1 & -1 & 0 & 1 & -1 \end{bmatrix}^T \quad (A.2)$$

Finally, $\vec{r}$ is the resulting vector containing the total potential for threat and for cooperation.

Now to classify the type of stakeholders a reference of frame is required. This is done by determining a prototype for each type of stakeholders (supportive, non-supportive, mixed blessings and marginal) by using equation (A.1). Here, the only thing that differs is the vector $\vec{s}$ which could be found in table (A.2). When the ranking $\vec{r}_{prototype}$ for each type of stakeholder is found see table (A.2), equation (A.3) is used to determine the distance difference between a stakeholder and the prototype stakeholders (supportive, non-supportive, mixed blessings and marginal). The smallest distance between a stakeholder and a prototype stakeholder determines its classification, for example: if the smallest distance difference is between a stakeholders and the prototype marginal stakeholder then the stakeholder is classified as marginal.

$$\Delta T = \left\| \vec{r} - \vec{r}_{prototype} \right\| \quad (A.3)$$

**Table A.1: List of stakeholder characteristics with their effect on the stakeholder's potential for threat and cooperation**

| | Threat | Cooperation |
|---|---|---|
| **Stakeholders controls key resources needed by the organization** | Increases (1) | Increases (1) |
| **Stakeholder does not control key resources** | Decreases (-1) | None (0) |
| **Stakeholder more powerful than the organization** | Increases (1) | None (0) |
| **Stakeholder as powerful as the organization** | None (0) | None (0) |
| **Stakeholder less powerful than the organization** | Decreases (-1) | Increases (1) |
| **Stakeholder likely to take supportive action** | Decreases (-1) | Increases (1) |
| **Stakeholder likely to take non-supportive action** | Increases (1) | Decreases (-1) |

| | | |
|---|---|---|
| **Stakeholder unlikely to take any action** | Decreases (-1) | Decreases (-1) |
| **Stakeholder likely to form coalition with other stakeholders** | Increases (1) | None (0) |
| **Stakeholder likely to form coalition with organization** | Decreases (-1) | Increases (1) |
| **Stakeholder unlikely to form any coalition** | Decreases (-1) | Decreases (-1) |

**Table (A.2): Ranking and potentials for prototype stakeholders of the supportive, mixed blessings, non-supportive and marginal**

| | **Supportive** | **Mixed blessings** | **Non-supportive** | **Marginal** |
|---|---|---|---|---|
| **Controls key resources** | 1 | 1 | 1 | 0 |
| **Does not control key resources** | 0 | 0 | 0 | 1 |
| **Stakeholder more powerful** | 0 | 0 | 1 | 0 |
| **Stakeholder as powerful as the organization** | 0 | 1 | 0 | 0 |
| **Stakeholder less powerful** | 1 | 0 | 0 | 1 |
| **Likely to take supportive action** | 1 | 1 | 0 | 0 |
| **Likely to take non-supportive action** | 0 | 1 | 1 | 0 |
| **Unlikely to take any action** | 0 | 0 | 0 | 1 |
| **Likely to form coalition with others** | 0 | 0 | 1 | 0 |
| **Likely to form coalition with organization** | 1 | 0 | 0 | 0 |
| **Unlikely to form any coalition** | 0 | 1 | 0 | 1 |
| $\vec{s}$ **vector for each type of stakeholders** | $\vec{s}_{sup}$ | $\vec{s}_{non}$ | $\vec{s}_{mix}$ | $\vec{s}_{marg}$ |
| **Total potential for threat and cooperation:** $\vec{r} = \vec{s}P$ | (-2,4) | (0,0) | (4,0) | (-4,-1) |

# Appendix B

In chapter (3), a number of improvements and modifications have been added to VOM. This appendix presents the improved version of VOM step by step which is used in chapter (4) in building the value model for the turnaround process.

**Identify and select relevant stakeholders**

**Identify firm's all stakeholders:**

1. **Create a long list of stakeholders using the sub-questions from step 2 from the analysis of complex neighborhoods**
2. **Select the stakeholders that fall within the scope of the value model**
3. **Map the relationships among the stakeholders using step 3 from the analysis of complex neighborhoods**

**Select relevant stakeholder**

**1. Rank the identified stakeholders based on their potential for threat and cooperation using qualitative ranking method**

- Test each identified stakeholder based on the influencing factors listed in table (B.1)

Table (B.1): Qualitative ranking of stakeholders based on the influencing factors

| Dimensions | | Threat | Cooperation |
|---|---|---|---|
| **Resources** | Control resources | Significant high | Significant high |
| | Does not control resources | Low | Neutral |
| **Power** | More powerful than the organization | Significant high | Neutral |
| | Equally powerful as the organization | High | Neutral |
| | Less powerful than the organization | Low | High |
| **Likelihood to take action** | Likely to take supportive action | Significant low | Significant high |
| | Likely to take non-supportive action | Significant high | Significant low |
| | Unlikely to take any action | Neutral | Neutral |

| | | | |
|---|---|---|---|
| **Likelihood to form coalition** | Likely to form coalition with others | High | Low |
| | Likely to form coalition with organization | Low | High |
| | Unlikely to form any coalition | Neutral | Low |

- Translate the qualitative ranking as shown in table (B.2)

**Table (B.2): Interpretation of the qualitative ranking**

| Qualitative grading | Strength |
|---|---|
| Significant high | ++ |
| High | + |
| Low | - |
| Significant low | -- |
| Neutral | +- |

- Sum the total positive and negative signs for the potential of threat and of cooperation for each identified stakeholder

**2. Based on their rankings, classify the stakeholders in one of the four categories from Savage's approach**

- **Supportive**: the total number of positive signs is larger than total number of negative signs for cooperation and the total number of negative signs is equal to or larger than the total number of positive signs for threat
- **Non-supportive**: the total number of negative signs is equal to or larger than the total number of positive signs for cooperation and the total number of positive signs is larger than the total number of negative signs for threat
- **Mixed blessings**: the total number of positive signs is larger than the total number of negative signs for both cooperation and threat
- **Marginal**: the total number of negative signs is equal to or larger than the total number of positive signs for both cooperation and threat

**3. Select supportive, non-supportive and mixed blessings stakeholders as relevant stakeholders**

<u>**Formulate set of objectives**</u>

1. Create a long list of objectives for each relevant stakeholder
2. Omit the objectives that are unrelated to the research scope
3. Structure the objectives using objective tree

4 Select the right level of abstraction using the following list
   - **Essential:** All objectives indicate the consequences in terms of the fundamental reasons for interest in the decision situation.
   - **Controllable:** the consequences of the decision are only influenced by the choice of alternatives as opposed to some other mechanism that is not included.
   - **Complete:** All fundamental aspects of the consequences of the alternatives have been included.
   - **Non-redundant:** the set of fundamental objectives should not contain similar items in order to avoid double-counting of the consequences of the alternatives

5 The selected objectives should be characterized by the following three features else they should be omitted or redefined:
   - Decision context
   - Object
   - Direction of preference (reduce or increase)

6 The selected objectives should be checked with the following characteristics
   - **Decomposable:** this allows objectives to be treated separately in the analysis.
   - **Concise:** the set of objectives should not contain more items than necessary to the analysis
   - **Understandable:** All fundamental objectives should be easily interpreted by those involved in the decision making process. This facilitates communication and enhances insights.

7 The selected objectives should be checked with the following characteristics by consulting the relevant stakeholders
   - **Measurable:** the objectives are defined precisely and specify the degrees to which objectives may be achieved
   - **Operational:** The requirements the objectives pose on information gathering for the analysis are reasonable.

**<u>Determine objectives weight factors using AHP</u>**

**1. Perform AHP to determine the weights of relevant stakeholders which determines their importance relative to the centered firm**

a. Compare the importance of relevant stakeholders in a pair-wise fashion using power series rating scale with the base a=2 as follows:

- $\frac{Mixed\ blessing}{Supportive} = more\ important = a^2 = 4$
- $\frac{Mixed\ blessing}{Nonsupportive} = slightly\ more\ important = a^1 = 2$
- $\frac{Nonsupportive}{Supportive} = slightly\ more\ important = a^1 = 2$
- $\frac{Nonsupportive}{NonSupportive} = \frac{supportive}{Supportive} = \frac{Mixed\ blessing}{Mixed\ blessing} = equally\ important = a^0 = 1$
- $\frac{supportive}{Mixed\ blessing} = less\ important = a^{-2} = \frac{1}{4}$

- $\frac{Nonsupportive}{Mixed\ blessing} = slightly\ less\ important = a^{-1} = \frac{1}{2}$
- $\frac{supportive}{NonSupportive} = slightly\ less\ important = a^{-1} = \frac{1}{2}$

b. Collect the results of these comparisons in a reciprocal comparison] see the following equation

$$M = \begin{bmatrix} 1 & \frac{wa}{wb} & \dots & \frac{wa}{wn} \\ \frac{wb}{wa} & 1 & \dots & \frac{wb}{wn} \\ \vdots & & \ddots & \vdots \\ \frac{wn}{wa} & \frac{wn}{wb} & \dots & 1 \end{bmatrix}$$

c. Use the largest eigenvalue from this matrix and related normalized eigenvector to determine the weights for the relevant stakeholders

d. Compute the consistency ratio of eigenvalue to check the consistency of the comparison matrix which is calculated using the following equation

$$CR = \frac{CI}{RI} = \frac{\frac{\lambda - n}{n-1}}{RI}$$

**2. Perform AHP to determine the weights of objectives according to each relevant stakeholder**

a. Compare the objectives in a pair-wise fashion according to each relevant stakeholder using power series rating scale with the base as=2 as follows:

- $a^3 = 2^3 = 8 \rightarrow significant\ more\ important$
- $a^2 = 2^2 = 4 \rightarrow more\ important$
- $a^1 = 2^1 = 2 \rightarrow slightly\ more\ important$
- $a^0 = 2^0 = 1 \rightarrow equally\ important$
- $a^{-1} = 2^{-1} = \frac{1}{2} \rightarrow slightly\ less\ important$
- $a^{-2} = 2^{-2} = \frac{1}{4} \rightarrow less\ important$
- $a^{-3} = 2^{-3} = \frac{1}{8} \rightarrow significant\ less\ important$

b. Collect the results of these comparisons in a reciprocal comparison matrix according to each relevant stakeholder see the following equation

$$M = \begin{bmatrix} 1 & \frac{wa}{wb} & \dots & \frac{wa}{wn} \\ \frac{wb}{wa} & 1 & \dots & \frac{wb}{wn} \\ \vdots & & \ddots & \vdots \\ \frac{wn}{wa} & \frac{wn}{wb} & \dots & 1 \end{bmatrix}$$

c. Use the largest eigenvalue from this matrix and related normalized eigenvector to determine the weight factors for the objectives according to each relevant stakeholder

d. Compute the consistency ratio of eigenvalue to check the consistency of the comparison matrix which is calculated using the following equation

$$CR = \frac{CI}{RI} = \frac{\frac{\lambda - n}{n-1}}{RI}$$

3. **Determine the objective weight factors for all relevant stakeholders by multiplying vector V by matrix A. Vector V contains the weights which determine the importance of relevant stakeholders relative to the centered firm and matrix A contains the weight factors of objectives according to each relevant stakeholder.**

**<u>Formulate set of attributes</u>**

1 The attributes must be defined such that data required is available in the correct format (here consultation is required with the relevant stakeholders)
2 The selected attributes should adhere to the following list which is proposed by (Keeney, 1992)
   - **Unambiguous**: “a clear relationship exists between consequences and description of consequences using the attribute”
   - **Comprehensive**: the attribute levels cover range of possible consequences for corresponding objective, and value judgment implicit in the attribute are reasonable
   - **Direct**: the attributes levels directly describe the consequences of interest
   - **Operational**: the information necessary to describe consequences can be obtained and value tradeoffs can reasonably be made
   - **Understandable**: Consequences and value tradeoffs made using the attribute can readily be understood and clearly communicated

**<u>Determine attributes weight factors</u>**

1.Compare the attributes in a pair-wise fashion according to their importance for the achievement of the objective using power series rating scale with the base equal 2 (a=2) as follows:

- $a^3 = 2^3 = 8 \rightarrow significant\ more\ important$
- $a^2 = 2^2 = 4 \rightarrow more\ important$
- $a^1 = 2^1 = 2 \rightarrow slightly\ more\ important$
- $a^0 = 2^0 = 1 \rightarrow equally\ important$
- $a^{-1} = 2^{-1} = \frac{1}{2} \rightarrow slightly\ less\ important$
- $a^{-2} = 2^{-2} = \frac{1}{4} \rightarrow less\ important$

$a^{-3} = 2^{-3} = \frac{1}{8} \rightarrow significant\ less\ important$

2. Collect the results of these comparisons in a reciprocal comparison matrix see the following equation

$$M = \begin{bmatrix} 1 & \frac{wa}{wb} & \dots & \frac{wa}{wn} \\ \frac{wb}{wa} & 1 & \dots & \frac{wb}{wn} \\ \vdots & & \ddots & \vdots \\ \frac{wn}{wa} & \frac{wn}{wb} & \dots & 1 \end{bmatrix}$$

3. Use the largest eigenvalue from this matrix and related normalized eigenvector to determine the weight factors for attributes

4. Compute the consistency ratio of eigenvalue to check the consistency of the comparison matrix which is calculated using the following equation

$$CR = \frac{CI}{RI} = \frac{\frac{\lambda - n}{n-1}}{RI}$$

**Combine all into one model using the following equations**

$$\Delta V(V1, V2, \dots, Vn) = \sum_{j=1}^{n} \lambda_j \frac{V_{j_1}}{V_{j_0}}(x1, x2 \dots xq)$$

$$\frac{V_{j_1}}{V_{j_0}}(x1, x2 \dots xq) = \sum_{j=1}^{m} \omega_j \frac{(x_{ij})1}{(x_{ij})0}$$

Here, $\lambda_j$ represents objectives weight factors, $\omega_j$ represents attributes weight factors, (V1, V2,…,Vn) represent the set of objectives and (x1,x2,…,xq) represent attributes. This yields three decisive rules:

- $\Delta V > 1$, alternative creates value relative to the reference
- $\Delta V$= 1, alternative has equal value as reference
- $\Delta V < 1$, Alternative reduces value relative to the reference

During calculations two rules should be applied:

- Apply consistent ratios
- The attributes should be defined in a feasible range

# Appendix C

**Raw data from FTA Database**

Raw data received from (KQ) contains several columns. Each column contains the following data information

- Date
- Activity (e.g. boarding sub process)
- Outbound flight number
- Aircraft type
- Aircraft registration number
- Destination of the outbound flight
- ETA of the flight
- ATD of the flight
- Expected start of activity
- Expected end of activity
- Actual start of activity
- Actual end of activity
- Duration of activity
- STD of the flight
- Passengers on board
- Gate
- Bay
- K1 (name of turnaround coordinator)
- Amount of bags on board
- Turnaround type