Evaluating Aircraft Turnaround Process in the Framework of Airport Design and Airline Behaviour

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ABSTRACT

This dissertation study attempts to identify the problems pertaining to the process of aircraft turnaround and ground handling. There are many variables that influence the process of aircraft turnaround, each of them contributing to the process in various ways and to different extents. Handling operations and aircraft turnaround are not independent of the facilities of the airport, as well as the airline itself. Therefore, this research study investigates the structure of the handling company, airline behaviours, as well as airport facilities, so as to define their role in aircraft turnaround.

Unfortunately, the unfolded chain of actions required in ground handling makes it difficult to analyze exactly which factors cause and also magnify the handling of delays. Therefore, decomposing the problem of delay could shed light on the characteristics of turnaround delays, as well as their patterns. There is currently an information and knowledge gap regarding the standards for handling operations and aircraft turnaround. This is because airlines usually tend not to picture and classify delay patterns in handling operations. Even though there are spoken approaches, there is no systematic way of picturing the correlations between handling delays and facts. In this study, the author is to identify the dominant patterns of effects on handling delays and correlations between causal effects, to see which combinations have the greatest impacts on delays and impact of airport facilities to handling delays.

This dissertation employs a mixed method design, first to picture trends and pattern of delays in Lisbon airport by Multiple Correspondence Analysis (MCA). A multiple correspondence analysis is employed by assigning a value to each category of effect, using the data from a sample of airlines offering services from Lisbon Airport, Portugal.

The findings suggest that a handling company can cause different delays for different airlines, depending on different reasons related to airport facilities. Those delay related problems could be local to the airport or to the airline. In addition to other delay causes,

handling companies with combinations of airport related problems enhance the delays of airlines.

RESUMO

Este tese procura identificar os problemas associados aos processos de viragem e aterragem de aviões. Existem diversas variáveis que influem no processo de viragem do avião, cada um deles contribuindo para este processo segundo diferentes formas e níveis de influência. As operações de manobra e viragem do avião não são independentes das instalações do aeroporto, assim como da própria companhia aérea. Por conseguinte, esta pesquisa investiga a estrutura da empresa de manobras, os comportamentos da companhia aérea, assim como as instalações aeroportuárias, de forma a definir o seu papel no processo de viragem dos aviões.

Infelizmente, o desdobramento na sequência de acções requeridas para as manobras no solo dificultam a análise exacta de quais os factores em causa e também potencia a ocorrência de atrasos nesta manobras. Consequentemente, dissecar as causas dos atrasos nas manobras de viragem poderá lançar luz sobre as características dos mesmos, assim como sobre os seus padrões de ocorrência. Actualmente, existe um desfasamento de informação e conhecimento quanto aos standards para operações de manobra e viragem de aviões. Isto prende-se com o facto de que as companhias aéreas normalmente tendem a não registar e classificar os padrões de atraso nas operações de manobra. Muito embora existam abordagens verbais, não existe qualquer forma sistemática de registar as correlações entre os atrasos nas manobras e os factos que os causam. Neste estudo, o autor propõe-se a identificar padrões dominantes no atraso de manobras e as suas correlações causais, de forma a perceber que combinações terão os maiores impactos nos atrasos, assim como os impactos das instalações aeroportuárias nos atrasos das operações de manobra.

Esta tese recorre a uma metodologia mista, primeiramente para registar tendências e padrões de atraso no aeroporto de Lisboa através de uma análise de correspondências múltiplas (ACM). Uma análise de múltipla correspondência é empregue através da atribuição de um valor a cada categoria de efeitos, utilizando dados de uma amostra de companhias aéreas oferecendo serviços a partir do aeroporto de Lisboa, Portugal.

Os resultados sugerem que uma empresa de manobras pode causar diferentes atrasos para diferentes companhias aéreas, dependendo de diversas razões relacionadas com as instalações aeroportuárias. Tais problemas relacionados com os atrasos podem ser intrínsecos ao aeroporto ou à companhia aérea. Conjuntamente com outras causas de atrasos, empresas de manobras com combinações de problemas relacionados com o aeroporto potenciam os atrasos das companhias aéreas.

1. INTRODUCTION

Air transportation is a growing sector that carried over 2.2 billion passengers and 41 million tonnes of freight in 2008 (International Civil Aviation Organization, 2008). “Air transport industry generates 32 million jobs globally (through direct, indirect, induced and catalytic impacts) with the US$ 3,560 billion global economic impact, which is equal to 7.5% of world Gross Domestic Product (GDP). The world's 900 airlines have a total fleet of nearly 22,000 aircraft. They serve some 1,670 airports through a route network of several million kilometers managed by around 160 air navigation service providers” (Air Transport Action Group, 2008).

Air transportation is also an increasingly competitive industry as governments have gradually removed economic regulations and allowed market forces to determine what services are provided, by which airlines, and at what price. As the competition fiercely increases, airlines have experienced more pressure to provide better service with a lower price in a shortest time to survive in the market. Schedule reliability and punctuality have become one of the most important performance indicators for airlines, since tangible consequences of lacking operational reliability in airline schedules results in delays and increasing operating costs. If delays are transformed into monetary scales, it is estimated that a top-10 European carrier bears €100 to €400 million of delay costs annually in 2000, which significantly degrades the profitability of airline business, as well as its business competitiveness (Niehues *et al*., 2001). The empirical studies show that an airline’s on time performance affects the airline’s market share related to switching rate of passengers from one airline to another according to their previous flight delay experience, and passengers who experienced delays in their flights attempt to change their flight more in comparison with the ones who did not (Suzuki, 2000). Additionally, airlines have to endure quite considerable sanctions when their flights are delayed. For instance, an airline must provide meals and refreshments, as well as hotel accommodation and refund tickets, depending on the delay duration and haul type (Reichmuth, 2005). Qantas, the Australian carrier, estimates that 1% improvement of schedule punctuality will bring Qantas an additional $15 million profit in a year (Guo, 2005). Airlines report that their direct and indirect delay costs typically range from 0.6 % to 2.9 % of revenue, depending on the size and type of operation, as well as the method of calculation. Research on the performance of major airlines suggests that there is a positive correlation between on-time performance and operating profit, as shown in Figure 1-1(Niehues *et al*., 2001).

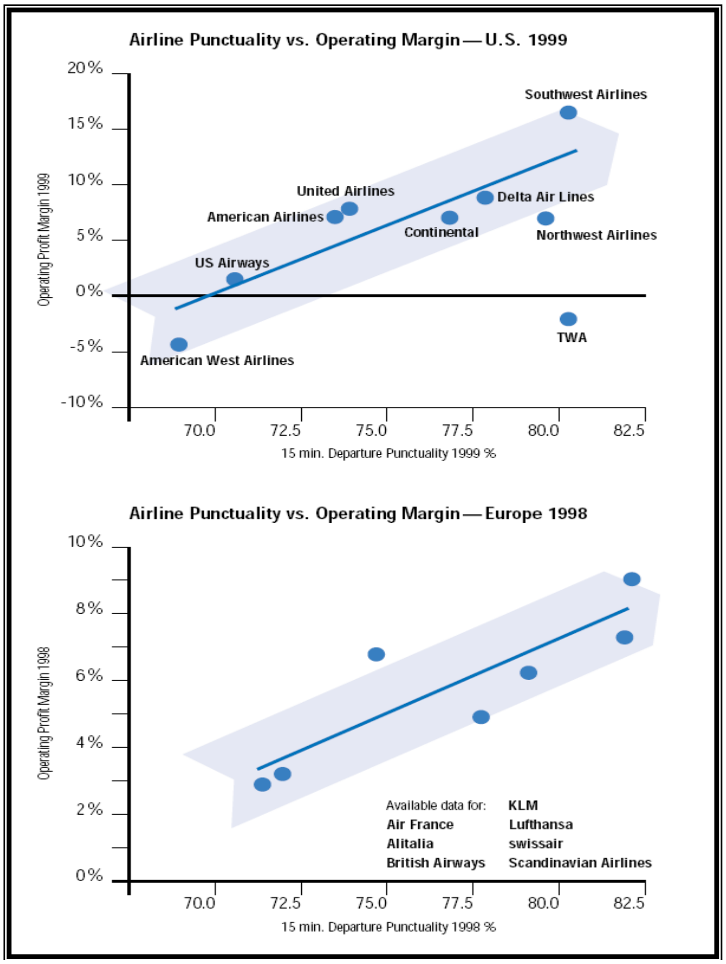

Figure 1-1 Airline Punctuality versus Operating Margin

Source: Niehues *et al*. (2001)

As indicated in Figure 1-1, major airlines both in the U.S and in Europe, with average punctuality rates, have been more profitable than those with lower than average punctuality performance. In other words, punctual airlines appear to be more profitable, with each percentage point improvement in punctuality resulting in a potential profit improvement of €4-16 million, depending on the size of the airline (Niehues *et al*., 2001).

Punctuality is the “end product” of a complex interrelated chain of operational and strategic processes, carried out by different stakeholders during different time phases and at different levels (local/ network) up to the day of operation (Eurocontrol, 2005a). The advantages of maintaining a high turnaround punctuality and reliability are to improve schedule punctuality, to utilize aircraft fleet, to minimize the operational disturbance at terminals and to maximize the utilization of airline resources (Wu and Caves, 2004b).

The US Department of Transportation describes on-time flight as the flights which are operated within 15 minutes of the scheduled time shown in the carriers’ computerized reservation system. Therefore, all the publications of aviation associations about the delays only indicate the delays which are more than 15 minutes. In other words, even if there is a 15 minute delay in the departure of an airline, it is still considered as on-time. This evaluation makes no sense, especially in the domestic or intra European routes where a 15 minute-delay in flight of only 60 minutes is quite considerable, and each minute of delay requires special attention.

In 2000, 23% of delays in airlines occurred due to airport facilities, while 77% of the delays are attributable to the en-route phase of a flight in Europe. This ratio has changed dramatically in recent years, and in 2003, 46% of delays took place at airports while the delays attributable to en-route decreased to 54% (Griffins, 2005a), airport infrastructure problems accounting for half of the congestion problems which also impacted the work pattern in ground handling. Towards the end of 2008, as shown in Figure 1-2, two very important delay reasons appeared, mainly called aircraft turnaround delays, which are aircraft and ramp handling, and passenger and baggage handling, with a total of 18% (Eurocontrol, 2008).

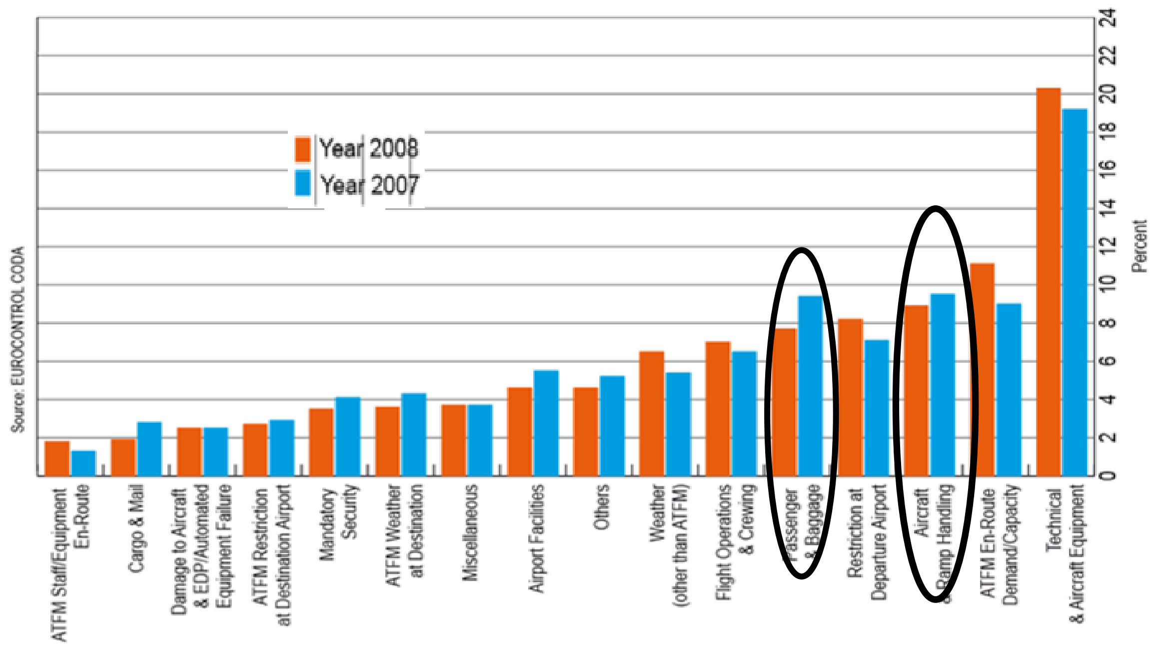

Figure 1-2 Delay causes grouped by IATA Codes in Europe
Source: Eurocontrol (2008)

Given the fact that a one-minute delay cost in ground results in approximately 50 €, while in the air it is 70 € (Eurocontrol, 2004)[1], it is of paramount importance that the airlines come up with ways to deal with the delays. The fuel cost, cost of flight crew, cost of leased aircraft, airport expenses and also the unmeasured costs (e.g. costumer complaints and disloyalty cost) are some of the examples that airlines have to cope with as a result of an increase in the delays.

Delays in the handling chain not only provoke impacts on the quality of the service experienced by the passengers, but also affect the operational efficiency, and as a result, the costs of the airline. Delays resulting from ground handling comprise one of the highest costs of the airlines, despite the fact that handling related delays are a cheaper and easier way of reducing departure delays, and consequently the costs, when compared to

[1] For more detailed cost calculation see Eurocontrol Commission Report prepared by University of Westminster.

the difficulty of reducing other reasons for delays, such as weather conditions and air traffic control (ATC). Various costs that European airlines have to endure are presented in Figure 1-3, while cost classification of US Airlines is presented in Figure 1-4.

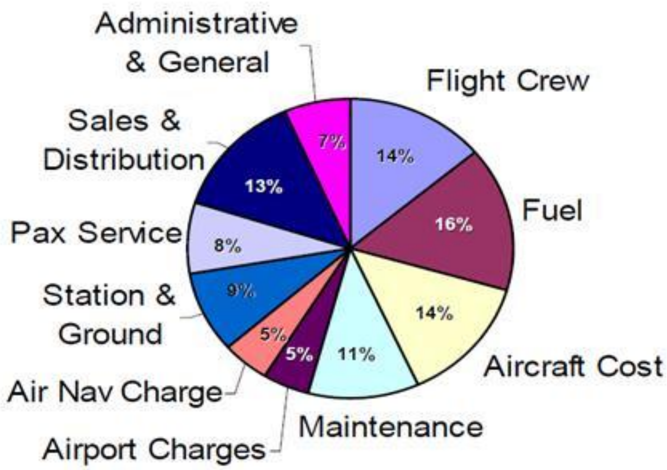

Figure 1-3 Cost Distribution of European Airlines
Source: Smith (2004)

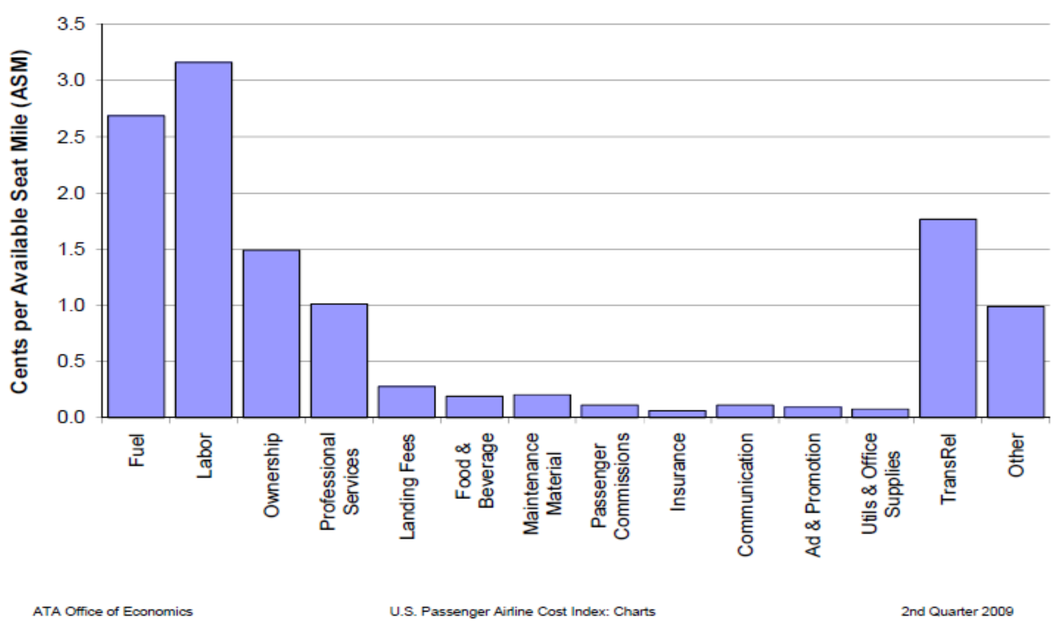

Figure 1-4 Cost Distribution of US Airlines
Source: Air Transport Association (2009)

Airline delays result from various reasons, and ground handling is only one of them. Handling involves a wide range of operations that vary from cleaning to supervision, and catering to maintenance, and their efficient provision is critical in optimizing aircraft turnaround. “The aircraft turnaround process separates an aircraft from its load (e.g. passengers, baggage, cargo and mail) on arrival and combines it with its load prior to departure” (International Air Transport Association, 2007). It also includes complementary services such as catering and cleaning.

There are many potential disruptions in the chain of actions entailed in an aircraft’s efficient turnaround, and these may be inhibited by late arrivals, and airport and air traffic control (ATC) delays that shorten the time available for turnarounds. The characteristic problem of handling delays is that there are many facts influencing the handling process, as well as the lack of procedures to monitor the interaction between these facts in limited aircraft turnaround period.

The differences between the planned aircraft and the committed aircraft turnarounds result usually from the delays in arrival at most of the airports. Congested airports that became bottlenecks in the hub-and-spoke systems favoured by many airlines have network impacts on handling operations further down the line, with knock-on effects on the punctuality of other services. Nevertheless, regardless of whether an airport is a hub or not, the form of airport ownership (e.g. public or private), as well as its size, design and condition, all pose challenges in the minimization of ground handling delays.

The overall efficiency of air transport is thus dependent on the smooth operations of all elements in this aviation supply chain. Airlines, however, are part of a larger transport services supply sector that embraces, amongst others, airports, air navigation services, air frame and aero engine manufacturers, and sophisticated information and ticketing systems.

Michael Porter's value chain[2] is a good example of showing the location of the ground handler in airline operations. Porter's value chain is based on the process view of organizations as a system, made up of subsystems each with inputs, transformation processes and outputs. Each activity in different levels adds some value to the end product (output).

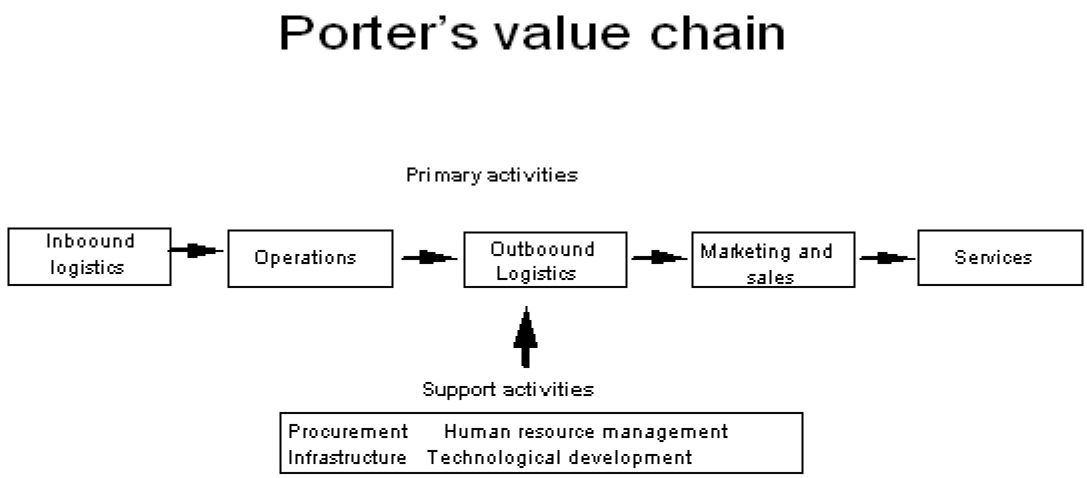

Figure 1-5 Value Chain of Porter
Source: Porter, 1985

On a smaller scale, if Porter's value chain is applied to the airline business, the inputs can be assigned as baggage and passenger, while ground handling can be assigned as "operation", and "outbound logistic" processes which transforms the airline input to be an output as an on-time departure flight. In the operation chain, ground handling is

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[2] According to Porter (1985), the primary activities in value chain are:

1. **Inbound Logistics** - involve relationships with suppliers and include all the activities required to receive, store, and disseminate inputs.
2. **Operations** - are all the activities required to transform inputs into outputs (products and services).
3. **Outbound Logistics** - include all the activities required to collect, store, and distribute the output.
4. **Marketing and Sales** - activities inform buyers about products and services, induce buyers to purchase them, and facilitate their purchase.
5. **Service** - includes all the activities required to keep the product or service working effectively for the buyer after it is sold and delivered.

Secondary activities are:

1. **Procurement** - is the acquisition of inputs, or resources, for the firm.
2. **Human Resource management** - consists of all activities involved in recruiting, hiring, training, developing, compensating and (if necessary) dismissing or laying off personnel.
3. **Technological Development** - pertains to the equipment, hardware, software, procedures and technical knowledge brought to bear in the firm's transformation of inputs into outputs.
4. **Infrastructure** - serves the company's needs and ties its various parts together, it consists of functions or departments such as accounting, legal, finance, planning, public affairs, government relations, quality assurance and general management.

responsible for collecting the bags from chutes and loading them on aircraft or bringing them to passenger waiting at the baggage reclaim area. In outbound logistic, ground handling is in charge of processing the passenger through check-in and boarding, simultaneously with their luggage. The efficiency level of service standards that handling activities are carried out in each level of the chain determines the overall quality of the service supplied to passenger at the end.

1.1 Research Objective

The aim of this study is twofold: first, to identify the main factors affecting turnaround delays, and second, to monitor the interaction between these factors within the frame of airport conditions and handling agent.

In this respect, the main goal of this dissertation is to develop a better understanding of the controllable facts that have an impact on aircraft turnaround and to underline the importance of airport in handling operations. Therefore, the case of Lisbon Airport will be explored in order to achieve the purposes of this study. The findings of this study will provide insights into possible measures, as well as solutions that can be taken to diminish the delays.

1.2 Methodology

More specifically, in order to gain insight into the nature of delays in ground handling operations, the departure and delay data from the handling company, Ground Force (formerly SPDH) was analyzed by Multiple Correspondence Analyses (MCA). MCA basically builds on correspondence analysis, a well-established procedure that has its pedigree in the work of Hirshfield (1935). It relies on a statistical visualization method for depicting associations between levels in a two-way contingency table. MCA is a descriptive/exploratory technique designed to analyze simple two-way and multi-way tables containing some measure of correspondence between the rows and columns. This technique has a number of attractive features that appeal to the purposes of this dissertation. For instance, it produces a visual representation of the relationships between the categories of the rows and the columns in the same space. The technique is also versatile and can be used with frequency data, with percentages, with data in the form of ratings and with heterogeneous data sets. In terms of output and insights, MCA can suggest unexpected dimensions and relationships in the tradition of exploratory data and, although model-free itself, the results of correspondence analysis often provide a useful preliminary analysis to more structured and traditional multivariate modelling.

Multiple correspondence analysis (MCA), also known as homogeneity analysis (HOMALS) or dual scaling, produces a solution in which objects within the same category are plotted close together, and objects in different categories are plotted far apart. Each object is as close as possible to the points of categories that apply to the object. In this way, the categories divide the objects into homogeneous subgroups. Variables are considered homogeneous when they classify objects in the same categories into the same subgroups.

Departure data of four European scheduled airlines using Lisbon Airport – Air France (AF), Iberia (IB), Lufthansa (LH), and TAP (TP) – is extracted for the period 2000 to 2004 from the SPDH handling company data, which provide details of delays, including handling. The most frequently experienced handling delays are extracted to make the data-base manageable. Using the extracted data, interpretation of dimensions through quantification of the categories and spatial presentation of categories was used for diminishing delays.

1.3 An Overview of the Dissertation

This dissertation focuses on handling operations, as well as delays in handling by considering the intertwined structure of the airline-handler-airport relationship. In this respect, it relies on the premise that there are several facts influencing the delays in handling and there is interaction between them. Each possible factor is examined under different subtitles. In order to strengthen the theoretical framework, the departure information of four European scheduled legacy airlines flying from Lisbon Airport is used to clarify the airport handling relationship and to see the correlation between them for each airline.

In this respect, this dissertation is composed of six chapters. Chapter I, as an introduction, designates the research objectives, as well as a brief description of the methodology.

Chapter II presents the structure, problems and the delays in ground handling. Operational tasks of ground handling, some of the quality and performance measurement programs and their application in ground handling companies will be explained in this chapter. This part also discusses the aircraft turnarounds and punctuality relations. Importance of punctuality and how to use turnaround as a tool to obtain punctual departures will also be mentioned.

Chapter III traces the airports and their conditions in terms of handling operations. In this chapter, the effects of airports on the handlers, as well as on the delays will be explained. The design and facilities of airports (only the handling parts) and handling-airport relationship in delays will be discussed.

In Chapter IV, there is data mining of flights which were served by handling agent, SPDH. Before seeing the correlation of variables and facts in the following chapter, in this chapter, each variable will be decomposed and explained in order to create a concrete base for the analysis.

In Chapter V, the statistical tool that was employed to examine the data, Multiple Correspondence Analyses (MCA), is explored to identify the dominant fact patterns on delays and correlation between these facts in categories to see which combination of facts has a bigger impact on handling delays for sample airlines that SPDH had served between the years 2000 and 2004. Then, in this chapter, the analysis delves further into a certain element, departure time, which has the biggest impact on delays at Lisbon airport. To fulfil the conclusion of the dissertation, an analytical approach was used by examining the dataset from SPDH to reveal the interaction between Lisbon airport, congestion, amount of traffic and handling delays, and deduce the reasons underlying the delays of selected airline, TAP.

Chapter VI elaborates on the main conclusions derived in this dissertation, including the integrations of the theoretical framework and the results discussed in previous chapters. It further provides suggestions for reducing the delays at Lisbon airport, as well as recommendations for efficient practice of operational process in ground handling so as to have more punctual departures.

2. GROUND HANDLING

2.1 Definition of Ground Handling

“The term 'ground handling' refers to a complex series of processes that are required to separate an aircraft from its load (passengers, baggage, cargo and mail) on arrival at an airport and combine it with its load prior to next departure” (International Air Transport Association, 2010). Ground handling not only serves as a crucial sub-system of an airline, as well as all airport operations, but also “plays a paramount role in the delivery of the airline’s final service to the customer” (Bonus 1986, cit. by Fuhr, 2006).

In the past, airlines used to perform handling services themselves, having their own personnel and equipment. With deregulation and the need to be more cost conscious, airlines began ‘unbundling’ those activities that could be performed more cheaply by specialist third party companies. This has often included the outsourcing of ground handling activities to specialist companies[3], to another airline that enjoys a comparative advantage in handling or to an airport. These ground handling services are listed in International Air Transport Association (IATA) *Airport Handling Manual* and constitute eleven main categories of activities along with their subcategories, as follows:

Ground handling and supervision

- Representation and liaison services with local authorities or any other entity, disbursements on behalf of the airport user and provision of office space for its representatives;
- Load control, messaging, and telecommunications;
- Handling, storage, and administration of unit load devices;

[3] Some of the main specialist suppliers of such services in Europe are Menzies, Globalia and Fraport.

- Any other supervision services before, during or after the flight, and any other administrative service requested by the airport user.

Passenger handling

Passenger handling comprises any kind of assistance to arriving, departing, transfer or transit passengers, including checking tickets and travel documents, registering baggage and carrying it to the sorting area.

Baggage handling

Baggage handling comprises handling baggage in the sorting area, sorting it, preparing it for departure, loading it on to and unloading it from the devices designed to move it from the aircraft to the sorting area and vice versa, as well as transporting baggage from the sorting area to the reclaim area.

Freight and mail handling

- For freight: Physical handling of export, transfer and import freight, handling of related documents, customs procedures and implementation of any security procedure agreed between the parties or required by the circumstances;
- For mail: Physical handling of incoming and outgoing mail, handling of related documents and implementation of any security procedure agreed between the parties or required by the circumstances.

Ramp handling

- Marshalling the aircraft on the ground at arrival and departure;
- Assistance to aircraft packing and provision of suitable devices;
- Communication between the aircraft and the air-side supplier of services;

- The loading and unloading of the aircraft, including the provision and operation of suitable means, as well as the transport of crew and passengers between the aircraft and the terminal, and baggage transport between the aircraft and the terminal;
- The provision and operation of appropriate units for engine starting;
- The moving of the aircraft at arrival and departure, as well as the provision and operation of suitable devices;
- The transport, loading on to and unloading from the aircraft of food and beverages.

Aircraft services

- The external and internal cleaning of the aircraft, and the toilet and water services;
- The cooling and heating of the cabin, the removal of snow and ice, the de-icing of the aircraft;
- The rearrangement of the cabin with suitable cabin equipment, the storage of this equipment.

Fuel and oil handling

- The organization and execution of fuelling and defueling operations, including the storage of fuel and the control of the quality and quantity of fuel deliveries;
- The replenishing of oil and other fluids.

Aircraft maintenance

- Routine services performed before flight;
- Non-routine services requested by the airport user;
- The provision and administration of spare parts and suitable equipment;
- The request for or reservation of a suitable parking and/or hangar space.

Flight operations and crew administration

- Preparation of the flight at the departure airport or at any other point;
- In-flight assistance, including re-dispatching if needed;
- Post-flight activities;
- Crew administration.

Surface transport

- The organization and execution of crew, passenger, baggage, freight and mail transport between different terminals of the same airport, but excluding the same transport between the aircraft and any other point within the perimeter of the same airport;
- Any special transport requested by the airport user.

Catering services

- Liaison with suppliers and administrative management;
- Storage of food and beverages and of the equipment needed for their preparation;
- Cleaning of this equipment;
- Preparation and delivery of equipment as well as of bar and food supplies.

These activities are sometimes provided by a single handling agent, or each of them can be the responsibility of different authorities. This situation is the root of the complex nature of handling operations. For example, some services such as catering, aircraft maintenance or fuelling can be provided by external companies, while passenger processing can be handled by the airline itself or by independent handling agents, and ramp handling can be handled by Airport Company itself. An airline may also use different combinations of in-house and outside suppliers at different airports[4].

[4] For example Easy jet does its ramp handling at London Luton airport on its own via Joint Venture Company, while uses other Ground handling companies in other airports. BA outsourced the ground

Handling services can be carried out mainly through the two subsections: passenger handling and baggage handling (ramp handling). Passenger handling includes all the activities for processing passengers and baggage through the passenger terminal to aircraft on gate, while the ramp handling is the activities that take place in the apron area, such as baggage loading/unloading, cabin services, cleaning, supplying external power units, etc. Although passenger handling is mostly performed by airlines, ramp handling and other peripheral services are performed by handlers. In some cases, airlines devolve all handling services, including the passenger handling in the terminal. This situation differs from airline to airline, airport to airport. For instance, in Esenboga Airport, Ankara, Turkey, a handling company represents the German carrier, Lufthansa in all handling processes, but on the other hand, in Frankfurt Airport and Lisbon Airport, check-in is performed by Lufthansa's own crew.

Handling operations in airports can be performed by three different service providers. These are:

- Third Party or Independent Handlers: “Third party handlers” refers to any ground handler provider different from the operating carrier (ardent.mit.edu). Third party handling is performed by specialized individual handling companies which specialise in handling operations. Third party handlers can operate at any airport during their concessions as soon as they keep up to the standards agreed. Fundamental shifts in airport business from traditional, monopoly concept (providing all services) to focus on core business resulted in the emergence of new global third party handlers such as Menzies, Globeground, Aviapartner. These companies have their own handling equipment apart from the airlines’ as well as the airports’. This equipment forms the largest part of the asset capital of the handling companies’. In some cases, third party handlers also can capitalize from the equipment pools of airlines or airport.

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handling activities at Newcastle airport and at many airports while doing its own handling at Heathrow and Gatwick.

- Self Handlers: Self handling refers to the situation in which an airport user directly provides for himself one or more categories of ground handling services, and concludes no contract of any description with a third party for the provision of such services (SH & E Limited, 2002). In self handling, handling of aircraft is performed by the airline itself instead of other parties. For instance, Lufthansa undertakes the ground handling operations as a self handler at Frankfurt and Munich Airports; Alaska Airlines handles all ground handling operations at seven airports in United States; and Air China undertake all the ground handling operations at Hohhot, Beijing Capital Int. and Tianjin Binhai Airports.

- Airport Handler: An airport can serve the airline as a handling agent, besides being the interface where aircraft land and takeoff. The airports participating in handling services can take advantage of being in charge of all activities (equipment, gates, stands, slots, etc) to perform the handling of aircraft and passengers, and this is one of the common applications in Europe (such as Fraport in Germany, Portway in Portugal, ADP in France). Especially in Europe, airport operators which conduct the ground handling have become very professional since the 1990s[5]. Previously, the monopoly structure in ground handling at airports, especially at the ones where the airport operator performs the handling, resulted in a challenge for the third party handlers to enter the market. After the liberalization of the handling market by enforcement of the European Council, the market structure changed slightly, and the entrance of the third parties is regulated. Nowadays, airport handlers also launch third party subsidiary ground handling companies to focus on their core business, such as SATS (Singapore Airport Terminal Services) which launched the wholly-owned low cost ground handling company, Asia-Pacific Star.

[5] Globalization and merging between these companies allowed the operators to be more revenue making. For example, Swissport reached the revenue of $ 1.2 billion in 2004 and interests at 108 airports in 39 countries. Frankfurt AGS owned by Fraport generated $524 million in 2001 by providing handling at 25 airports in 9 countries. Worldwide Flight Services owned by Vinci, which also is a global airport management company, has revenues $44 million with handling services at 17 airports at 13 countries in 2003 (Graham, 2003)

2.2 Market Structure

Liberalization, outsourcing, airline alliances, privatizations, and consolidations of handling companies are some of the macro trends that impact the handling industry. The airlines which were restricted by strict governmental rules for many years attempted to deregulate the air transport market so as to fly wherever they wanted at the price they preferred. After the liberalization, the number of market entries increased dramatically (Forsyth, Gillen, Mayer and Niemeier, 2005). “There was an 8% increase since 1999 compared to the previous year. 73 bilateral services agreements in 2000 were concluded between countries to expand their air transport network. 70 % of these agreements were sample of liberalization with 17 ‘open skies’ agreements” (Abeyratne, 2004). Consequently, this development not only brought competition to the market, but also led airlines to seek ways to reduce the costs to survive with the help of alliances, partnerships, and outsourcing of noncore businesses.

As an expensive and luxury travel means, the airlines used to have all of the operations in one hand, from the restaurant to the hotel chains. After numerous economic fluctuations, crisis and terrorism, most of the airlines changed their management strategies to survive in this volatile market. In this respect, one of the outcomes of looking for more profitable operations was outsourcing. Both the airlines and airports started to outsource non-core activities, and the handling services was one of the first processes that airline and airports consigned.

The airline market had been changing and progressing versus a stable handling market structure. For many years, a monopolistic structure was dominating the handling market in Europe. The emergence of alliances between airlines, the hubbing systems and the strategies taken for more profitable flights forced airlines to search for quicker, cheaper and reliable handling services. The emergence of low cost airlines also had a large impact on the major carriers in such a way that they also started to search for quicker handling in order to be able to compete with full service carriers.

“In the United States, the domestic cargo airline market was liberalized in 1977, and passengers services in 1978, way before Europe[6]. Prior to the liberalization, airlines used

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[6] For details of changes in the United States, see Morrison and Winston (1995).

to serve as the handling agent themselves or to the other smaller airlines, while in Europe this situation was quite different. Handling was in the control of the airport in most of the European cities after the World War II. Until 1996, there was no single action to regulate the handling market. In ground handling three types of market structure has been existing; monopoly, oligopoly and open market**.** Historically, often the national airline or airport operator may have had a monopoly or near monopoly in ground handling. Some airport operators such as the ones at Milan, Rome, Vienna, and Frankfurt Airports have been heavily involved in ground handling" (Graham, 2003), and some airlines like the national carriers in Greece and Spain, have also done the same thing.

Transforming handling to meet the challenges of a competitive airline industry is one of the objectives of liberalization of air transport. Having more than one handling company at the airports reasonably will ensure that airlines have more alternatives in handling services in terms of service prices and service quality. In 1996, the EU introduced EU-Directive 96/67/EC for deregulating the handling market. The objective of the Directive is to eliminate restrictions on freedom to provide ground handling services in the community, and thereby open up and encourage competition. As a result, this action should help reduce the operating costs of airlines and improve the quality of service provided to airport users (SH & E Limited, 2002). This directive has led to better conditions, especially to independent handlers, for entering the market. The number of independent handlers increased substantially after the implementation of council. 22 new third party handlers have entered the European Ground Handling market since the introduction of the Council Directive 96/67/EC[7], even though the directive did not manage to meet all the expectations of all related parties, such as airports and airlines.

[7] There are some arguments stating that having too many competitors runs the risk of instability, as some of the competitors may be driven out of the market, as well as of deterioration in service quality due to pressure to reduce costs (De Neufville and Odoni, 2003)**.**

2.2.1 Globalization

Globalization and merging strategies have started to become popular among the handling companies after many aviation crises. Besides regional handling companies, some big global handling companies have emerged in the handling market and standardized their service. On a global scale, there are some strong handling agents such as Menzies, Aviapartner, Swissport and Serviceair, and regional ones like Globalia in Iberian Peninsula. For instance, Menzies operates in 24 countries in 109 stations, while Swissport operates in 43 countries in 187 stations. On the other hand, SATS[8] (The Singapore Airport Terminal Services) in Asia established a network in Asia through joint ventures in China (including Hong Kong & Macau), India, the Philippines, Indonesia, Taiwan, Vietnam and the Maldives. Figure 2-1 and Table 2-1 show the size and the market share of some of these global handlers.

Table 2-1 Size of Global Handlers

	Revenue	Employee (thousand)	Customer	Passenger (million)	Cargo (mil. Tonnes)
Servisair (2008)	4,05 bil	22	700	102	1
Swissport (2008)	1,182 bil.	30	650	70	3
Menzies (2008)	576 mil.	14	500	60	1.6
WFS (2006)	580 mil	12	300	50	3.5
Fraport (2006)	650 mil	8	100	54.2	2.1
Aviapartner (2006)	378 mil	6	400	31.2	1.5

These global handlers are able to make contracts with any airline and handle its operations not only in one airport, but also at all the other airports that this airline operates to and from. In this way, these companies are able to profit from scale of

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[8] SATS also launched a low cost ground handling agent in March 2009, called Asia-Pacific Star, which provides passenger, ramp and baggage handling, and aircraft interior cleaning at Budget Terminal of Singapore Changi Airport, with shorter turnaround time to low-cost carriers.

economies and asset utilization. It is foreseen by one global handling company, Aviapartner, that the share of network contracts in Europe will grow from less than 20% in 2005 to 50%-60% by 2010, due the fact that airlines and alliances are tending to strengthen their global network in order to strengthen their market share and supply base (Buyck,2007).

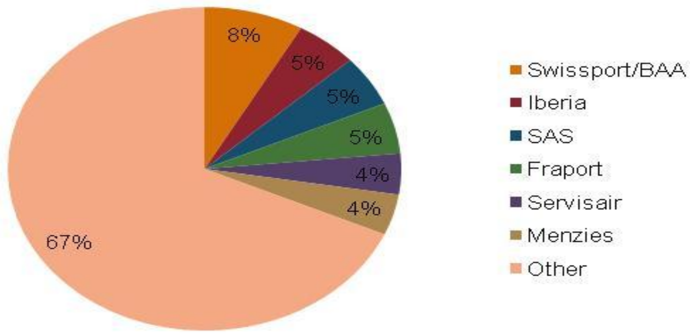

Figure 2-1 Market Share of Global Handlers
Source: Fuchs (2007)

Not only the airlines, but also the handling companies have been looking for the ways to cope with the fluctuations in aviation and to amortize their equipment capital. For instance, Aviance is the first international alliance in airport and handling services, providing a large array of opportunities from exchanging employees to joint marketing strategies to member handlers.

2.3 Handling Delays

Every factor that has an impact on the airline performance requires particular notice. The number of undelivered or late baggage delivery, late check-in and boarding, and low on-time performance due to ground operations are some of the indicators of airline performance which are closely related with the handling operations. Service level of ground handling operations have an impact on passengers, other airlines, as well as the whole functioning of the airport relating to land-side (e.g., check-in desks, baggage delivery) and air-side (e.g., transport on the ramp, maximum turnaround time...). Therefore, it can be concluded that handling operations can not only result in delays of the flights, but also have an impact on the other performances of an airline related to passenger experiences.

Every year, airlines have been experiencing additional delays. The percentage of each reason for delay may differ from year to year. Until now, one of the main concerns of the airlines was ATC and ATFM (Air Traffic Flow Management) delays. Limited airspace in airport and en-route, increasing airline operations in certain routes, and city pairs had been affecting all transport networks. Attempts to solve these problems by related units, such as EUROCONTROL and ACI, resulted in a positive outcome, and delays due to ATFM and ATC have started to decrease. Airport and handling operations which have been disregarded in the past have started to attract the attention of the airlines. Figure 1-2 depicts the list of these delay causes. As seen in Figure 1-2 in the introduction of the thesis, while Aircraft and Ramp Handling is in the second place, other handling related delays such as passenger and baggage, as well as airport facility follow it with higher percentages than the rest of the reasons. On the other hand, ATFM and En-route delays are listed as the third highest delay reason.

Figure 2-2 presents delay affecting overall departure punctuality in Europe. This figure also displays the importance of handling services in airline operations and indicates the increase in aircraft turnaround delays, along with the airport facilities.

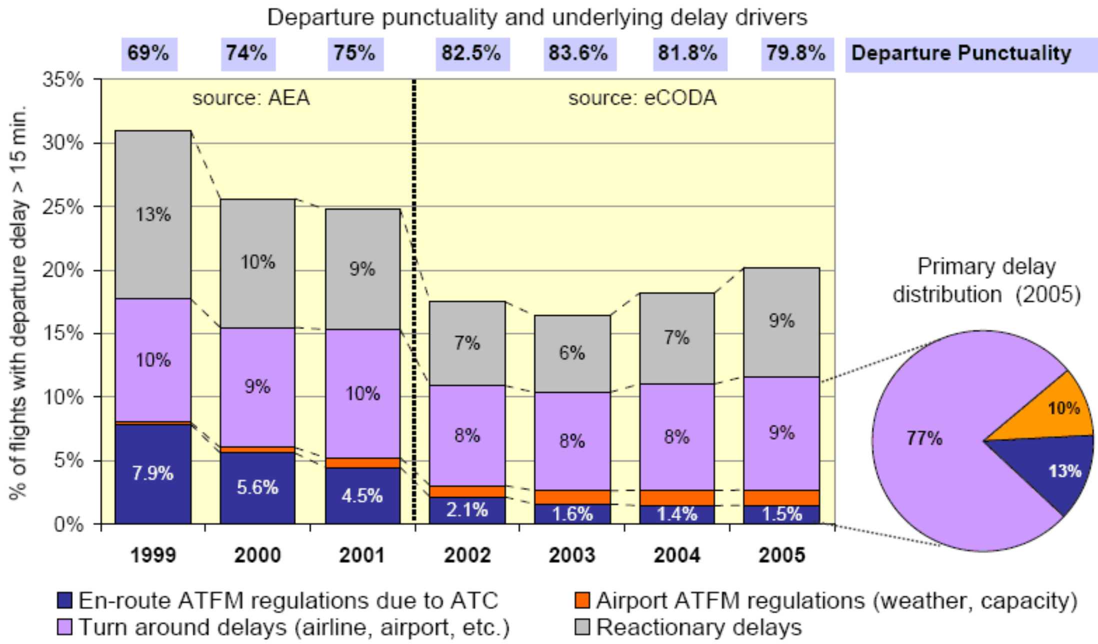

Figure 2-2 Delay drivers affecting overall departure punctuality in Europe
Source: Eurocontrol, 2006

Any disturbance in service supply of handlers has a major impact on all operations of airlines. Inadequate service of the handling company influences the airline image, and thus it can be said that the handling agent is the vitrine of the airlines. Any consumer at airports or any airline passenger who experienced defects on services would not blame the ground handling company, since perceived service by consumer is seen as being provided by the airline or airport. Therefore, the image of the airport or airline is negatively affected, despite the fact that it may not provide the service concerned. At all the airports where the airlines assign passenger services to handling agencies, passengers will consequently blame the airport or airline for any service disruption experienced as a result of insufficient handling service in both terminal side and airside operations (e.g., long check-in and boarding schedules, baggage delivery, buses, maintenance and availability of ramp equipment). Inefficient ground handling leads to low level of airline and airport productivity, and also causes congestion at the airport as well as at the gates, which results in over usage of the airport capacity.

On the other hand, ground handling is one of the highest costs of airlines, and as depicted also in Figure 2-3, the expectation of airlines from its handler is inevitably to have the quickest, the most efficient and value added operations.

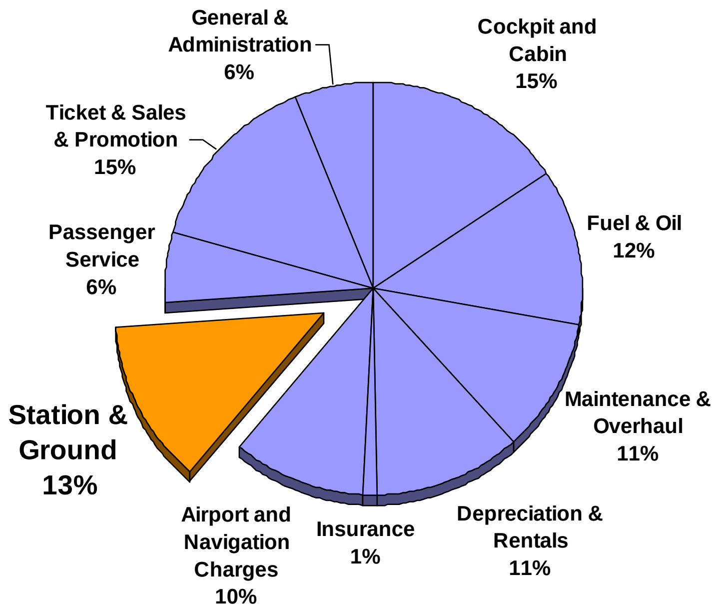

Figure 2-3 Station & Ground Cost of Airlines
Source: Association of European Airlines (2004)

2.4 Definition of Aircraft Turnaround

Aircraft turnaround, which is the core of the handling business, can be defined as the process of "preparing the plane for the next flight". This process is accomplished by the simultaneous work of different operational departments to prepare the aircraft for its next flight.

Aircraft turnaround process is established in a defined period of time, under any given circumstances, and has to be done without wasting time or resources. Turnaround time refers to the time between on block and off block of aircraft. During this period, many tasks take place simultaneously and in relation to each other. Aircraft turnaround time has to be in the limits of standard ground time, which is around 45-90 minutes depending on the type of the aircraft. The differences in ground times, and consequently the differences[9] in aircraft turnaround times between major carriers and low costs depend on the strategies taken by the airlines.

The efficiency of the ground handling process, especially for the expeditious aircraft turnaround, mainly depends on issues like the availability of staff, scheduling, amount of equipment, positioning, adaptability to traffic peaks, work tasks, meteorological conditions, capability, performance, compatibility of ground handling staff and equipment. On the other hand, the efficiency of aircraft turnaround relies on how all these simultaneous tasks and conditions are managed in an effective and coordinated way.

In this respect, it can be inferred that the process of aircraft turnaround is a very complex one. When the aircraft arrives at its parking stand, many different operational departments work together to make the aircraft ready, such as:

- *Passenger Services* are responsible for passengers to be checked-in and boarded in departure.
- *Ramp Services* are responsible for loading of bags, and under-deck operations such as lavatory.
- *Cleaning Company* is in charge of cabin cleaning, replacing of sick bags and headers.
- *Cabin Crews* prepare the cabin before boarding.
- *Duty Free* is responsible for uploading onboard shopping products.
- *Fuel Company* is responsible for delivering requested fuel on time.
- *Catering Company* is responsible for uploading the new galleys and removing the empty ones.
- *Airport Authority* is responsible for providing bridge service, boarding gates and custom services (unless it is a handling provider).
- *Cargo Department* is responsible for preparing related documents for cargo and delivering the cargo to ramp department.

[9] Difference between ground times is very noticeable between low cost carriers and major carriers. Some of the reasons are LCCs don't have connecting passengers, they don't need to wait for transfers and they don't have cargo services.

- *Fire Department* is responsible for being in the parking position if there is boarding, and fuelling is performed at the same time.
- *Flight Operations* is responsible for preparing the load and balance sheet, and delivering it on-time.

In this respect, all these departments work together in an interactive way during aircraft turnarounds to accomplish the different processes that are displayed in Figure 2-4.
As shown in the figure below, most of these tasks depend on or build upon another task. For instance, before the cleaning finishes, the passengers cannot be boarded, or before the crew boarding, fuelling cannot be completed.

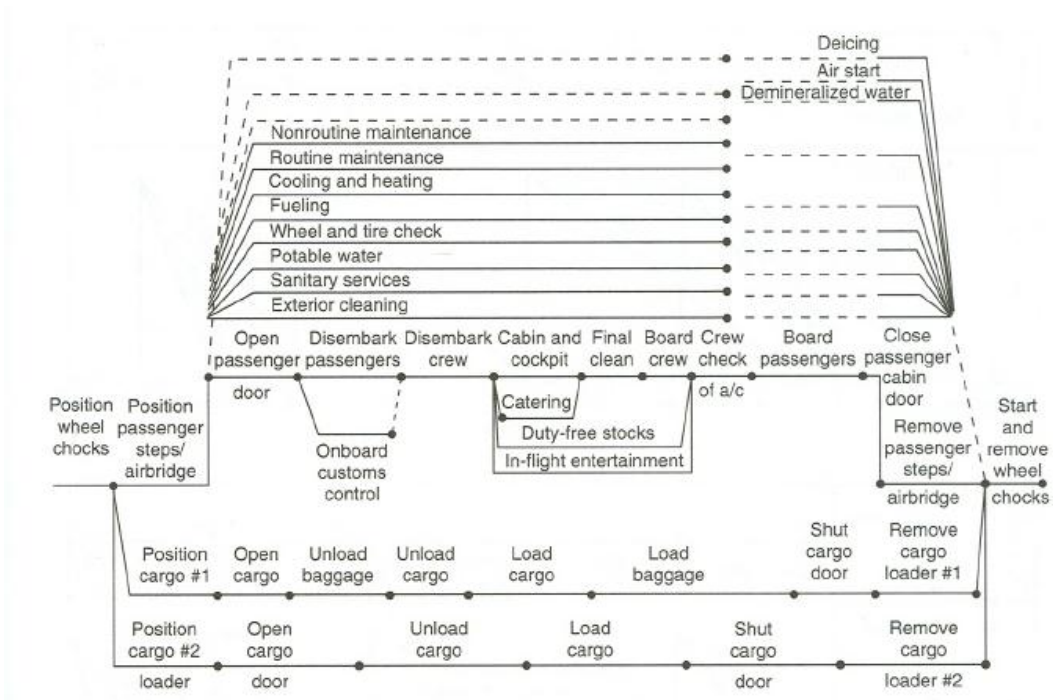

Figure 2-4 Critical Path in aircraft Turnaround
Source: Ashford, Stanton and Moore (1997)

Most of the tasks in turnaround are sequenced. Cleaning has to wait for disembarkation, boarding has to wait for crew to arrive and cleaning to be completed, duty free has to wait for cabin crew to be onboard, fuelling has to be started after the disembarkation and has to be finished before the embarkation of passengers, and so on. Consequently, if the crew arrives late, loading of onboard duty free will be late; if duty free is late, then boarding will be late; if cleaning takes longer than scheduled, boarding will be late; if boarding is late, the seating will be late; if loading of the bags is late, closing the doors of airplanes will be late - and as a result, push back of aircraft will be late.

Another point that is worth mentioning with respect to turnaround operations is that there are many mobile types of equipment and many tasks peripheral to, on the ground, as well as the ones on the upper deck in a limited space and time, as seen in Figure 2-5. These operations require exact and dense concentration of crews when they are manoeuvring and positioning the equipment to perform the aircraft turnaround process.

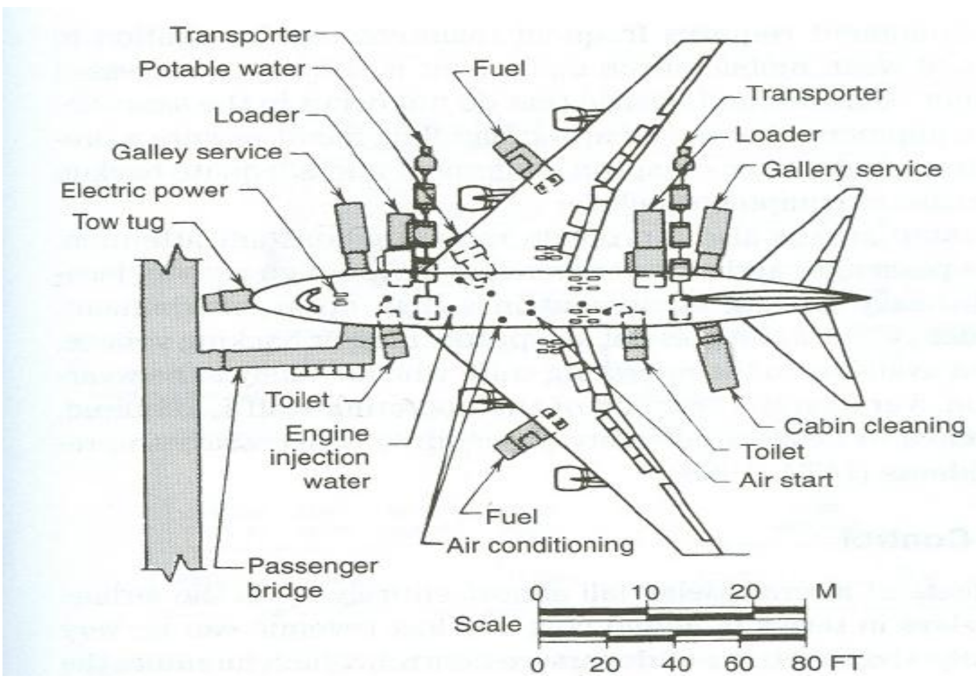

Figure 2-5 Ramp layout of aircraft
Source: Ashford, Stanton and Moore (1997)

The synchronization of ramp activities provides smoothness in operations and leads other tasks in the chain to be performed without any defect. To provide this synchronization, there is a responsible person in ramp who may be called redcap, operation staff (ramp coordinator) or airline representative. This person acts as an orchestra chief and controls all the tasks at the same time. The duties of operation staff[10] or ramp coordinator can vary according to the airline and airport strategy devoted to the subject.

Aircraft turnaround is performed in almost only one hour, and consequences of problematic operations have a big impact on the rest of the operations which the airport and airline have to proceed with.

The efficiency of an aircraft turnaround operation is defined as the capability of an airline to execute the required aircraft turnaround services within available service time and to deliver a punctual departure flight (Wu and Caves, 2002a), but it is not easy to perform efficient turnaround under many circumstances that occur during this time period. In the preparation process of aircraft, sometimes things may not be conducted as planned. In turnaround, arrival time of the airplane is very important. Limited time for turnaround is reduced more with late arrival, which is also called ‘reactionary delays’. On the other hand, aircraft turnaround is the only tool for recovering the arrival delays and decreasing the impact of reactionary delays for the following flight leg. Late arrival of the airplane can be covered by efficient ground handling and provide punctual departure.

Airlines have a defined ground time in each airport[11]. If an airline’s operation exceeds the ground time, it is called a delay, even though airlines have 15 minutes additional time not to be announced as delayed. This can be called “buffer time”, and gives a chance to the airline to still be able to enrol the route which is provided by Eurocontrol[12]. Buffer time also enables the ground handler to complete the aircraft turnarounds within this additional 15 minutes. In the following, according to arrival time of aircraft, demonstration of possible situations is presented:

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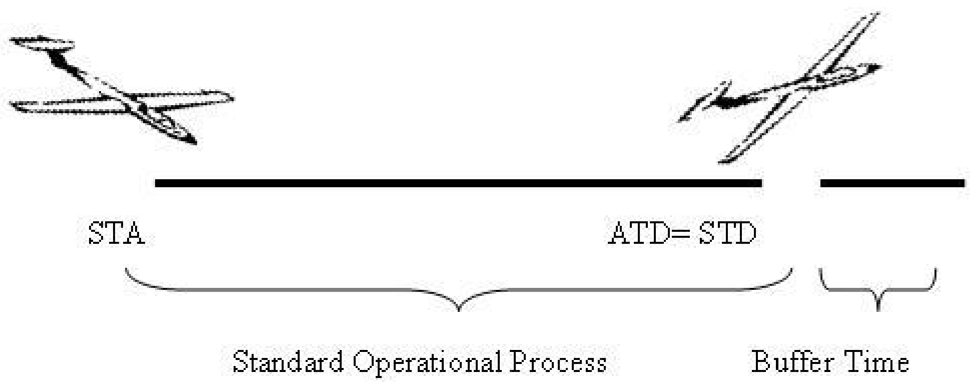
[10] An operation staff is a person who decides the load and passenger distribution of the aircraft. He is responsible for the corrective actions in any malfunctions, and also he decides the time of boarding, together with the airline representative or solely himself. Some airlines work with their own operation staff, and operation staff usually works in the airline office during the passenger and load calculations. He prepares the load sheets and delivers the load and balance sheet to the captain before the departure. On the other hand, some airlines assign all the responsibility to third party and third party assigns operation staff to do all these tasks for the airline.

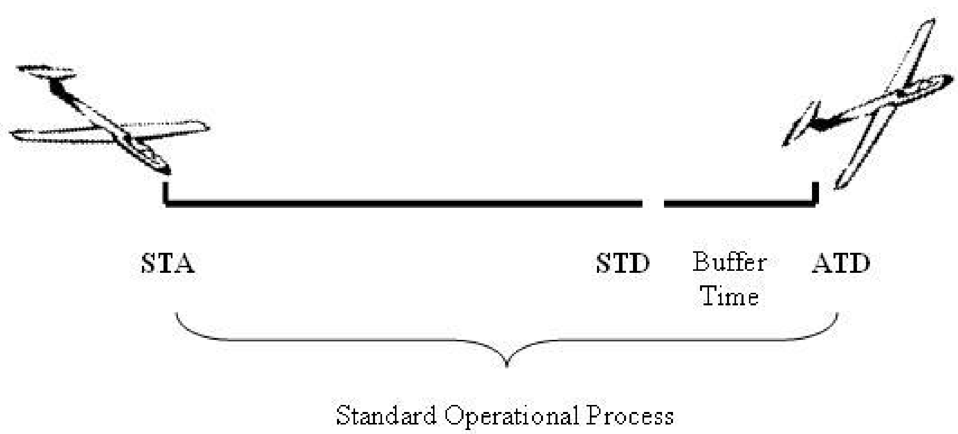
[11] Ground time is the time between block-on and block-off time of aircraft.

[12] Impact of buffer time is investigated by Wu and Caves in several papers. Buffer time indicated by them is basically the time that airline inserts in their ground time to have departure punctuality, but here, in this dissertation, buffer time indicates the extra time added to scheduled ground time of airline by Eurocontol before the departure of aircraft.

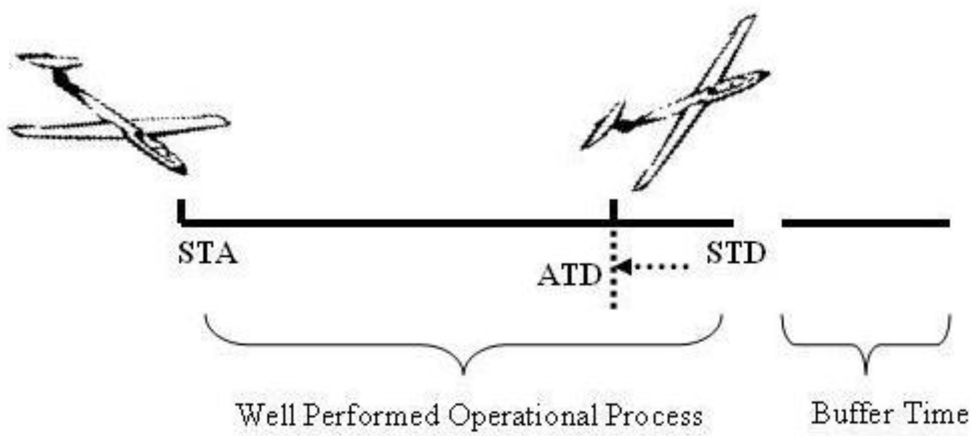
Case 1: Aircraft arrives on time and aircraft turnaround time is completed as planned, and airplane departs on time, not including buffer time. In this situation, Actual Time of Departure (ATD) is equal to Schedule Time of Departure (STD).



Case 2: Aircraft arrives on time and aircraft turnaround is completed as planned, and airplane departs on time, including buffer time. In this situation, the equation is expressed as ATD= STD + Buffer Time. No delay is assigned to the airline in this case.

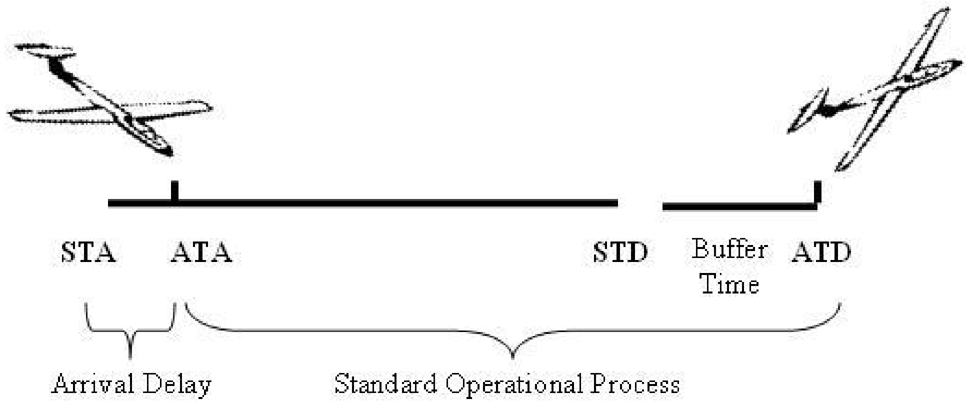


Case 3: Aircraft arrives on time and departs earlier than planned, not even including buffer time unless it is in the limit of air slots[13]. This case depends on the amount of load and number of passengers on the aircraft, and also the ground crew performance and efficient team work of different departments. Here, the situation is=ATD<STD

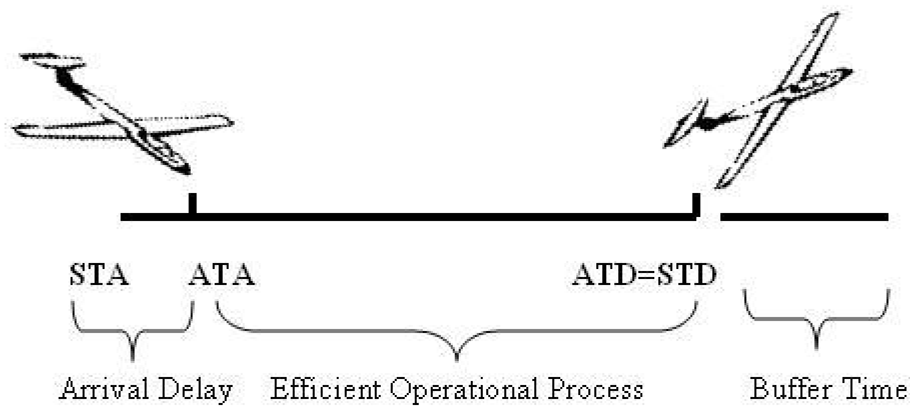


Case 4: Aircraft arrives late and there is buffer time to absorb the arrival delay by the planned ground handling process. Although it is expected as a normal standard operation, some airlines, such as low cost, put pressure on handlers to complete the turnaround before buffer time. Equation is ATD=STD + Buffer Time

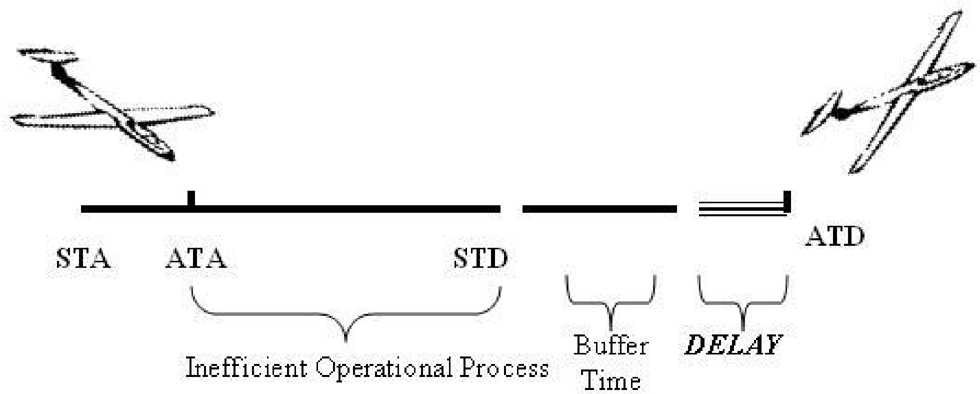
[13] In some situations, early departure of airline can also be problematic due to assigned routes to a certain number of aircraft. In this condition, the aircraft also has to wait for take off despite earlier completion of handling services



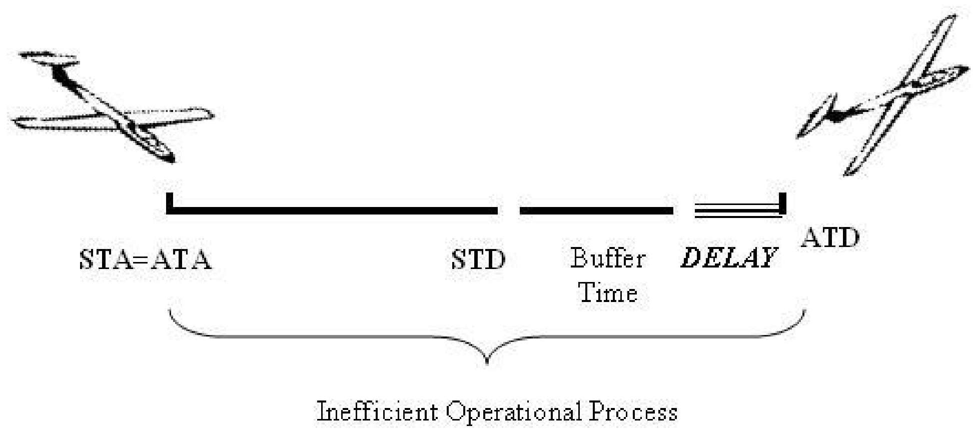
Case 5: Aircraft arrives late and departs on time, not including buffer time, due to the efficient ground handling. In this situation, efficient ground handling covers the arrival delay and also the reactionary delays of further legs of aircraft. Equation is ATD=STD



Case 6: Aircraft arrives late and departs late by exceeding the buffer time because of ground handling or any other reason. Additional to arrival delay, if the ground handling is inefficient, this boosts the departure delay which can cause enormous costs to both airline and ground handling company. ATD= STD + Buffer Time + Delay



Case 7: Aircraft arrives on-time and departs late because of inefficient ground handling or any other reason. This situation is the worst. Ground handlers with lack of equipment and staff in the peak seasons can be one of the reasons for this kind of delay.



By using the buffer time, the handling agent has additional capability to manage the possible delays. On the other hand, there is an optimal trade-off between schedule buffer time and the expected system cost. The longer an aircraft stays on ground according to the type and class, the more the expenses will increase. In every additional minute on ground, the airline has to pay an extra amount to the airport authorities: unit price is multiplied by the weight of the airplane for each minute if staying in the parking stand exceeds the planned ground time.

Airlines schedule their flights close to the minimum schedule time, even though they are aware that they will have delay on certain routes. Airlines can plan longer schedule time for their entire network not to be announced as delayed, and also planning longer schedule time can give enough time to the handler for turnaround (Mayer and Sinai, 2003). This is one of the ways to absorb the delays in network schedule, and is called "buffer time"[14]. Although airlines can use buffer time in flight schedules to control schedule punctuality, it decreases the aircraft utilization and increases the staff cost (Wu 2002, Mayer and Sinai, 2003). Cutting five minutes off this buffer time would be worth around € 1,000 million in better use of airline and airport resources (Commission of European Communities, 2006). For this reason, in most of the busy airports, handlers have to accomplish the aircraft turnaround in minimum ground times to serve the airlines. Each type of aircraft requires a certain time of turnaround according to type of destination, such as long-haul or short haul, and type of airline, such as low cost or full carrier. In the following figure, the approximate turnaround time of a B-747 and main tasks of turnaround are depicted. The duration of each task is shown in Figure 2-6.

[14] Buffer time mentioned here is different than the one mentioned in the previous paragraph. Buffer time here indicates the time which airlines allow in their network schedule to absorb arrival delays and pushback delays.

Activity	Time (min)
Position passenger Bridge	1
Supply Power	1
Deplane Passengers	11
Unload aft lower lobe	14
Unload main deck cargo	25
Service lavatories	30
Service galleys	30
Service cabin	29
Service potable water	14.5
Fuel aircraft	28
Board passenger	18
Unload FWD lower lobe	10
Load maindeck cargo	28
Load FWD lower lobe	10
Load aft lower lobe	14
Start engines	3
Power supply removal	1
Remove bridges	1
Push back	2

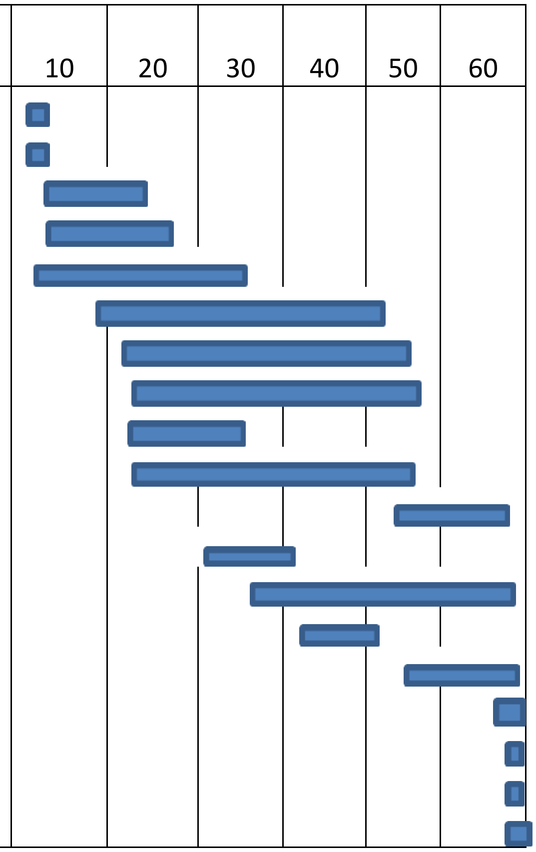


Figure 2-6 Turnaround time of B747
Source:http://ardent.mit.edu/airports/ASP_exercises/ASP%20Zerbib%20Ground%20Handling.pdf

The duration of turnaround depends not only on the aircraft type and airline service level, but also the number of passengers, as well as the amount of cargo, the efficiency of ground crew and accurate communications between departments. There are many tasks that can be manipulated in a shorter period of time than standard time if there are convenient conditions during turnaround.

2.5 Preparation for Aircraft Turnaround

Aircraft turnaround preparation starts with the process of data sharing through messages. During the preparation process, messages are received and distributed, and then necessary actions are taken. There are some kinds of messaging systems for accurate sharing of information and to improve traffic prediction. These systems provide data interchange between airports, handlers, and the aircraft operators. The messages that are received and sent have a common international language to inform the destination and origin stations. Although different kinds of programs are used by the airlines, these messages include similar information, such as the number of passenger, estimated time of arrival, loading instruction and disabled passengers, etc.[15]. Some of the main messages are listed in the following:

- Movement Messages (MVT)
- Load and Distribution Messages (LDM)
- Passenger Service Message (PSM)

2.5.1 Movement Messages (MVT)

Movement messages are composed of actual departure (AD), estimated departure (ED), estimated arrival (EA), and actual arrival (AA) messages. These messages are used to inform the destination stations about the departure time of the aircraft, together with the information about the number of passengers. This message is transmitted to all units in the handling company. Depending on the message, the passenger services department decides when check-in has to start, the ramp and operation department allocates the staff and equipment, the airport authority allocates the parking stand, etc.

[15] These messages are different then the ATM, CFMU messages. They have their own messaging systems for data flow which also help the airport and airline operations, such as flight update message (FUM) which provides real-time arrival updates, and departure planning information (DPI) which provides departure updates.

```
MVT
>NA313/04.N760NA.ADA
>AA0428/0435
>FR 8.4
>PILOT ID 2691
```

Figure 2-7 Example of Movement Message

2.5.2 Load and Distribution Message (LDM)

LDM is sent by origin station to destination station in order to clarify how loading had been performed on the related aircraft. The distribution of the luggage, mail and cargo, amount of the load and number of passengers are indicated in this message. LDM message also can be in the form of another message, named Container-Pallet Message (CPM), which shows the distribution of baggage containers in the aircraft's holds (Figure 2-10).

LDM message is passed to the ramp department, operation department and cargo department. Following the receipt of this message, the ramp and cargo department prepare an adequate number of equipment and staff for offloading the arrival aircraft; and operation staff decides the sequence loading plan according to this message.

QN ESBKQXHESBGSXH HAMHH4R MUCLHXH .MUCSOLH 4R /031250 25055 FEB06	Date & Addresses
LDM →	Name of the message
4R5968/03.DAHID.Y148.2/3 →	Description of the Flight
-IST.25/36/9/0.T1749.4/1749.PAX/70 -ESB.31/31/5/2.T1573.1/1101.4/472.PAX/67	Destinations and Load Information
SI IST B/1749.C/0.M/0.E/0	Notes

Figure 2-8 Example of Loading Message

LDM is crucial for the ramp department in turnaround, especially for the transfer/transit flights. When the flight has more than one leg and carries the luggage of different destinations, the ramp department can only know the locations of these bags through this message. Thus, instead of opening all the doors, ramp staff directly opens the related hold's door and start to unload and load to the proper hold.

The following figure illustrates the meaning of a loading message in a load sheet. The sample message in Figure 2-8 is used for illustration in Figure 2-9. There is baggage and passenger information for two destinations. In the first leg, 70 of the total passengers will fly to Istanbul (IST) with a total 1749 kg bags, and these bags are all in hold 4 of the aircraft. In the second leg of the flight, 67 of the passengers will continue to fly to Ankara (ESB) with a total 1573 kg bags, and these bags are both in hold 1 and hold 4. This loading does not include the information of any first class bags, business bags, co-mails and any other special arrangement which also requires attention in loading/unloading operations. The simplest way to illustrate this sample loading will be as follows:[16]

[16] Colourful tags, codes or many different methods are used to distinguish the different type of bags and type of loadings in holds for quick offload and easy separations.

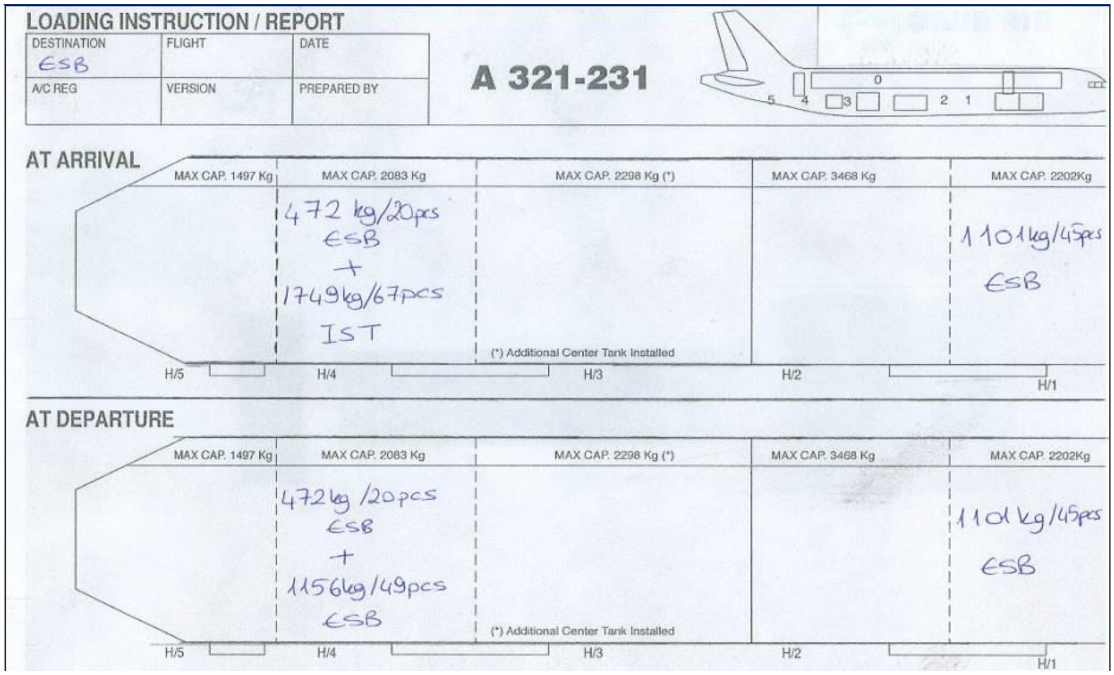


Figure 2-9 Sample of Bulk Loading Instruction
Source: OnurAir Loading Instruction Papers

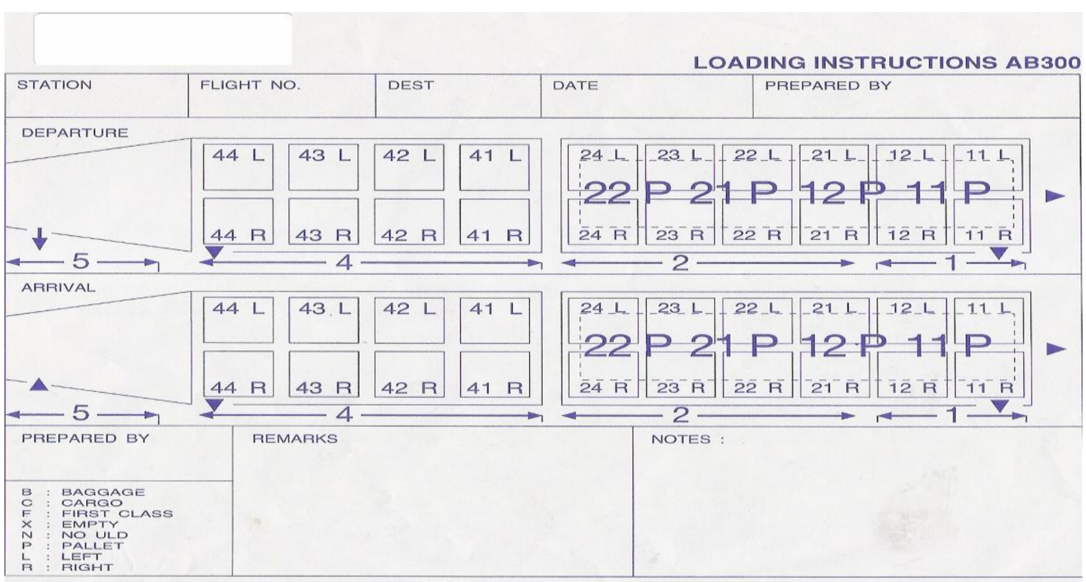


Figure 2-10 Sample of Container Loading Instruction
Source: OnurAir Loading Instruction Papers

The requirements of the loading message for both origin and destination station are:

- Origin station has to write the message correctly by clarifying the location of the destination bags, as well as additional information such as the location of buggies and hand bags. The message has to illustrate the correct distribution of the bags for the destination airport. Especially in the flights with more than one leg, clarifying the location of the bags is essential so as not to confuse the destination stations and disrupt offloading operations. For example, in the sample above, proper procedure of this loading has to be like this - bags for ESB destination have to be loaded in the back part of the hold, and bags for the IST have to be loaded near the door of the hold because the airplane will first arrive at Istanbul so that if the bags of ESB station would have been loaded to the front, the workers would have to offload all the bags belonging to ESB and then reload the ESB bags again after picking up the IST bags.
- The responsibility of the destination station is to transmit the message to the ramp coordinator to inform the workers about which and how many equipment they have to allocate at the parking stand, which bags have to be removed from the aircraft and which ones have to stay on the aircraft. Load Messages provide information about the amount of baggage. According to this information, the staff arrange the equipment. For example, one tractor is limited to carrying four baggage carts in its back due to apron security.[17] Each cart can be loaded by approximately 20-25 bags. In this respect, if there is a hundred pieces of bags arriving with the aircraft, the ramp operator has to make ready one tractor with the four carts in its back, or if there are 200 pieces of bags arriving, two tractors will be required with eight carts, along with two tractor drivers. On the other hand, if there is not enough equipment, instead of two tractors with eight carts, there can be one tractor - but the trips that the tractor makes between baggage sorting area and aircraft concourse will probably increase and, as a result, unloading time will be longer. In this respect, planning of the staff and equipment for each aircraft is conducted in the light of the LDM message.

[17] In some airports, tractors are limited to 3 carts.

2.5.3 Passenger Service Messages (PSM)

PSM messages give information about handicapped passengers, young passengers who need help to travel (unaccompanied), and deportee passengers (passengers who have missing papers, passport or visa problems). This message has to be passed particularly to the passenger services department to meet the flight on arrival for disembarkation and embarkation on departure of these special passengers.

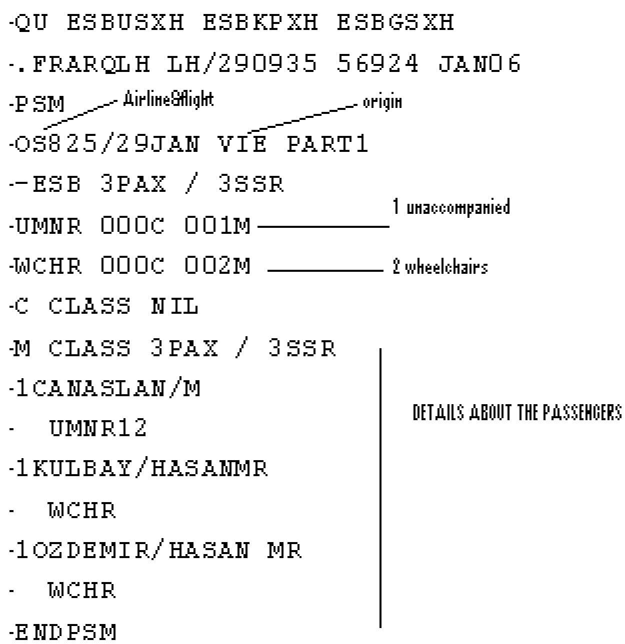


Figure 2-11 Example of PSM

2.6 Process of Aircraft Turnaround

The process of aircraft turnaround actually starts some time before the landing of the aircraft. The preparation and the turnaround process can be examined in 3 stages: before arrival, on the ground, and after departure. The next part will mention small details and faults which are commonly experienced by handling agents in all stages of the aircraft turn around process[18].

2.6.1 Before Arrival

Aircraft require pre-provision before their arrival according to the type of the flight, as well as the aircraft, the amount of passengers, and load. Airports, especially congested ones, handle many aircraft during the peak hours. Usually, consecutive arrivals make it more difficult for the handlers to meet the demand at peak hours. Previous preparation of handling agent helps to decrease chaos during the peak hours. The preparations which the handling agent has to consider before the arrival of aircraft are mentioned in the following.

Flight Data Check

There are some important data about flights which have to be checked before the arrival, as well as the departure of the aircraft. Flight permits, slots[19] and flight plan time of the airline are the most important ones to be considered before the departure of the flight. The permits given by related authorities on related flight on related date and hour, have to be controlled as well. The other data which should also be checked is airport slot, especially in the case of deviation on arrival or departure time. For example, if there is a delay on arrival at the airport which has slot application, delay information has to be declared to the airport authority, and a new airport slot is requested according to the new arrival time of airplane. Additionally, a new slot time from air traffic control (ATC) has to be obtained by the airline dispatchers or by the operation staff of the handling agent. As shown in the following example, the revision of slot is requested from Brussels with a

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[18] These explanations will be made from the perspective of operation and ramp department.

[19] Usually, slots are taken in a yearly bases by the airlines but sometimes in the case of additional flights or cargo flights, it can be necessary to confirm the slots from the EUROCONTROL.

slot message. This message asks for the new departure time. If operation staff forgets to renew the slot time with this message, the aircraft can stay on the ground for hours. Figure 2-12 is an example of a slot revision message which is sent to EUROCONTROL to ask for new calculated take-off time (NEWCTOT). In this message, the reason for the delay is declared, and availability of new take-off time is requested from the EUROCONTROL in the format of the example in the following Figure:

BRUEA7X 031221	→	EUROCONTROL Address
TITLE SRM	→	Slot Revision Message
BRUEA7X 031221	→	EUROCONTROL Address
ARCIDAUA826	→	Aircraft Call Identification
IFPLID BB67317757	→	Flight Plan Identification
ADEP LTAC	→	Departure Airport
ADES LOWW	→	Destination Airport
EOBT 060203	→	Estimated Operation Date
EOBT 1245	→	Estimated Off-Block Time
NEWCTOT 1251	→	New Calculated Take-off Time
REGUL LOWWA03M	→	The reason of the Slot Revision
TAXITIME 0006	→	Duration of Taxiing
REGCAUSE GA 87	→	The Code of the Delay Cause

Figure 2-12 Example of Slot Renew Message (NEWCTOT)

Aircraft Type Data Check

All airlines have the information about aircraft in their fleet in a document called Ground Operation Manual (GOM). Before the arrival of the aircraft, loading instructions, aircraft configuration and aircraft limitations are checked from GOM by the handling agent. GOM includes information such as dimensions of holds (baggage and cargo), passenger seat configurations, operational weights[20] and centre of gravity point limits. This information helps to achieve the best loading of the aircraft. The centre of gravity point in aircraft may differ according to its type. For example, gravity point in MD type airplanes is aft, which means most of the bags have to be loaded to the back of the aircraft to get the best balance, whereas Airbus 300-6 requires front loading. If operation staff does not check this information and if loading is done in the wrong way, the airplane will be out of trim and it will be necessary to unload the airplane and load it again - which results in average 30 minutes of delay, depending on the amount of the load. Nowadays, most of the airlines use computerized systems for load sheets, which makes it easier for operation staff to prepare the load data for the related flight. In these systems, it is easier to see the loading faults and aircraft loading limitations in the computer. Whether it is a computerized or manual load sheet, it is of paramount importance to know these details in order to be able to prepare load and trim sheet as quickly as possible.

Evaluation of Flight Messages

The evaluation of messages means understanding the need for the message and distributing it to related units. This action is necessary for all units to be ready for aircraft operations. Each message includes different information related to different units. For instance, an estimated arrival (EA) message is important for the airport authority to arrange parking stands and gates, to update information boards in the terminal building, etc., while a loading message is important for the ramp department to prepare the equipment and staff.

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[20] Weights such as maximum takeoff weight (MTOW), maximum taxi weight (MTW), etc.

Radio Frequency

Aircraft which are close to final approach or in the final approach, are able to communicate with handling agents through radio frequencies (VHF). Gardiner (2009) explains the VHF as follows:

> "VHF provides a simple, reliable, communications system. It is essentially short-range as reception is limited to a line-of-sight direct path between the transmitter and the receiver. The process by which the signal (the fixed carrier frequency plus the information) is conveyed between the transmitter and the receiver is propagation. These VHFS provides propagation of radio waves within the high frequency (HF band the 'short wave' bands between 3 MHz and 30 MHz, with 12 aeronautical sub-bands in the domestic and international HF networks between 2850 and 22 000 kHz)".

Via VHF, the pilot is able to inform the ground staff about what they need at the parking position and exchange some operational information. This frequency can be used in reducing turnaround time. For example, before the landing of the aircraft, load-sheet data can be requested from the cockpit, which was traditionally received sometime after landing. In this way, the load sheet can be prepared earlier and passed to the captain for departure in a reduced time period. Currently, Ryanair, a low cost carrier, utilizes this tool for the handler to start the boarding of its passengers just before its landing.

Being at the Parking Position

A certain number of staff from different departments has to be at the parking position before the landing of the airplane. The operation staff checks whether all equipment and crew are ready or not, and undergoes a briefing with the ramp chief about the loading and unloading process; the ramp supervisor controls the number of workers and ramp equipment, and undergoes a briefing about loading/unloading; traffic personnel prepare the documentation in order to pass the paperwork to the cabin crew.

Positioning the Equipment

Each type of aircraft requires different equipment depending on its design. According to the type of the airplane, a suitable and sufficient amount of equipment is brought to the parking position. For example, if the type of the airplane requires unit load devices (ULD) for loading, related equipment such as dollies, loaders or forklifts have to be brought there. It is crucial to bring the checked equipment (if they are working properly or not) to the park position. If it is bulk loading according to bulk loading requirements, tractors, sufficient number of carts and conveyors have to be brought.

Briefing

When an airline representative is not in charge of the aircraft turnaround process, the redcap or ramp supervisor is in communication with the airline representative to manage the process. Briefing includes the final information sharing with airline representatives and related units. Sometimes, representatives can ask for extra services such as an extra bus, VIP service or some differences in planned service. For example, instead of full cleaning they can ask for a transit cleaning or fire brigade, etc. After the briefing, if there are these kinds of requirements, they are passed to the related units before the arrival.

2.6.2 ON THE GROUND

Disembarking of Passengers

Passengers are disembarked in three ways: through the airbridges (fingers), through the buses in the remote positions, or by walking from airplane to terminal (only in close parking stands to terminal, especially by low cost carriers' passengers).

If the aircraft is parked in a remote position, buses have to be in the parking stand to meet the flight on its arrival. In remote parking stands, quick disembarkation requires enough buses for the passengers. Numbers of buses in disembarking or embarking of passenger is decided in the service level agreements with the airline. Airlines have different choices for the number of buses. This decision depends on how the airline would like to serve its customers. For example, while a full service carrier may prefer two buses for 80 passengers, a charter or low cost airline may prefer one bus for the same number of passengers. The responsibility of the ground handling is to provide the numbers requested, as promised to the airline in the service level agreement, and make the buses ready at the position.

For the bridge operations, an airbridge operator goes to the bridge control panel to position the airbridge. In airbridges, which are mostly under the management of airport authorities, a bridge operator has to be in the parking stand at least at the moment when the aircraft arrives.

Cleaning

Cleaning of the aircraft is performed by subcontracted cleaning companies or by the ground handling agent. Airlines notify the number of the cleaning staff needed in each airplane type and what kind of cleaning they prefer in their service agreement with the handling company. The handling company is responsible for fulfilling the requirements of the service level agreements, either by itself or through the cleaning subcontractor.

Cleaning of an aircraft can differ depending on the flight type. Aircraft cleaning can be classified as transit cleaning, standard cleaning, and deep cleaning. Standard cleaning of aircraft on board includes the cleaning of toilets, catering boards, removing the garbage, vacuum cleaning, cleaning the floors and seats, wiping the seats' tables, cleaning and tidying the seat pockets, tidying the seat belts, replacing the sickness bags and head covers, and cleaning the windows. In the transit flights, cleaning is usually just composed of removing the garbage and cleaning the toilets, which takes approximately 15 minutes. When deep cleaning is performed with hygienic detergents, cleaning takes longer.

The duration of the cleaning is important because unless the cleaning is done, the boarding cannot be initiated. The number of cleaning staff and aircraft type are closely related to the duration of the cleaning. For instance, in small body with a single corridor aircraft such as MDs or B737, having additional cleaning crew does not help to hasten the operation, but rather it hinders the work flow inside. Therefore, an optimum number of cleaning staff has to be arranged, depending on the aircraft type with regard to the service level agreement of the airline.

Duty Free

Duty free companies load products for the onboard sales. The loading of duty free is done with the help of the cabin crew, as well as the related duty free company. Duty free loading starts some time after the disembarkation of the passengers, and has to be completed before passengers arrive at the airplane. In the flights which have duty free loading, turnaround time is usually hindered because airplane corridors and also flight attendants are kept busy by the duty free company.

Catering

Catering service in aircraft turnaround includes the removal of the empty galleys and replacement of them with the new ones before the boarding starts. It is crucial for the operation staff to organize the work flow onboard to have quicker loading. Specifically, the movement inside of the small/narrow body airplanes is very difficult in a limited time period. The usage of the airplane's doors between catering, cleaning and duty free has to be very efficient.

Usually, external companies such as catering and fuelling are located away from the apron area so that for them to arrive at the parking stand requires some time. In turnarounds, missing meal or additional offers of cabin crew requires more time for completing catering, so that it can be useful to check the number of meals versus the number of passengers so that there will not be a missing meal. This cross-matching must be primarily done by the catering company, and also as a precaution, crosschecking can be conducted by the handling staff or by the airline representative.

Loading/Unloading of Bags

Unloading/loading of the aircraft is the most important part of aircraft turnaround, being performed under the responsibility of two different units: operation and ramp.

Responsibility of operation department: The responsibility of operation is to plan loading/unloading by considering the rules and limits. Each aircraft type requires certain ways of loading for safe take-off. The distribution of the passengers in the upper deck and the distribution of the bags and cargo in the lower deck are planned by operation staff. Operation staff consider the factors such as limitation of holds, gravity centre of aircraft, and amount of payload (total weight of passenger, baggage, and cargo) for the loading/unloading process.

Responsibility of Ramp Department: Loading/unloading process requires different methods according to type of aircraft. In the aircraft where the gravity centre is in front, unloading has to start from the front and loading has to start from the back. For the aircraft where the gravity centre is in the back, loading has to start from the front and unloading has to start from the back, so as to keep the aircraft in balance during the loading/unloading. Ramp staff is responsible for considering these rules during the process of loading/unloading. Figure 2-13 is a very good example of wrong unloading. As soon as the staff removed the load from the front hold, the back of the aircraft collapsed because of the fact that the aircraft was out of balance. The unloading of this aircraft should have started from the back hold to have a balanced and safe offload.

Figure 2-13 Example of Wrong Unloading/loading in Turnaround Process
Source: Selman, (2004)

Fuelling

Fuelling can be purveyed to the aircraft by the fuel trucks or hydrant fuelling system which is located on each parking stand. Even though the fuel companies have the flight schedules to serve the aircraft, the only thing that the handling company can do is to call the fuel on time, and inform them about the changes in the schedule in case they are not informed. Ground staff is in charge of checking whether there is a fuel truck in the parking stand when the aircraft touches down.

Boarding Announcement

After the preparation of the aircraft on ground is completed, the boarding process starts. Initiating the boarding process requires communication between ramp, traffic and cabin crew[21] Before starting the boarding, the operation staff has to evaluate:

- Approximate completion time for cleaning and fuelling processes to pass the information of boarding time to passenger and ramp services: Through this information, the passenger services announce the boarding time to the passengers, and ramp services arrange the buses for remote parking positions;
- The number of buses the handling agent assigned for the related flight: At the peak-hours where all buses are in use or when the airline only demands one bus for the entire boarding process, the time needed to complete the boarding is longer; therefore, the boarding should start earlier;
- Required time for the bus to bring the passengers from the terminal building to the related parking position: Aircraft in remote positions require more time for boarding, because the distance between the terminal and parking stand can be long and might require more than one bus trip to embark all passengers.

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For instance, in the remote stands, if the boarding starts earlier than it should have started, the passengers wait in front of the airplane without going out of the boarding buses. If the boarding in the remote position starts late, even though cleaning and fuelling finish on time, because of the fact that buses arrive late at the parking stand, the airplane will have a delay. Figure 2-14 summarizes this issue at hand. However, congested terminals and aprons also cause late boarding of passengers, even though everything is ready in the aircraft.

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[21] Here, operation staff passes the cabin crews' request for boarding to traffic department.

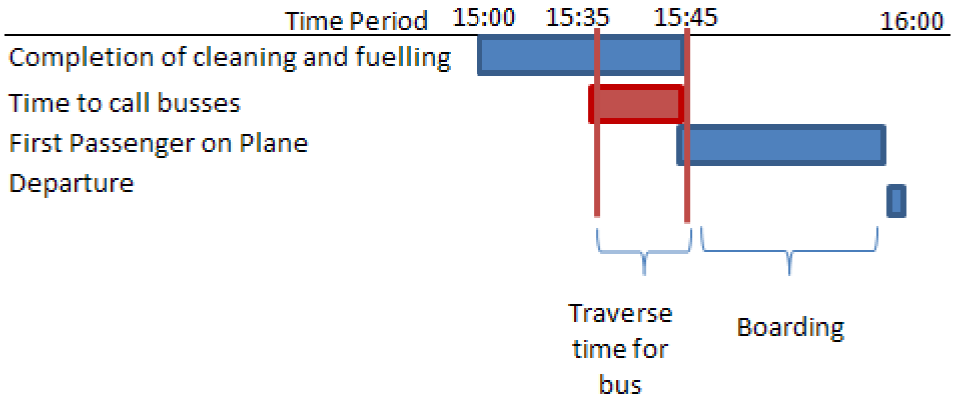

Figure 2-14 Illustration of Optimum Time to Call Passengers

Preparing and Approval of Load and Balance Sheet

The Load and Balance sheet is a form which is filled in by the person in charge with the information received from the pilots and the information of actual payload[22]. In order to fill out the load sheet, actual payload has to be known. Actual payload can only be available after all passengers are checked-in. After check-in, the accurate numbers of the passengers and the bags are passed onto the person who is responsible for preparing the load and balance sheet. This person can be operation staff or an airline representative. In addition to the bags and passenger information, cargo amount is also received from the cargo department, and fuel amount from the captain is received to complete the load sheet. This process includes last-minute changes due to last-minute cargo, passenger and fuel uplifts. When the payload is more than expected, the airline decides to remove some of the weight for safety reasons. For instance, the airline representative decides to load or unload cargo, or on the contrary, the pilot may decide to de-fuel to balance the aircraft. Operation staff makes the final adjustments in calculations in the balance sheet and presents it to the captain for approval. Without the signature of the captain on this sheet, the aircraft turnaround cannot be completed. The faster the load sheet is completed, the

[22] Payload refers to total passenger, cargo, baggage and mail

quicker the pushback can start. If the captain does not agree on the loading and load sheet calculations, reloading may be required.

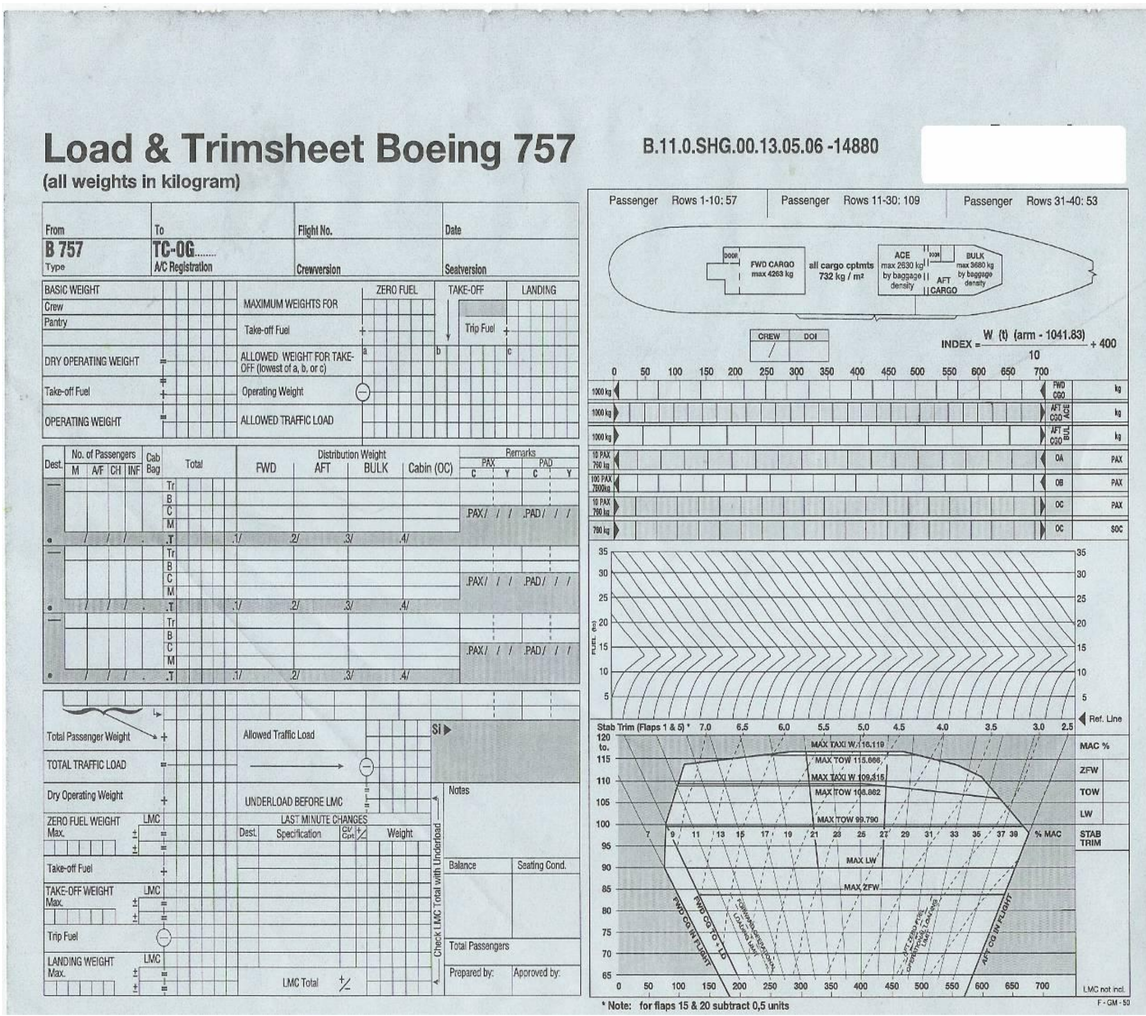

Figure 2-15 Load and Trimsheet Boeing 757
Source: AtlasAir Operation Manuals

Pushback

Ground time of aircraft is ended by removing the chocks-which is called chockoff time- and the chock-off time is recorded as “Actual Time for Departure” and announced to all related parties via “movement messages.” Chocks can only be removed when the pushback is connected to the aircraft, and following the removal of chocks, pushback starts. The aim of pushback is to drag the aircraft from the parking stand in the rearward direction of the aircraft nose until the aircraft is turned in the direction of the taxiway, without starting engines and consuming fuel. There are different types of pushback trucks: the one which can be called traditional pushback requires the tow bars for each type of aircraft, and the other types are the new ones without using a tow bar. Close to the end of the turnaround process, the pushback car is connected to the aircraft. All the required equipment in the pushback process, such as headset and pins, have to be at the parking stand.

Obstacles may not be perceived by the pilots during the pushback, so that operation staff are the ones who can see around to avoid the obstacles while pushing back the aircraft. Staff in charge of pushback has to be aware of the movements of the aircraft and other vehicles. Before starting to pushback, technicians or operation staff walk around the aircraft to clean the area from foreign object damage (FOD). This final control is called walk around check. Walk-around-check is designed to avoid any crash or accident occurring because of the obstacles around the aircraft. The distance between obstacles in the apron and aircraft engines has to be evaluated well and checked well, before and during the pushback, so as not to damage the aircraft and hinder the turnarounds.

2.6.3 After Departure

Sending Departure Messages

There are messages to be sent to destination stations following the departure of the aircraft. Loading configuration, the number of passengers with passenger manifest, the list of special passengers, the actual departure time and estimated arrival time information are transmitted to related units, such ATC, Eurocontrol, airport authorities, handlers and airlines. These messages have to be sent as soon as possible and on time in order to inform the other stations about the status of aircraft so that they can start their preparations.

2.7 What affects the Aircraft Turnaround Pattern?

A multi-task structure of the aircraft turnaround process is influenced by many factors. The large array of factors varies from crew performance to weather conditions. Basically, in this dissertation, the factors in which the ground handling agent, airline or airport can intervene, are grouped under six main topics:

1. Effect of Different Departments
2. Ground Crew Performance
3. Worker strategies of Handling Companies
4. Air Traffic and Airside Restrictions
5. Airline Strategies
6. Airport

2.7.1 Effect of Different Departments

In aircraft turnaround, many departments involved in the process, such as passenger services, ramp services, cargo handling, fuel, catering, airline, airport authority, each having different responsibilities. Aircraft turnaround is composed of many synergetic work tasks of each department. Each department has a vital importance in the success of turnaround. It is difficult to provide departure punctuality with only the efforts and success of just one of these departments. For instance, aircraft can be delayed if operation staff (ramp coordinator) does incorrect load planning although the passenger services accomplish excellent check-in and boarding, or loading can be delayed because of searching for a bag of a missing passenger.

Besides the internal operational departments, this short time period is constrained by many variables and affected very easily by the other parts of the chain, such as airline, airport and other users of airport. Figure 2-16 demonstrates the communication and cooperation between these different departments that play a role in the process. Each colour represents a different unit. The success of the turnaround depends on the harmonized and simultaneous work of all different departments involved in the process.

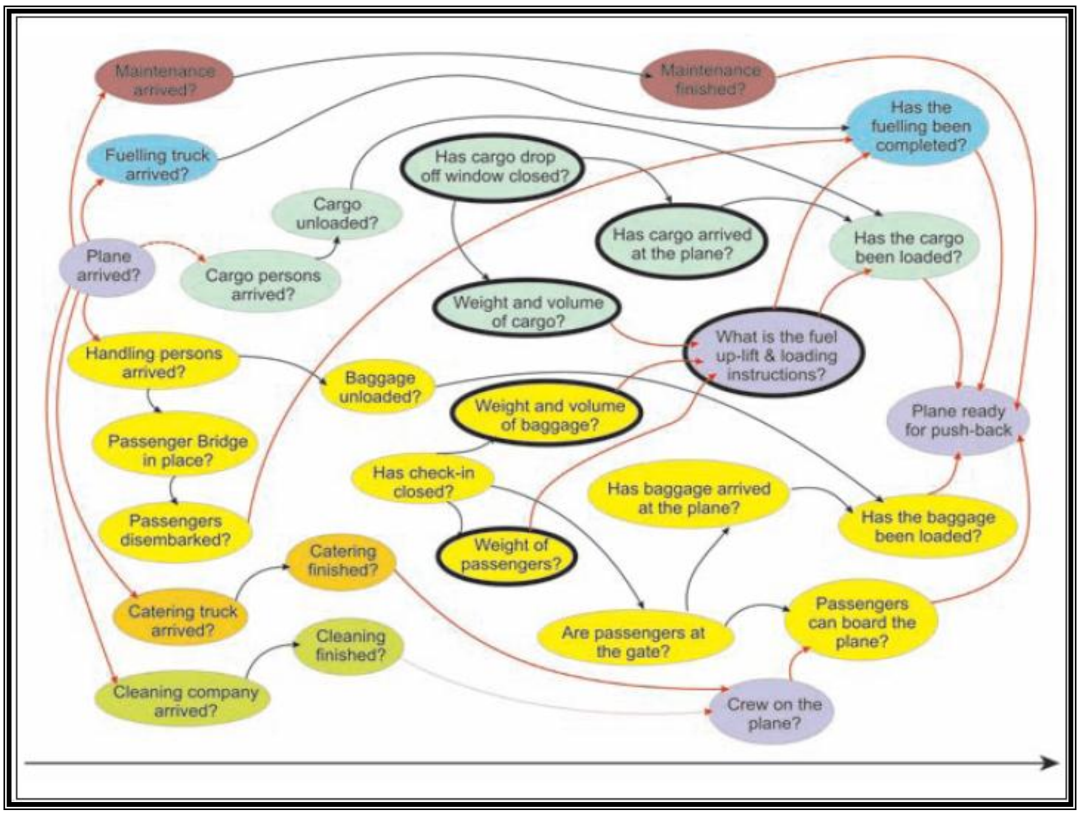

Figure 2-16 Work Flow Between Different Operational Departments
Source: Thorne, Price and Zitkova (2007)

2.7.2 Ground Crew Performance

The nature of the handling business requires dense labour care and attention. Basically, problems in turnarounds not only arise from equipment, but also from the managerial mistakes or the faults of the crew. There are some problems and mistakes that are routinely made by the ground handling employees which hinder the departure punctuality. Although attempts of automating the handling process and diminishing the human factor in handling operation have been observed in some of the airports, such as Dallas Forth Worth, the desired and planned success has never been accomplished when compared with the huge costs and investments. This complex handling process definitely requires a certain number of staff, even though the handling systems are automated. Therefore, as long as humans are involved in this process, the faults related to the human factor will be present.

Each flight requires a certain number of workers and equipment. Equipment and staff are arranged according to the number of flights in a certain time period. If late arrivals cause more congestion at airports due to overlapping with on time flights at related times, a gap will occur between the number of staff and the number of aircraft. If delays can be foreseen, extra employee(s) can be allocated. On the other hand, if the flight is cancelled on short notice, there will be unutilized staff.

The devotion of staff in the turnaround improves this process. For instance, ramp staff who checks the equipment and reports the defects on a regular basis, can prevent broken equipment from being brought to the parking stand. In most companies, there are reports to be filled in, just before leaving the work, with a list of the points that have to be known by the new group of staff before they start their shift. For example, if the defects of any equipment have not had been reported, without this information, staff that have just started their shift might bring the broken equipment to the next flight, and it would take extra time to replace it with an alternative from the equipment area.

Ramp staff mainly works between the baggage sorting area and parking stand during the aircraft turnaround, and they drive tractors to carry baggage carts and ULDs (Unit Loading Device). Ramp staffs are responsible for using the equipment and driving the vehicles under some rules. Table 2-2 illustrates possible errors at ramp that staff can make during both inbound and outbound of aircraft operation.

Table 2-2 Ground Crew Related Potential Break Down Points

Inbound	Errors/ Problems	Outbound	Errors/ Problems
Being ready at the position	• late arrival of ground crew • late offloading	**Load the bags from carousel to transporters**	• wrong distribution • damage the bags • slow loading
Manoeuvring	• wrong manoeuvre • hinder other equipment • time lose	**Locking the equipment**	• wrong locking • damage to equipment • damage to the load • falling bags, danger in the apron
Bringing the right equipment	• bring wrong equipment • less equipment	**Bringing the bags to park stand**	• apron accidents • falling bags to apron
Separating the bags from A/C	• wrong distribution • damage to the bags	**Manoeuvring**	• wrong manoeuvre • hinder other equipment • time lose
Locking the equipment	• wrong locking damage to the equipment • damage to the load • danger in the apron ways	**Loading the bags**	• wrong distribution • loading errors
Loading the bags to the carousel	• damage the bags • forget the bags • wrong carousel	**Pushback**	• late arrival of P/B car • missing equipment • break the equipment

Figure 2-17 is an example of another mistake of the crew which can result in apron accidents. Except in operational hours, equipment which is used in the apron has to be in equipment areas, or in the proper place and in the proper condition. If there are aircraft which have long ground time, equipment can stay at the parking stand only under some safety rules. For instance, loaders, wheelchair or catering trucks, which have a lift system to reach high doors of the aircraft, cannot be left in the lift up position. Wind or strong engine emissions present can make this large equipment fall over.

Figure 2-17 Ground Crew Error in Ramp Operation-Leaving the Truck Lift on
Source: Carvalho (2000)

Figure 2-18 and Figure 2-19 demonstrate another example of crew error. There are certain roads and certain speed limits for these vehicles that have to be followed for safety reasons. Each staff has to drive the vehicles within these speed limits. Especially, where there is limited time for aircraft turnaround, staff tends to drive faster for quicker completion of operations. This situation can cause accidents, and as a result, hinder the operations. Additionally, these errors affect the other tasks of handling and can result in unexpected departure delays, as well as extreme costs for both airlines and handlers.

Figure 2-18 Ground Crew Error in Ramp Operation-Leaving the Equipment in Improper Areas
Source: Christoper, (2000)

Figure 2-19 Example of ground crew error in ramp operation
Source: Elbert (1980)

2.7.3 Worker Strategies of Handling Agents

The success of the handling companies, as previously mentioned, depends on equipment and staff, as well as how the company manages these two factors. Economic crises and fluctuations in oil prices, as well as the terrorist attacks have hit the aviation industry very hard. Therefore, handlers also have to be more strict and careful about their expenditure and investments. As mostly witnessed in many markets, the first cost the companies usually cut is the labour expenses, which leads to a further decline in airline services and standards. This practice also leads to further expenses due to additional delays and unexpected accidents of the ground crew.

Equipment and Staff

Airlines are the only customer of ground handlers. The number of contracted airlines of handling companies may change every year. Because of the worldwide crisis and due to fluctuation in economies, while some of the airlines go into bankruptcy, some of them change the handling company to the one that provides the lower price in service. Handling companies may have, for example, 20 airlines to work for within one year, and in another year they may have 10 airlines to serve, or vice versa. In this respect, the equipment and staff allocation, and investment planning are very crucial in ground handling companies.

Period of turnaround is very closely related to the number of equipment and staff which serve the related aircraft. When the aircraft arrives, the ground crew has to position the equipment, offload the bags, clean the aircraft and then reload the outgoing bags. This work flow requires a certain number of specific workers and equipment, depending on the type of the aircraft, as well as the amount of payload. Airlines determine staff and equipment requirements for turnaround in the service level agreement which is signed with handling.

In handling companies which work with a minimum equipment pool, the equipment maintenance has to be done in the low season and scheduling maintenance has to be arranged in the most proper way. An increase in unscheduled equipment outages during core working hours gives handlers and airlines increased levels of maintenance activities, and consequently, more equipment related delays.

Seasonal Employment

Seasonal employment is needed by some sectors in certain periods of time, such as sugar and preserving industries in Hungary, fruit and vegetables processing in India, or more general tourism in almost every country (Geneva International Labour Office, 1991). Aviation is one of those sectors that requires seasonal employment to meet the boom in demand at certain periods. The nature of the business also requires seasonal employment due to high demand in summer time. Unfortunately, even though the seasonal employment is necessary to reduce annual labour costs, this application also brings some problems.

Airlines and commonly, the ground handling companies prefer to employ part time and temporary staff to cope with increased traffic, but unfortunately this tendency causes many problems, especially in establishing aircraft turnaround. It is customary for many handlers to employ seasonal staff in order to cope with the demands that are brought about by the “peak season”. However, during the “Low season”, their services are no longer needed and they are eventually laid off. This short term solution apparently brings more problems than solutions, creating a menace unto itself. Insufficient experienced employees and untrained workers increase the interruption of the harmonization of the turnarounds. In the operation with new seasonal employees, the ground chief is the essential person to direct and control the operation. It is observed in Istanbul that non-experienced supervisors without managing skills have failed in the operations of aircraft turnarounds, and this has resulted in delays, especially in charter flights. On the other hand, while the experienced workers can start to process their tasks without supervision, unfortunately, it is not the case with the seasonal employees.

2.7.4 Air Traffic and Airside Restrictions

Arrival Delays

Schedule Punctuality of airlines depends on arrival punctuality of inbound aircraft, and also on the efficiency of aircraft turnaround (Wu and Caves, 2000), but on the other hand, efficiency of turnaround is deeply related with arrival punctuality. The departure punctuality and regular work pattern of ground crew is mostly seen in the flights which have arrival punctuality.

Arrival delays and clashing of many aircraft at once are events that can cause extra workload for the handling agent. To have more aircraft on ground than planned at certain hours, causes incorrect distribution of certain types of staff[23] and numbers of ground crew.

Late arrival of aircraft is the biggest problem facing handling companies in terms of aircraft turnaround. The number of staff and equipment arranged for any planned turnaround decreases in peak hours when there are many aircraft on ground waiting for service. If there are any changes in the arrival time of aircraft, equipment and staff distribution will be more difficult for handlers to serve the delayed airplane on-time.

Problems can occur when delayed arrivals combine with the on-time arrivals. For example, the table below demonstrates scheduled arrival time of airlines and estimated arrival time of airlines.

Table 2-3 Actual and Estimated Time of Arrivals

	STA*	***ETA****
AIRLINE A	*14:00*	*14:50*
AIRLINE B	*14:05*	*14:55*
AIRLINE C	*14:20*	*15:00*
AIRLINE D	*15:00*	*15:00*
AIRLINE E	*15:05*	*15:05*
AIRLINE F	*15:20*	*15:20*

**STA=Scheduled Time of Arrival*

**ETA= Estimated Time of Arrival*

According to the table, the handling agent expected three flights at 15:00 period, but the flights which were expected to arrive at 14:00 are delayed, and they will also arrive at 15:00 period as well. Numbers of employees and equipment which are planned for serving three aircraft will definitely not be enough for serving six aircraft at the same

[23] Ground crews have different responsibilities and different certifications according to their ability to use ground equipment. This discrimination arises from the type of equipment that they can use. The standard crew has no permission to drive specific equipment unless they are certified. Another classification among the workers depends on the part they work, such as cleaning crew, loading/offloading crew or drivers.

time. Late arrivals clashed with on-time flights and results in the service being performed with less number of employees than planned.

Slots

“In Europe, aircraft operators are required to submit a flight plan at least one hour prior to the flight departure. They receive in return an air traffic flow management (ATFM) slot, which corresponds to the time at which the aircraft can take off without creating an overflow in the air traffic management system. ATFM slots are typically issued when there is a lack of intrinsic capacity, in air traffic control centers or airports, or when there is an unexpected constraint on capacity (such as fog, thunderstorms, technical systems failure, etc.)” (Commission of the European Communities, 2007). Another slot, which are known as airport slots, “are usually defined as an arrival or departure time at an airport- typically within a 15-or 30- minute period. As soon as airport capacity is no longer available in excess, it becomes necessary to specify and define slots.[24] They are different from ATC slot which are takeoff and landing times assigned to the airline by ATC authorities” (Graham, 2003). In ATC slot, basically, there are some routes and committed number of aircraft to these routes according to the report points.

Whatever the reason for the slot is, airlines have restrictions on departure times in some busy airports, and these restrictions force handlers to perform their duty in more limited time because exceeding the slot time can cause enormous costs to airlines. Sometimes, handlers can use their initiative to serve first and work more intensely for the airlines which have a slot restriction. This situation affects the balance of the number of workers and work rhythm of handlers which have to serve many aircraft at the same time.

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[24] In airport slot, each airport authority determines its own capacity. If the airport slot capacity is determined as 30 aircraft in a certain hour period, there is no slot application to first 30 aircraft according to the slot request priority. When the number exceeds 30, the arrival time of these aircraft are adjusted and spread to the most convenient time period for airport. Situation of overrunning the slot time, airport charges certain amount of payment according to some conditions.

2.7.5 Airline Strategies

In the compensating of late arrivals and for efficient turnaround, an airline's strategies are very important. It is observed that airlines create differences in the working pattern of workers. With the exception of positioning the equipment, all other tasks in the graphic are mostly related with number of passenger and amount of load. The embarkation of 178 passengers cannot be the same as 50 passengers for another plane. Loading an almost empty aircraft requires less time compared to an aircraft full with cargo and bags.

Figure 2-20, below, was created from the flights with a full complement of passengers, and shows a comparison between two major airlines served by the same handling company. As depicted in the figure, the loading process of X airline is shorter than Y airline.

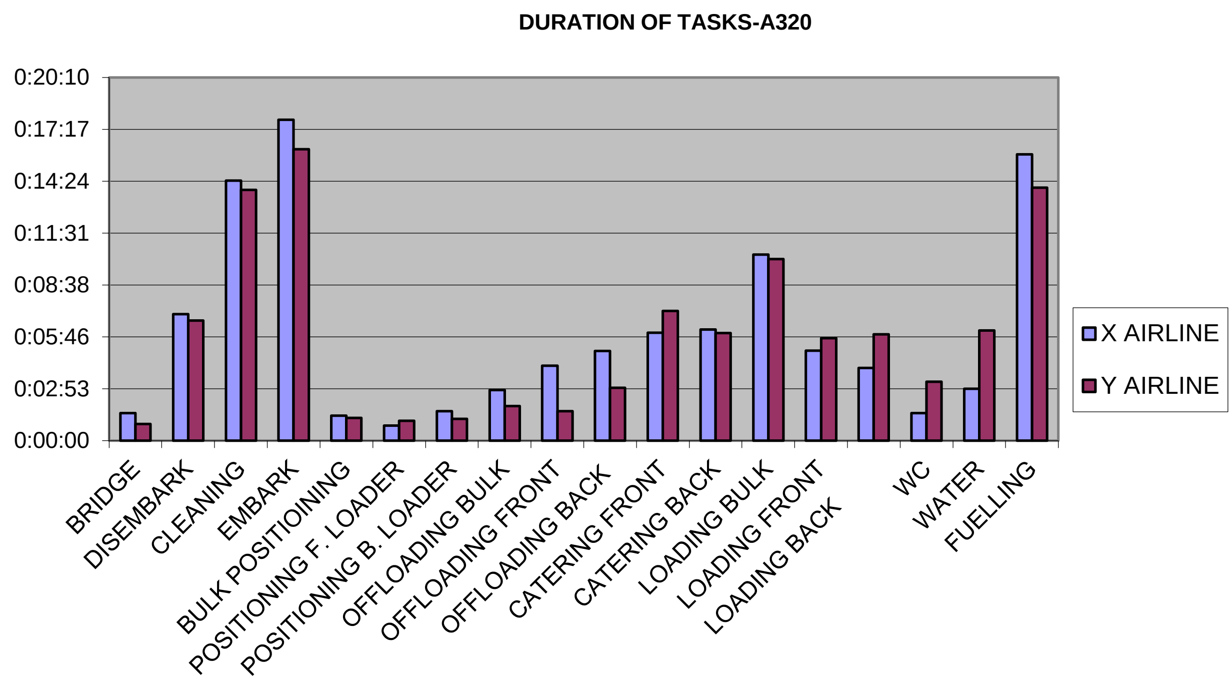

Figure 2-20 Duration of Tasks in A320

The reasons for different loading times in this observation depend on some criteria related with the airline, such as:

Container stock:

Airlines have to have sufficient numbers of containers stock at airports, especially in busy or hub airports, to have faster unit load device (ULD) loading times for each type of aircraft. Airlines have to have efficient ULD Management to control ULDs number in each airport. Not only the airline, but handling companies also have to be aware of their container stock and have to inform the airline about the container needs via messaging systems. The container stock problem is one of the reasons which increases the departure delay, especially in the late arrival flights. Workers wait for offloading the containers of incoming flights to have free containers, and then the loading process can only start after the offloading of arrival containers. Operating with minimum container can work properly for the airline if there is a sufficient number of handling staff and if it is not a peak hour. If there are containers in stock, ULDs can be prepared for the next flight, and most of the containers can be ready before the arrival of the aircraft.

Figure 2-20 shows that X airline has faster loading times compared with Y airline. One of the reasons for this is that X airline always has an adequate number of container stock in Istanbul, and there is no problem with container loading and preparing.

The container stock problem becomes more crucial in peak hours if aircraft park in a distant parking position. The parking positions which are away from the baggage sorting area require more time for transportation of containers from aircraft to baggage area and baggage area to aircraft.[25] Figure 2-21 depicts the travelling time between parking position outside peak hours in a sample airport in Istanbul.

[25] Some parking positions which are close to the custom control or baggage area are reserved for some legacy airlines although there is no written act between airport and airline. These airlines with the opportunity of being close to key places have advantage of faster turnaround in terms of short distances between aircraft and facilities.

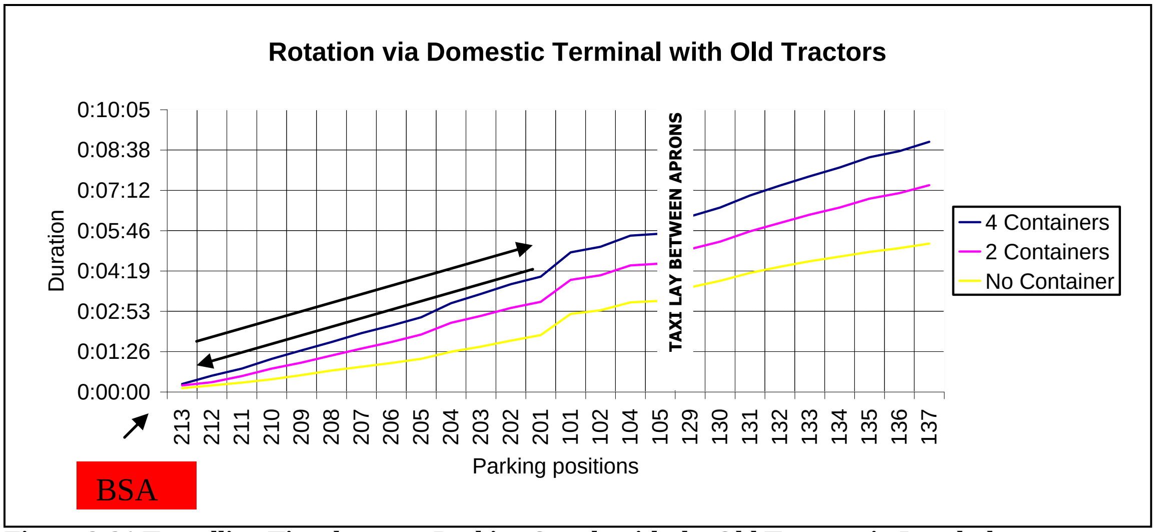

Figure 2-21 Travelling Time between Parking Stands with the Old Tractors in Istanbul

Figure 2-21 shows that if the airline does not have container stock, the aircraft which is parking at parking stand 201 has to wait minimum 08:14:00 minutes for its first four full containers to be at the parking stand. 08:14:00 minutes does not include the time spent in the baggage sorting area. Tractors which carry the containers also spend time in the baggage sorting area to change dollies and wait for preparation of containers to bring them to the aircraft stand. Congestion in the baggage sorting area and safety rules do not allow tractors to move faster. Especially, congestion in the baggage sorting area (BSA) causes delays in bringing containers to the parking position. The graphic below shows approximate time for travelling cycle between parking position and baggage carousel in Istanbul. If the airline has no container stock, the time that the tractor stays in BSA[26] and the number of trips the tractor has to traverse increases. When there are no containers in stock, the way of loading and offloading changes; instead of bringing 4 containers from aircraft to BSA, the tractor can carry each of them separately to gain time and start to put the bags in containers immediately. If the tractor has to increase the number of trips

[26] BSA is the place where all the bags are separated according to their destinations with the huge baggage carousel.

between parking position to BSA, then there will be a decrease in percentage of active ground crew numbers who can help to load under the aircraft.

Table 2-4 shows time that one tractor driver is occupied. From the parking stand 220 to BSA takes approximately 8 minutes and 31 seconds, and the return way is around 10 minutes 59 seconds, and the time that the tractor driver spends inside of the BSA is around 18 minutes 41 seconds - which means the tractor driver is occupied for 37 minutes 31 seconds. If 220 is considered as one of the closer parking stands to BSA, in other parking positions, especially the distant ones, having container stock becomes more crucial to the handler to avoid losing more time.

Table 2-4 Travelling Time between Baggage Sorting Area to Parking Position 220 in Istanbul Airport

	From 220→to BSA(213)	From BSA(213)→to 220	Inside BSA	Near the Aircraft
Full	0:02:09		0:00:25	
Empty		0:01:40		
Full	0:01:55		0:05:57	
Full		0:02:32		0:01:41
Empty	0:01:33		0:01:29	
Full		0:02:18		0:02:37
Empty	0:01:23		0:07:13	
Full		0:02:15		0:01:05
Empty	0:01:31		0:03:37	
full(only few bags)		0:02:14		
TOTAL	0:08:31	0:10:59	0:18:41	0:05:23

Apron configurations affect the duration of the travelling time of the baggage tractor. For example, while centralized pier finger airports, which have one or more central bag rooms in the main terminal area, can decrease the time of transporting the bags to parking stands, decentralized airports with a number of decentralized bag rooms can increase the travelling time in the apron area between terminals. Travelling time depends on location of parking stand and number of baggage sorting areas located in terminal areas.

Counters Hours

There is an average time for airlines to close their counters before departure. This time can be different according to airline strategies and flight type. IATA Delay Code 11- Late check-in due to acceptance after deadline is the result of this situation. In Figure 2-20, X airline's embarkation is longer than Y because X airline usually closes its counters later than Y airline so that, as depicted in the graphic, bulk loading of X airline is also longer than Y airline. The airline which accepts passenger up till the last minute for departure, has a longer bulk loading process because bags of final passengers are awaited by loading staff and the bulk conveyor is not removed from the aircraft to enable loading of those bags.

Airline Representatives

Airlines put in charge a group of people to represent themselves at airports. These people may work directly for an airline or be outsourced from external representative companies. Airline representatives are responsible for the affairs of the business. In turnaround of aircraft, airline representatives have some key duties. There are some standard times which each airline determines on its own, such as counter times, last passenger accepting time, opening time of counters, and time to start boarding, and airline representatives can have authority to intervene in these times. The decision of intervening in these times has an impact on passenger embarkation time, time of loading the bags and closing time of the airplane doors, and all these decisions have an impact on the under plane operations.

The airline representative's attitude can have a big impact on the ground handling working regime, and also on the ground crew. To have the best handling, airline representatives have to be aware of their handling agreements to compare how they are served and how they are promised to be served by the handling agent. It is observed in Istanbul that X airline's representative sanction is extremely high on the handling agent, and it results in satisfied service by providing the adequate number of workers, even in peak hour. None of the airline's turnarounds are performed with a staff gap. On the other hand, most of the representatives accept the situation of staff gap and don't mind, unless they have improper handling. Representatives' passive attitude stops the handlers from taking the necessary actions to have better service.

Aircraft Type

Aircraft type has significant impact on aircraft turnaround due to different equipment needs, different loading methods and time. For instance, different aircraft types have different ceiling height and, comparing to Boeing 737, DC9s cause employers to stow the baggage more in squat, stooped, kneeling or seated posture (Korkmaz *et al*., 2006), which also causes a longer loading time. This is probably why ramp operations are considered and require attention during the design phase of an aircraft, (Ashford, Stanton and Moore, 1997). Aircraft type has impact on service time of handlers and the aircraft turnaround process. While bulk loading aircraft requires more ground crew and a longer loading process, the ULD is the other way round. For example, W airline's back loading takes longer than the others, just because A321s in fleet have no bulk door for loading. To be able to load the ULDs to back hold[27] of aircraft, first ground crew has to wait for all bulk bags. After all the bulk bags are loaded, staff load the container from the doorway into the baggage compartment. This increases the time of the loading process, as seen in Figure 2-22. The back loading of W airline takes longer than Z; the other reason for this situation, as explained in the previous part, is not having enough containers in stock.

[27] The usual design of A321 includes back bulk door for the bulk type of bags. Models can be different because of the airline orders to the aircraft manufacturers

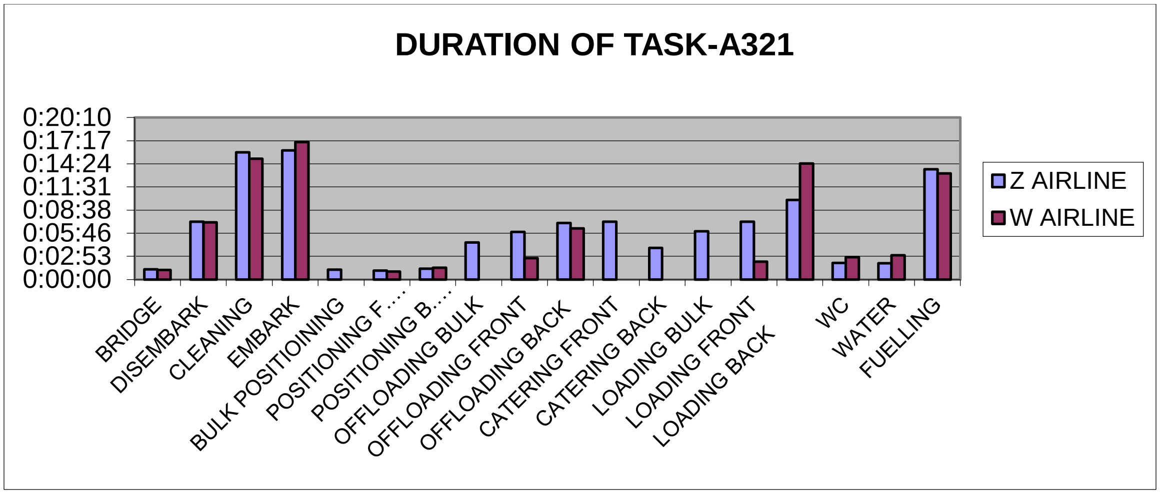

Figure 2-22 Modified Airbus 321's Time for Service in Turnarounds at Istanbul Airport

2.7.6 Airport

Terminal, apron design and facilities have considerable effect in the turnaround process. While the terminal design is related to passenger movements, arrivals and the boarding process, apron design and apron facilities are related to ramp operations, aircraft and ground vehicle movements. Location of parking positions, distance between equipment areas to parking stands or to loading areas determines the travelling time during ramp operations.

Apron lay-out is very important for airport users. The location of service suppliers, such as catering and fuelling, the location of baggage handling and equipment area, the design of airport and location of different aprons and connection ways between different aprons, is very important for handling companies. In Istanbul, impact of taxi lays, parking stands and the baggage sorting area in aircraft turnaround is observed. For example, taxi-lays have impact on travelling time of apron users. Figure 2-23 shows the taxi-lay and ground vehicle way intersection points in Istanbul Airport. These points are the bottlenecks in the peak hours. Especially in the peak hours, while aircraft are pushing back or waiting to go taxiing in taxi lanes, they hinder the flow of ground vehicles which are in a hurry to reach other aircraft waiting to be served at the parking stand.

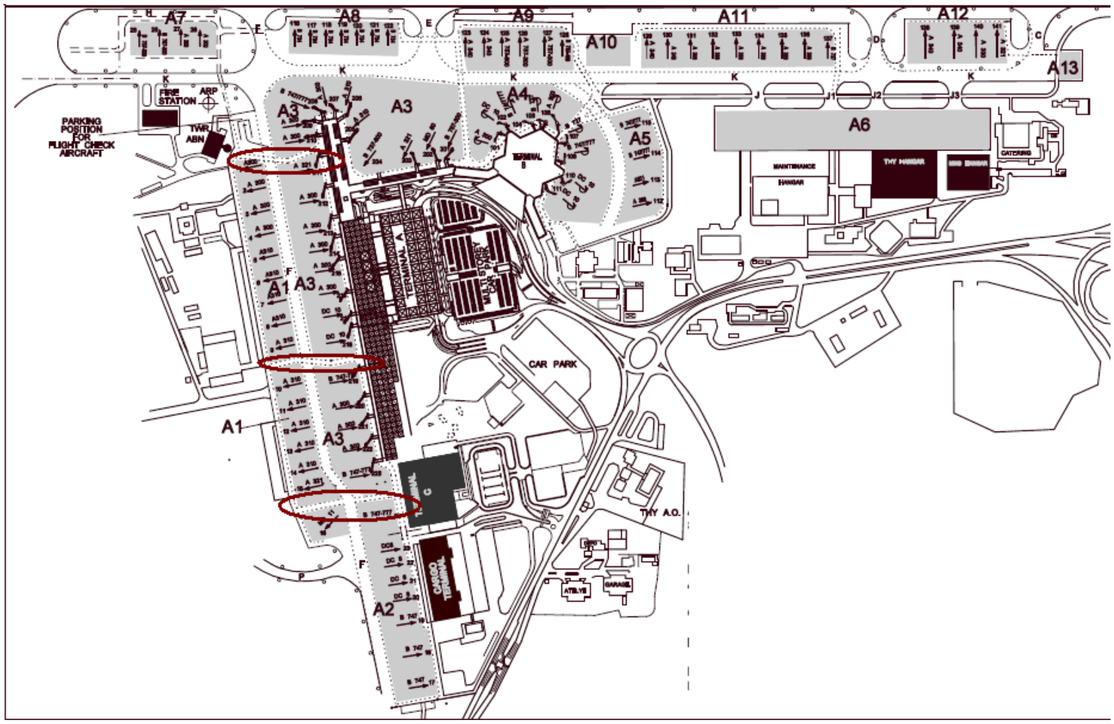

Figure 2-23 Istanbul Ataturk Airport Layout

Figure 2-24 depicts the travelling time between parking positions in non-peak and in peak hours. In peak hours, it is difficult to get a standard time for travelling because of congestion and density traffic of all the company's vehicles. Inevitably, these numbers show extreme deviations in the peak hours.

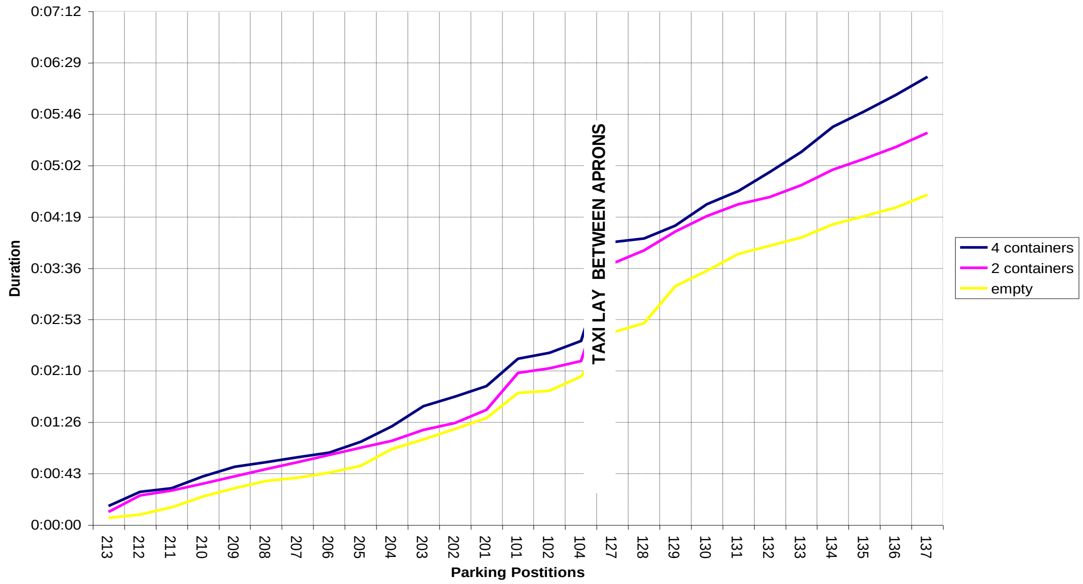

Figure 2-24 Travelling Time between Parking Stands

2.8 Improving Aircraft Turnaround Performance

"The extreme complexity of the ground handling operation requires skilled and dexterous management to ensure that staff and equipment resources are used at a reasonable level of efficiency" (Ashford, Stanton and Moore, 1997). In achieving the qualified and expected handling service, observing the process and interpreting each of the key steps in turnaround plays a significant role. Performance screening and interpreting can be done by airline, airport or handling agent by itself through service level agreements, or different models can be used.

There are common, well-known quality measurement systems used in the ground handling companies, such as IATA performance measurement of service delivery standards (AHM 804) and airport handling services (AHS 1000). Additional to these programs, some of the ground handling companies create their own quality measurement systems to monitor their handling performance. Handling agent and airline agree on which activities are to be measured, set standards and target achievement levels through a series of constructed interface meetings. Handling Agent then monitors performance and delivers measured results. Both parties then review the results - and then improvements can be made or corrective action can be taken. Usually, these systems are designed to be introduced into the normal working pattern of staff.

Performance and quality measurement systems are not an alternative for service level agreements, but they work with it and are compliant with service level agreements. These systems give an opportunity for the airlines to see measured results against agreed standards. However, these kind of programs are tools for handling companies to identify and solve recurring problems in operational processes, and also lead to improved staff efficiency. They also provide improved communications between handler and carrier.

Quality and performance measurement systems are usually composed of manual and computerized phases. In the manual part, staff are responsible for completing booklets which are prepared for recording when and how critical paths are performed. Staff have to note the exact time of the committed tasks in these booklets. Then, the data in these booklets should be transmitted to the programs in the computers which refer to the computerized phase. Monitoring each detail in every step in the process enables ascertaining which operational step caused the problems, or in which part staff lost more time in the turnaround process. If these programs are used in the most efficient way by handlers, the problems that hinder the turnaround process can be discovered and corrective actions can take place.

Figure 2-25 shows a sample of a quality management document from the different units-Ramp and Passenger handling agents. Required information is completed by staff. The accuracy of the information depends on the staff discretion.

Ramp Arrival		Airline:		Flt.No:	ÇELEBİ	
STA :	STD :	ATA :	ATD :	Date:		
RA A/C Type:	Block On :	ETA :	ETD :	Park Pos.:		YES/NO/ INSUFF.

1	Foreman in Charge in possession of CPM/LDM at ...		
2	All required equipment serviceable and on Stand at ...		
3	Staff available on Stand by block on.		
	Staff : / Foreman : / Operator (W/B Aircrafts) :		
4	A/C Beacon off before s/o coming near to the A/C.		
5	Hold Doors and IPLS serviceable		
6	Catering & Fuelling on Stand at ...		
7	Baby Buggies available at aircraft steps at ... / NO BUGGY		
8	Priority Bags leave A/C side at ...		
9	Inbound Priority Bags correctly stowed (stowed at .... (hold))		
10	Last Bags leave A/C side by NBA at ...		
11	by WBA at ...		
	AA signal sent at ...		
12	GSE Pax Crew buses ready to meet flight at ...		
13	Step positioned at ...		
	And Front door open at ...		
	Rear door open at ...		
14	Start Pax Disembarkation at ...		
15	First bag onto belt at ...		
	Last bag onto belt at ...		

COMMENTS:

Airline Rep. Approval

Ramp Departure		Airline:		Flt.No:	ÇELEBİ	
STA :	STD :	ATA :	ATD :	Date:		
RD A/C Type:		ETA :	ETD :	Park Pos.:		YES/NO

1	All current docs (Met, AIS, Flt. Pln, Slot, Load Sheet etc) available on board at ...		
2	Cleaning competed at ...		
3	Passenger doors and Holds closed at ...		
4	MVT sent at ...		
5	Catering completed at ...		
6	Boarding clearance given at ...		
7	Baby buggies all correctly stowed for quick offload		
	No Buggy / Yes, stowed at .... (hold)		
8	Steps removed at ...		
9	ULD's handling to be prepared for baggage at ...		
10	Use of Vacuum Cleaners .	..... ea	
11	Headset manned at ...		
12	Pushback tractor on aircraft at ...		

COMMENTS:

Airline Rep. Approval

Check-in		Airline:		Flt.No:	ÇELEBİ	
STA :	STD :	ATA :	ATD :	Date :		
PC Psg. In	Psg. Out	Check-in start:		Check-in close:		YES/NO

1	Briefing started at ...		
2	Correct number of desks open (average: 1 desk for 75 passengers)		
3	Desks are serviceable at ...		
4	Flight Identification displayed on VDU on time.		
5	All desks remain serviceable throughout Check-in process		
	Any discrepancy reported by Celebi staff during check-in regarding to failure of : DCS: FT: RT: / printer FT: RT: / belt FT: RT: / telephone: FT: RT: / other:............ FT: RT:	FT: Failed Time RT: Repaired Time	
6	Close-out at ...		
7	Final passenger figures/Purser Info to Rep./Ops at ...		

COMMENTS:

Airline Rep. Approval

Dep. Gate		Airline:		Flt.No:	ÇELEBİ	
STA :	STD :	ATA :	ATD :	Date:		
PD A/C Type:		ETA :	ETD :	Park Pos.:		YES/NO

1	Passengers called to gate at ...		
2	Staff at gate and equipment checked at ...		
	Equipment to be checked: printer: FT: RT: / gate reader: FT: RT: / announcement system: FT: RT: / telephone: FT: RT: / other:............ FT: RT:	FT: Failed Time RT: Repaired Time	
3	Buses ordered for boarding prior Boarding announcement made at ...		
4	Known delays announced at ...		
5	Security check starts at ... / NOT REQ.		
6	Special Care passengers pre-boarded / NOT REQ.		
	Is any equipment necessary?		
	Is equipment ready?		
	Is staff ready?		
7	General boarding starts at ...		
8	TOB confirmed to Ops staff at ...		

COMMENTS:

Airline Rep. Approval

Figure 2-25 Sample of AHS 1000-Quality Measurement Document
Source: Celebi (2006)

Although all these kinds of methods are useful to monitor the performance and operational efficiency of the ground handling companies, there are limitations and defects in the application of these systems. These problems usually arise from not understanding the meaning of quality systems and not understanding that the employees are the key element of these systems. To be able to use these programs in the most efficient way, a system has to be understood very well in all related departments which are involved in aircraft turn around, and also by administrative departments.

The quality and measurement systems require systematised data input. In the turnaround process, all related individuals, such as operation staff, ramp chiefs and traffic staff, have to write the exact time of the committed work. For example, the ramp supervisor or operation staff have to note when the first bag was on the belt, when the front door opened and when the buses were ready to meet the passengers, and traffic personnel have to note information such as when check-in counter is opened and closed or when boarding is started, etc. A major problem generally faced in this situation arises from the fact that staff do not write the exact time that they performed the task, but the appropriate listed time for doing it. This is because the staff do not understand the system and the logic behind it, and they think that writing the accurate time will display their performance in a bad way. Unfortunately, this kind of attitude of the staff brings about difficulties in understanding the problems in operations and the reasons for the time lost - in other words, preventing the goals set for quality and performance measurement.

Another problem in application of these systems is lack of time. The turnaround process is complex and has to be completed as quickly as possible, meaning that operational units are always in a hurry and the filling in of these booklets in the operational process is an additional work load for them. Most of the employees do not want to spend extra time filling in these booklets at the moment of the process, so they fill them in during another time period when they are free. This behaviour of employees also prevents obtaining exact data about the turnaround process because the data they note in the booklets after the operations are usually not the actual times of actions.

This negative attitude of the staff results from the fact that the system is not explained effectively and in relation to that, the staff do not feel a part of the system presented to them.

3. IMPACT OF AIRPORTS ON HANDLING OPERATIONS

3.1 Airports in Terms of Ground Handling

"Airports act as a forum in which disparate elements and activities are brought together to facilitate, for passengers and freight, the interchange between air and surface transport" (Doganis, 1998). An airport is like an intersection point for all aviation units. All activities from various partners, such as ground handlers, airport operators, aircraft operators, air traffic control (ATC) and central flow management (CFMU) units, intersect on this interface.

With the increasing demand for air transportation, recently, most of the European Airports, as well as the U.S. airports have shown a great increase in their numbers of passengers and aircraft operations. The capacity of these airports has started not to meet the demand from these various partners. The gap has occurred between airport facilities and aircraft operations. Most of the airports have become serious bottlenecks for air transportation, and this situation makes the work conditions of all other partners whose tasks depend on the airport more difficult.

There are certain factors, such as airport privatization, commercialization, congestion of airport infrastructure, rapid growth of traffic, the formation of global airport groups, airline market deregulation and alliances, which make airport managers and authorities consider the ways to make best use of airport capacity. Actually, the liberalization of the air transport market, proposing single "European Sky" initiatives, increased the air traffic and resulted in congestion, and it turned the focus on airports (Commission of European Communities, 2007). Most of the airports improve their management skills and look for ways to add value to their operations, and handlers are one of those areas which will benefit the most from any improvements on effective management and the usage of airport capacity.

Handling operators are one of the airport users whose success in the activities they conduct are closely related with the airport conditions. In order to deliver the final handling service to the airline, handlers need to contract with the airport for access and usage of central infrastructure facilities (Fuhr, 2006). Availability of check-in desk, queuing times and proper space in arrivals and departures, providing minimum connection times, baggage processing, conditions of baggage belts and condition of baggage sorting areas, are some of the handling issues which most airports are responsible for.[28] The conditions of baggage sorting areas, equipment areas, check-in areas, distances between facilities, design of apron area, and so on are all related to the handling companies.

Facilities of the airport are one of the factors that can help the handlers have more flexible operations at the peak and congested periods. As an infrastructure supplier, the airport is one of the key points that allows the ground handling to establish the processes of aircraft turnaround and to work efficiently.

Airports can function as supportive tools for the operators to minimize the turnaround time. All the improvements, as well as the enhancements conducted in the airports help the handlers work properly in a user-friendly atmosphere and reduce the airport related handling delays.

Airports, type of airports or the design and facility of the airports are extremely important issues, previously discussed and explained during the years by Ashford, Stanton and Moore (1997), De Neufville and Odoni (2003) and Kazda and Caves (2007). The issue of the design and the infrastructure of an airport is very detailed and intricate. In this thesis, only some of the airport facilities and design will be evaluated in terms of ground handling. Only those parts of the airport that have an impact on passenger and baggage handling, and aircraft turnaround operations will be touched upon and will be discussed.

From the moment that the passengers enter the airport, the work flow of the ground handling starts, and by the departure of the related aircraft, the work flow ends. During this intricate process, the facilities of the airport where the passengers and bags are processed play a paramount role in the handling operations. The control and the management of the passengers and baggage flow in terminal side and airside are some of the issues that most of the large and medium sized airports focus on to create strategies

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[28] In United States, airlines have control on most of these issues at the major airports.

for smooth flow - the easier and quicker passenger and freight processing, the increased probability of having better and quicker turnarounds.

3.2 Handling-Airport harmonization-Point view of Management

The influence of the government is still dominant in most of the European airports, mostly in the design of the construction, as well as the capacity enlargement period, but “commercial airports are managed or owned by the private sector, results been sufficiently encouraging to stimulate further interest by the private sector” (Button, 2006).

In terms of management of airports, in the case of the United States, local governments have the control of the airports. The strict control of the local governments did not let the airports in the United States be active in global competition. However, the management strategy of United States airports, which gives privileges to airlines on airport business and lets airlines control their own operations, results in an efficient use of airport facilities. For instance, baggage handling systems in most of the United States airports have been built by the airlines and paid for over long term periods, and many terminals are owned by airlines (Doganis, 1998). Consequently, the work style and responsibilities, labour and asset pool of handling companies differ due to airport managerial structure.

Airport activities are mostly shared between airport authority, aircraft operators or other authorities and agents. Proportion of the duties may differ from airport to airport. In some airports, most of the activities are established by the airport authority, such as Frankfurt and Hong Kong, and in some airports, especially in the United States, airlines establish most of the activities while some of the airports have individual handling companies to carry out their handling operations. Figure 3-1shows the difference between Frankfurt and Atlanta airports pertaining to the provided services and activities.

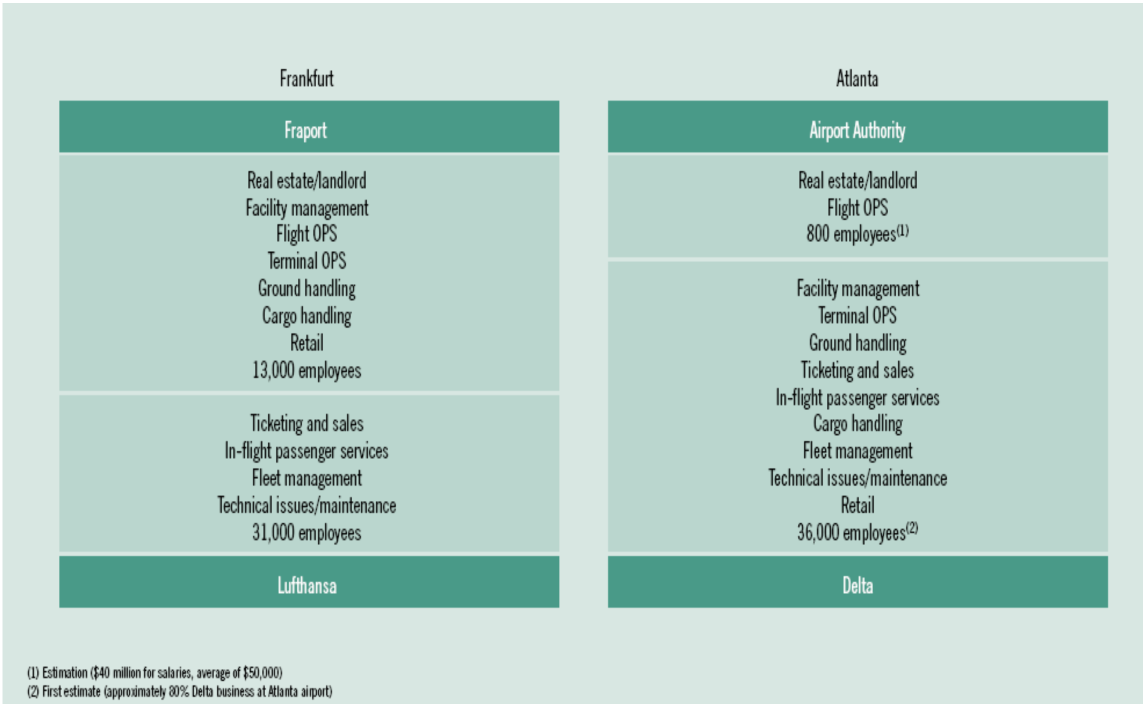

Figure 3-1 Service Supply Comparison of Atlanta and Frankfurt Airports in 2004
Source: Boston Consulting Group (2004)

At different airports, reasons for delays may differ due to different characteristics of airport and handling operations. For example, in Figure 3-2, London Heathrow, Charles de Gaulle and Rome Fuimicino airports have more problems in ground operations, while Amsterdam and Barcelona airports have less, regardless of the high traffic numbers they have. Local drivers at airports also have different impact on delays.

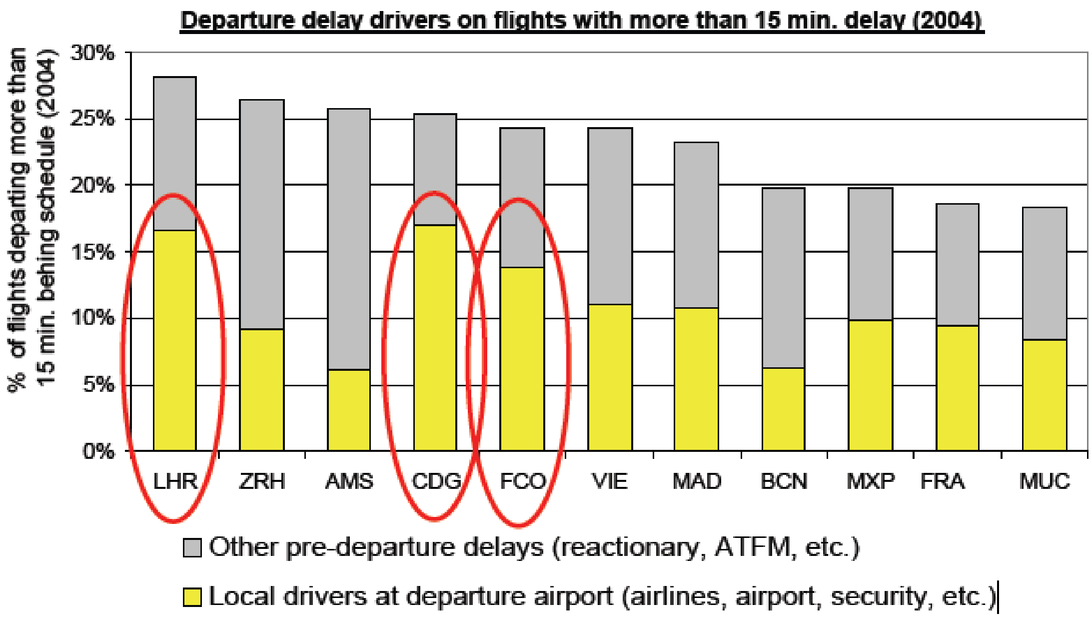

Figure 3-2 Departure Delay Drivers on Flights
Source: Reichmuth (2005)

3.2.1 New Management Approaches- CDM

An airport has three elements: the airspace, airfield and passenger terminal. Each element has different types of flows. The airspace is the element of the airport used by different types of aircraft in flight, the airfield is the element used by aircraft, vehicles and equipment on the ground, and the passenger terminal is the element supporting the flows of passenger and baggage. All operations which occur in these three different parts of an airport are closely intertwined with each other. The communication and the data flow among these parts enables harmonized operations at the airport. For the better operations at airports, some skills are improved, such as strong communication and data feedback from different authorities to increase traffic predictability and planning capability. Collaborative decision making (CDM) is one of the results of these efforts and understanding the importance of data flow of the different partners. "The objective of the Airport CDM project is to improve the overall efficiency of operations at an airport, with a particular focus on the aircraft turnaround procedures. This is achieved by enhancing the decision-making process by the sharing of up-to-date relevant information, and by taking into account the preferences, available resources and the requirements of those who are involved at the airport (such as airline operators, air traffic control, handling agents, and the airport management)" (EUROCONTROL, 2006). The U.S. Federal aviation authority (FAA) reported that airports with CDM implementation have shown an increase of on-time departures by 15% (EUROCONTROL, 2004).

3.2.2 Service Level Agreements between Airport and Airport Users

With the change in framework of airports from government bodies to private businesses, the importance of providing customer satisfaction has increased for the airports. Passengers are not the only users of airports; there are various constituent groups associated with the airports, and hence, the airport service varies according to their needs. "Main airports increasingly slide away from their historic ideal of providing a consistent level-of-service across all their passenger buildings, towards offering a range of differentiated processes for handling passengers and aircraft" (DeNeufville, 2006). Airports start to improve some skills to see how efficiently their facilities have been used by the airport users, and which level of quality is perceived by the customers. These efforts have positive impacts on harmonization and consistency of operations between airline, handlers and the airport. One of the conclusions of these efforts is the creation of the service level agreements which aim to set standards for the goodness of the operations and improve their facility usage. "There is a growing interest in the air transport industry to use such agreements in order to formalize service provision between airport operators and airlines and other key users" (Graham, 2003). Since the airports have been focused on quality monitoring and realized the importance of benchmarking between different airports, airport users, including airlines and ground handling agents, also benefit from these quality improvements of the facilities at the airports. Some of the main inputs of service delivery issues related to handling airline operations at airports, are listed in the following table.

Table 3-1 Criteria Related to Handling Operations at Airports

Performance Inputs	Design Inputs
• **Baggage delivery times** • **Number of check-in desks open vs length of check-in queue** • **Processing time at the check-in counter waiting time in check-in counter, availability of space at the check-in counter,** • **Performance of airbuses at gate** • **Performance of passenger boarding bridges** • **Airbridge usage rate** • **Flight punctuality** • **Availability of baggage belts** • **Customs waiting time** • **Waiting and processing time at the security screening** • **Connecting time of transfers**	• **Area of apron (m^2)** • **Departure lounge (m^2) number of seats and space availability** • **Number of check-in counters (m^2)** • **Number of vehicle parking spaces (m^2)** • **Baggage claim area (m^2)**

In order to achieve success and harmonization on these topics for better airline and handling operations at airports, there has to be well-settled service level agreements with the definition of standards and objectives. Any improvement in airport service quality on the common use facilities, such as availability of trolleys, lifts, passenger movers, baggage conveyers, congestion on the halls and baggage claim areas, etc., have a positive impact on airport customers in terms of quick and comfortable transfer of passengers and baggage. This kind of improvement can be made by setting clear objectives and making the responsibilities clear for each constituent group.

3.3 Handling-Airport harmonization-Point view of Traffic Type and Traffic Number

Airports are basically classified as hub and non-hub. Another more detailed classification is shown in Figure 3-3.

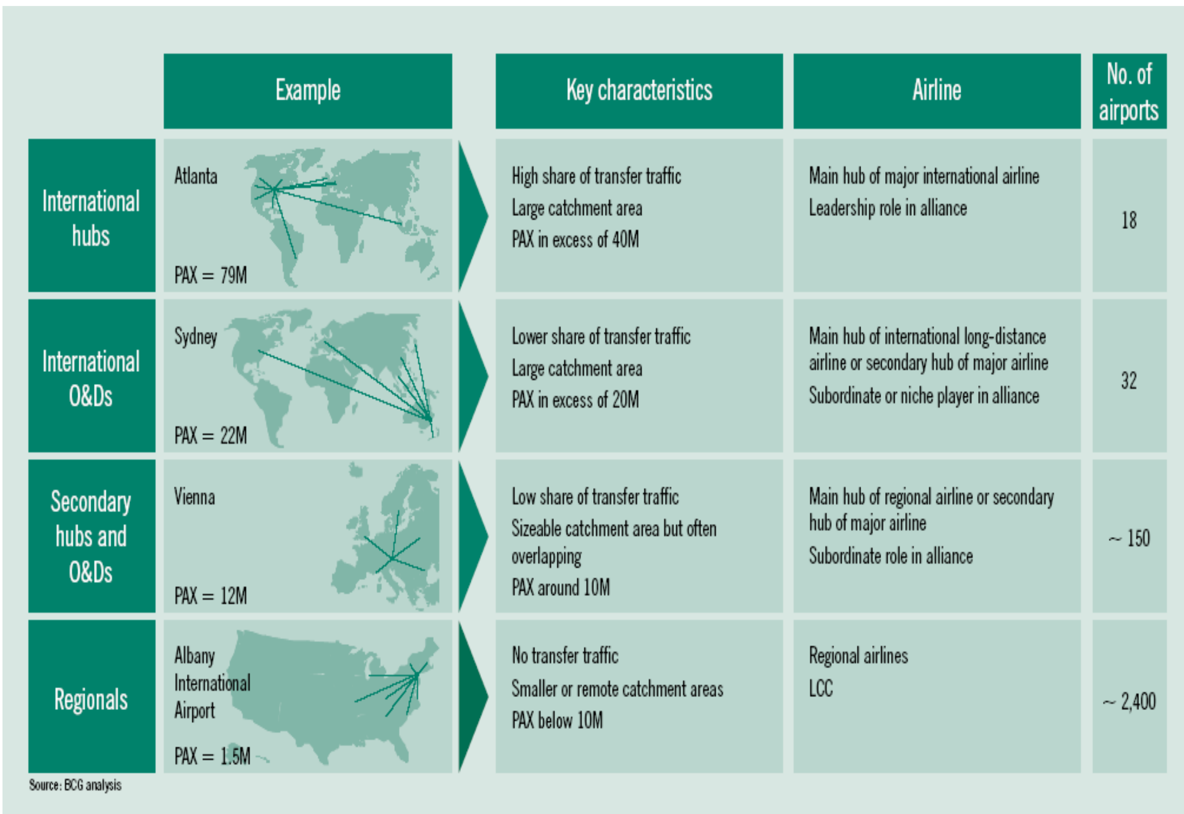

Figure 3-3 Airport Classification
Source: Boston Consulting Group (2004)

In this figure, definition of the hub airport depends on the transfer traffic, while the FAA defines the hub according to their level of traffic. Different airports with different type of traffic and different amount of traffic have different operational characteristics. Basically, operational differences arise from the size, the design and the management of the airports. The operations in hub airports differ from the international origin and destination airports. For instance, while most of the operations at the hub airports require quick transfer times and shorter ground times, most of the operations at origin and destination airports require longer ground time with longer and detailed aircraft turnarounds.

At a hubbing airport, an airline schedules a group of flights to arrive within a given peak hour during the day and depart as quickly as schedule permits, allowing passengers to change planes and be on their way with minimal inconvenience (United States Department of Transportation, 1991). “Consequently, airlines hubbing at an airport they wish to control their operations there, and wish to have particularly close control over the aircraft turnarounds and transfer of passenger and bags” (Caves and Gosling, 1999).

The airport operators and airlines which have a hub strategy, or the airports which have a dominant carrier have to consider the requirements of hub traffic. Generally, airport designs are not convenient for transfer passenger flow due to not being considered in the design and planning phase (De Neufville and Odoni 2003). Airports chosen as hubs have to be ready to meet the increased traffic, increased capacity and congestion. The management of the airport has to be able to react quickly and arrange the design of the airport in a timely manner.

The problem in a hub airport is related to traffic, but caused by airline scheduling practices. “As a complementary result of hub and spoke system, European airlines concentrated their networks in time by adopting wave system structure which is to optimise the number and quality of connections offered by an airline” (Burghouwt and Wit, 2003). In this situation, airports experience waves of inbound or outbound flights in certain hour periods. In these peak hours, besides the airport, handlers also have an over workload. These hours require a flexible airport and handling structure, which allows handling a high amount of transfer traffic.

Unlike the hub airport, the non-hub airport is not dominated by a home-carrier, but it is served by a greater diversity of airlines than the hub airport. Its network is mainly continental links. Non-hub operations do not depend on transfer traffic as it is the case in hubs, where the home carrier is feeding and de-feeding its intercontinental network with short and medium haul spokes. At the non-hub airports, handlers which have a wide range of customers, must have a sufficient number of equipment and staff for the long processes of loading, embarking and check-in services. Even if the airport is not a hub, they have bunches of flights in certain time periods of days due to the tendency of airlines to schedule flights in favourite times of the day, such as early in the mornings and nights.

It is clear that hub airports are larger and experiencing additional delays (Niehues *et al*., 2004; Mayer and Sinai, 2003). The hub airports serve much more traffic than non-hubs, and also, they experience a much higher number of fifteen minutes or longer delays each year (Rutner and Mundy, 1996). According to a study using the data derived from the U.S. Department of Transport (D.O.T.), on nearly 67 million flights at more than 250 airports between 1988 and 2000, flights leaving from large hubs are 6 % points less likely to be on time than flights departing from airports where the carrier does not hub, and on the other hand, flights that depart from the largest hub airports are arriving at their destination almost a minute more behind schedule than flights that do not depart from a hub airport (Mayer and Sinai, 2003). Figure 3-4 depicts the on-time performance of airlines at different types of airports. [29]

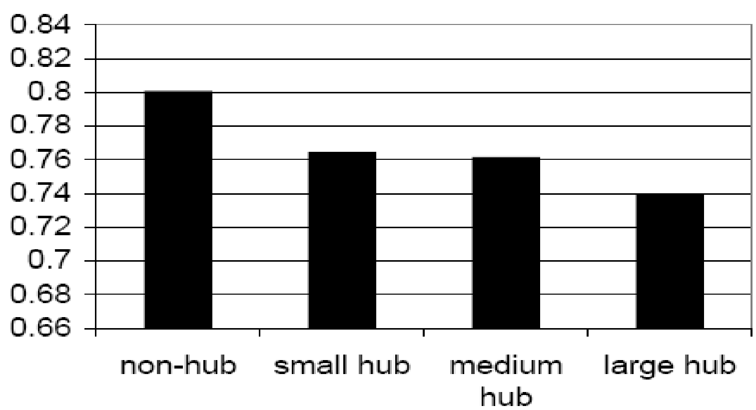

Figure 3-4 On-time Performance on Originating Flights by Airline Hub Status
Source: Mayer and Sinai (2003)

[29] According to another study, made by Rupp et al, 2003, at US airports, indicates, however, the contrary result, such as airport hub origination flights have significantly better on-time performance (2.3 percentage points higher) than flights that originate from non-hub airports. The airport hub destination effect is even larger in magnitude as these flights had higher on-time flight arrival rates than flights not destined for hub airports.

In terms of the handling operations, the services entail different characteristics in different types of airports. At the hub airports with more additional traffic, obviously the work pattern and organization of handling companies differs from the non-hub or less congested airports. On the other hand, “at the hub airports which basically depend on transfer traffic, terminal operations will be simpler since transfer passengers do not require check-in facilities, baggage delivery, or easy access to and from ground transportation” (DeNeufville, 2003). In terms of apron operations, hub airports require quick, transfer based operations, compared to origin and destination type of airports. In the last decade, with the emergence of LCCs (Low Cost Carriers), a new type of airport has also emerged, which is called the Low Cost Airport. Low cost airports are mainly the secondary airports which have reasonably low traffic compared to the main airports feeding the city. Low traffic lets airlines have better handling services and quicker turnarounds. “LCCs prefer to avoid congested airports which cause long waiting times to land or take off, queuing for an open gate, taxiing late distances, queuing in the handling services such as waiting for bags, boarding and cleaning. This strategy permits LCCs to achieve aircraft productivity often more than 50% greater than the legacy carriers” (Warnock-Smitch, et. al., 2005). The choice of the low cost airports for the quicker turnarounds is an indicator of how important the airport is in handling operations. Quicker baggage and check-in services, and quicker loading times in low cost airports inevitably decrease the time for turnarounds.

3.4 Handling-Airport harmonization- Point view of Design and Layout

“Deregulation/liberalization of the airport industry worldwide has increased the demands for airport services as well as the demand for faster and more efficient processing of aircraft, passengers, cargo and baggage” (Oum, Yu and Fu, 2003). This demand has to be met with proper capacity, both by handlers and airport, but airside infrastructure is not the only determinant of capacity of an airport - but also the ground resource elements (Reynolds-Feighan and Button, 1999).

In the new era where the new airports appear, the old, far located airports are renewed and even the old military airports are opened to commercial traffic, airports have to review their design and managerial methods according to their traffic type to conduct the operations in the most efficient way.

Whether the airport is a hub, regional or international origin destination airport, the well designed facilities in both terminal building and apron area are remedies for the handlers[30] to perform their duties.

"Handling operations are inseparable from airport facilities. Provision of handling services to the airline requires both, ex-ante investments by the ground handler and ex-ante investments with essential character by the airport" (Fuhr, 2006). The basic functions of an airport are to provide access for aircraft to the national airspace, to permit easy interchange between aircraft and to facilitate the consolidation of traffic. In order to perform these functions, the airport must have several basic infrastructure elements present, such as runway, taxiways, aprons (airside infrastructure) and airport ground resources for passengers or cargo. Excluding the ATC, network and runway capacity at airports, airport design and operational standards have a noteworthy impact on departure delays. Airport design and facilities can be an advantage or a disadvantage for the handlers in turnarounds, especially while they are trying to compensate for the arrival delays. The design of the airport influences the ground handling operations in terms of two main perspectives: passenger services inside of building and ramp operations outside of the building. Design and handling relationship will be explained in more detail in Chapter 3.5.

[30] The term of "handler" is used in this thesis to express any agent such as airports, airlines or the ground handling agents which perform the handling activities.

3.5 Terminal Design and Handling Operations

Terminal concepts are generally listed in five basic categories, and each of the concepts has different advantages and disadvantages in terms of handling operations. The type of traffic that flows from the terminal is the basic issue to decide which kind of terminal design is best for the current traffic, such as transfer, season traffic or origin destination traffic. "For instance, in general, finger piers are preferable when the level of transfer traffic is low, and linear midfield concourses are best when transfer traffic is high. Transporter solutions are economical when the seasonal traffic peaks are more than twice that of the low season" (De Neufville and Odoni, 2003). Airports which were built many years ago, where there was no significant traffic, were built using a simple design, and no one thought about their operational efficiency, especially for ground handling operations. So that ground handling companies try to operate in inappropriately designed airports and adapt their movements according to the design of the airport

3.5.1 Pier/Finger Terminals

The Pier/Finger Terminal concept can vary from airport to airport. Many airports have pier finger terminals in use. In most of the airports, as soon as the capacity reaches the limits, basically, the simplest way is to introduce or extend new piers to have more capacity in terms of new boarding areas and piers (Kazda and Caves, 2007).

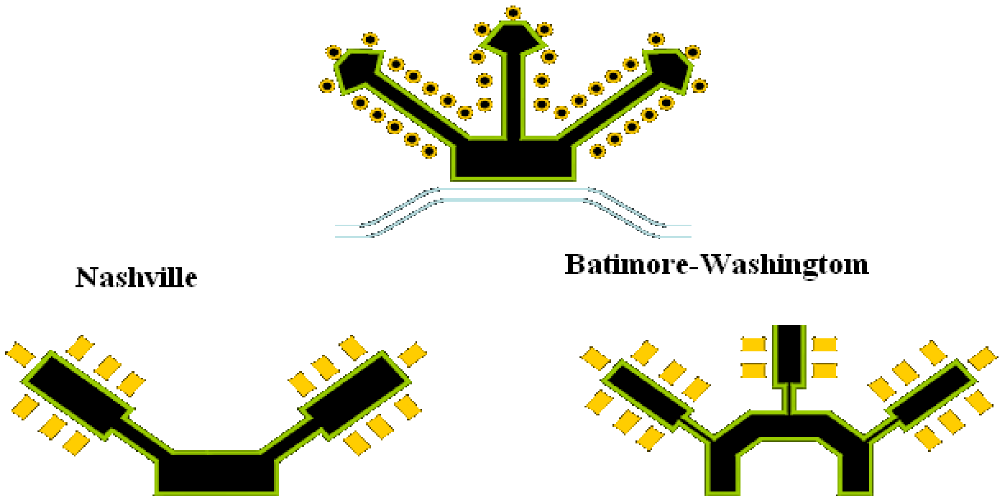

Figure 3-5 Pier/Finger Terminals
Source: Poh (2007)

On the other hand, by adding or lengthening concourses, the amount of apron space for aircraft parking and movement can be reduced. On the other hand, adding additional piers to increase capacity not only results in more distance between gates and other facilities, but is also confusing for passengers (Wells and Young, 2003). In terms of check-in, if the flights are assigned in the same pier, it is an advantage for all passengers to change flights, but this design requires early check-in and close-out times, and there also is potential for mishandling baggage due to movement between piers. In terms of ramp operations, since the manoeuvring of aircraft takes longer, blocks-on time usually takes longer and ramp operations start later.

Ground handlers in pier fingers need more than one place to locate their equipment and staff, and more care in ground movement due to complexity of apron lay out. Due to the distance between runway and taxiways being higher compared to other designs, pushback can take longer.

Some of the examples of this concept are seen in Frankfurt, Amsterdam Schiphol, Bangkok, London Heathrow T3 and Zurich.

Figure 3-6 Amsterdam Schipol Airport

3.5.2 Linear Terminals

"The linear Terminal Concept is the simplest and most straight forward of the four basic terminal concept types. Linear terminal consist of a single passenger processing area adjacent to a single common hold room area, which, in turn, is adjacent to the aircraft parking apron. Aircraft boarding is handled via a series of gates that lead directly to the aircraft parking apron or to passenger bridges, which are spaced along the terminal face" (Airport Cooperative Research Program, 2010).

This concept can be in simple design, linear design or curvilinear design. It may have minimum walking distances in the case where check-in facilities are semi-centralized. On the other hand, for transfer passengers and transfer baggage, the distance can be huge at the stands which are at the end of the concourses. Special logistics may be required for the handling of transfer baggage, depending upon the size of a terminal building.
"In terms of minimum parking time to parking stand, linear terminals can be a big advantage. Linear concourse reduces the average taxi distance around the passenger building by 25 percent and halves the number of turns" (De Neufville and Odoni, 2003).

“Passenger walking distance from “curb to the gate” is typically short. Passengers can directly reach their gates from the curb, but in order to provide this easiness, there has to be more entrance doors.

One of the main disadvantages of linear terminals becomes evident as the length of the terminal building increases. Length of terminal creates problems for airports with high numbers of transfer traffic.” (Wells and Young, 2003) As a stand-alone facility, the linear terminal is incapable of supporting large volumes of hub traffic.

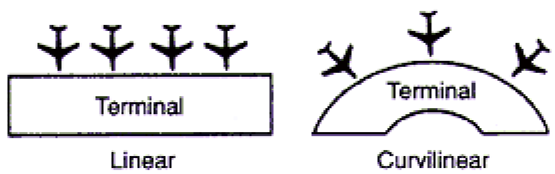

Figure 3-7 Linear terminals
Source: National Aeronautics and Space Administration

At the linear type of terminal, as the extent that the size of the building increases, the more is the distance that ground equipment has to traverse. Especially, big, heavy equipment such as loaders need more time to reach their related parking stand. The location of the baggage hall where the baggage are distributed in linear terminal design has to be more or less in the middle of the terminal building; otherwise, the transfer time of the bags for the aircraft which are at the end of the terminal need more time for the loading process. On the following graphic, the duration of travelling with tractor from one side of the terminal to the other side on the linear terminal of Istanbul airport is shown. From parking position 213 to 105 takes approximate 05 min 46 seconds with the full tractor (the distance between 2 positions is 1110m.) The location of the baggage hall is in the middle of the linear terminal across to parking positions 203 and 208, which distributes the travelling time between the farthest parking position almost equally.

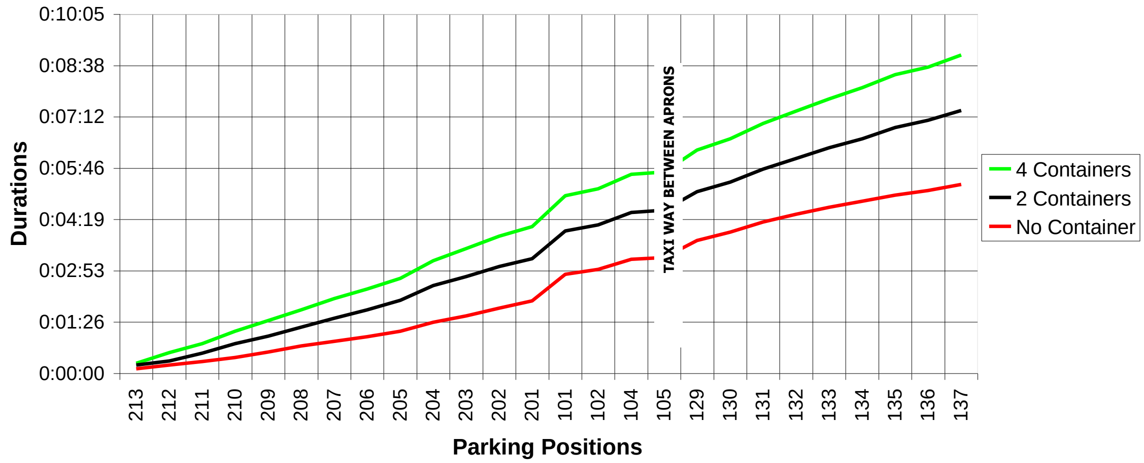

Figure 3-8 Duration of Travelling Time between Parking Positions in Istanbul Airport

Istanbul, Heathrow T4, Munich, Singapore Changi T2 are the examples of this concept.

3.5.3 Open Apron

“The open apron terminal concept, the stands are located on one or more rows in front of building. One of the rows maybe close-in, but most will be a long way from the terminal. The transport of passengers to the distant stands is provided by busses or mobile lounges, with only a short walk for passengers” (Kazda and Caves, 2007).

“In this concept, aircraft is parked at remote parking locations away from the main-unit terminal building. To travel between the aircraft and the terminal building, passengers would board transporters, known as mobile lounges that would roam the airfield among ground vehicles and taxiing aircraft. With the mobile lounge concept, walking distances were held to a minimum because the main, relatively compact, terminal building contains common passenger processing facilities; with automobile curbs and parking located in close proximity to the terminal building entrances.” (Wells and Young, 2003).

In this concept, the close-out times are much earlier for transferring the passenger to the parking stands. Handling companies have to have more equipment and staff, the number of buses increases, and because the passenger is carried by buses, the boarding has to be completed earlier.

Washington Dulles, Milan Linate, Montreal Mirabel are examples of this concept.

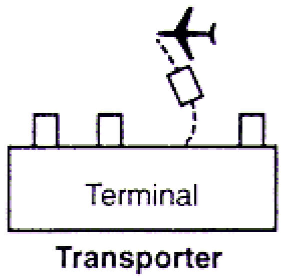

Figure 3-9 Open Apron Terminal
Source: virtualskies.arc.nasa.gov

3.5.4 Satellite Concept

"The satellite terminal concept consists of remote passenger loading satellites which are connected with the terminal building by above or below tunnels." (Kazda and Caves, 2007).

This design also requires early check-in and close-out times. Also, the probability of baggage mishandling is quite high because of the long baggage conveying/sorting systems between the satellites.

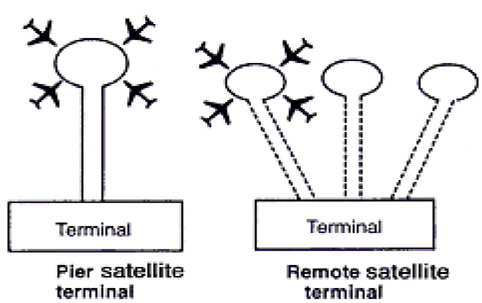

Figure 3-10 Satellite Terminals

Denver (US), Atlanta, Paris CDG T1 and Tokyo Narita T2 are examples of this concept of terminal design.

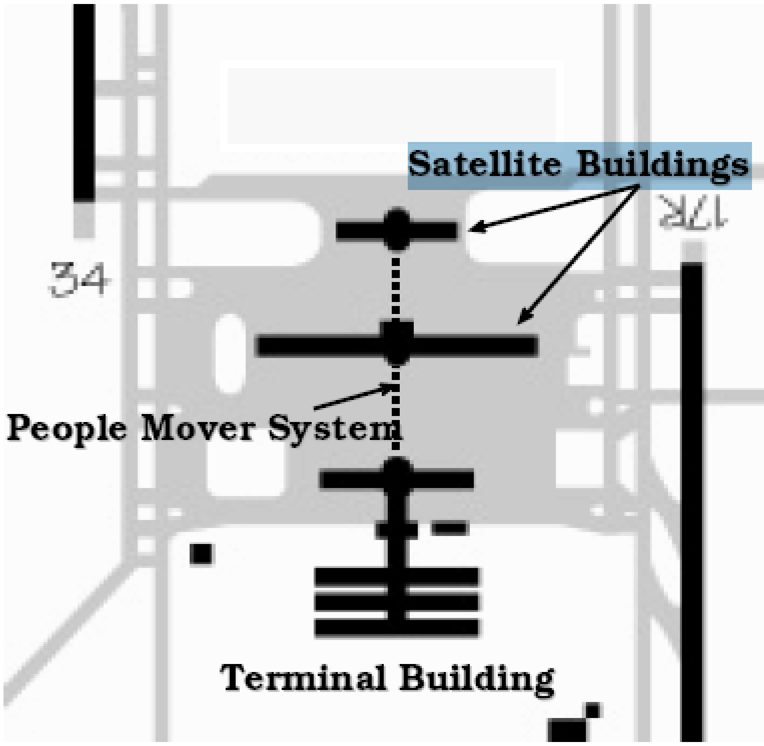

Figure 3-11 Denver Airport
Source: Poh (2007)

3.5.5 Compact Module Unit Terminal

This is the first simple terminal type in the history of the aviation. In the United States, each module of the terminal can be used or assigned by the individual carriers (Wells and Young, 2003).

In this concept, the numbers of contact stands are limited, and it is difficult to transfer the baggage and passengers between the terminals. It is also problematic to handle the high volume of passengers via this terminal concept.

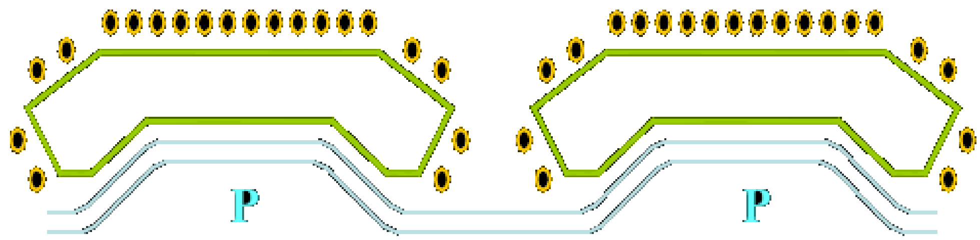

Figure 3-12 Compact Module Unit Terminal
Source: Poh (2007)

Examples of this terminal are, Paris CDG 2A, B, C, D; Budapest, Dallas Forth Worth and Hanover.

3.6 Inside Terminal Facilities and Handling Relationship

Terminal design and facilities can expedite passengers' travel inside the terminal and help them reach the aircraft as easily as possible. Actually, there are no standards for how a passenger terminal has to be built or how the design has to be for the best utilization. The cultural, social and governmental practices create differences in the design of the terminals. The terminal building serves many users, such as airlines, handlers, security and customs, and all these users need different facilities from the terminal design. The main issues in the terminal area for handlers are primarily the facilities such as check-in desks, check-in area, boarding area, etc. All facilities that help maintain "easy flow" and guidance have an effect on passenger processing of handling companies. Some parts of the terminal and applications of airport authority which help the handling processes and make the passenger flow more easily are:

3.6.1 Number of Entrance Door

One of the main aims of the terminal design is to provide the shortest distance for passengers to reach their check-in desk after they have parked their car or after they get off public transport. According to the terminal type, the number of entrance doors, as well as the location of these doors, can be problematic. For example, as explained previously, linear terminals can be excessively long and entrance points to the building can become more important in that case. How many entrance doors the airport has, if the location of these doors lets the passengers go inside smoothly and see their related check in desks as quickly as possible or not, are some of the questions that need to be considered in regards to the handling operations. The information pertaining to the number of doors and their location is especially important during the peak hours where the incoming flow to the airport increases. With the well located entrance and the doors, congestion in the airport doors, especially where the security controls are very high, can be distributed efficiently.

3.6.2 X-rays

The number of the x-rays and security control points are important in terms of welcoming the passengers to the airport as soon as possible. Increasing security controls, especially after September 11, have boosted long security queues at airports and increased the demand for extra X-rays. Sufficient number of X-rays will certainly decrease waiting time of passengers who want to reach their flights as quickly as possible. However, any additional security x-rays require additional employees, and they are a cost for the airport operator, so the number of these expensive tools is kept to an optimum. Especially in peak hours, queues in front of x-rays and security hinder the passenger flow to the check-in area or to the boarding area. Particularly US airports and other airports with the US as a destination have been suffering because of long security control queues.

3.6.3 Check-in Hall

There are two common types of check-in hall lay out; Linear type and Island type. Linear type is more suitable for the small or medium size terminal buildings. Linear type allows passengers to see all check-in desks at first glance from the entrance and to easily find the related check-in desk. Linear type of check-in hall design can cause distortions on people moving inside the terminal and complicate the traffic operations of handlers. The following figure presents this disruption;

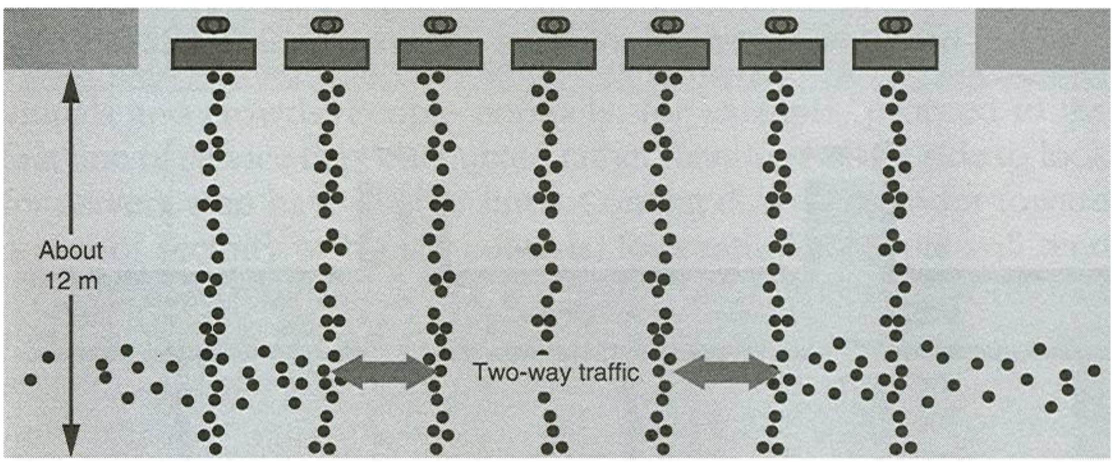

Figure 3-13 Bottlenecks in Linear Check-in Hall
Source: De Neufville and Odoni (2003)

Nowadays, airports which deal with a huge number of passengers commonly use the island check-in layouts. These layouts are parallel to the passenger flow and let the airport use its space more efficiently in terms of the numbers of check-in desks.

Sometimes, not all the bags are in the same regular shape and design. Oversized or oddly shaped bags require different check-in desks. In the design of the check-in hall, this extreme baggage also has to be considered, and the hall also has to have enough space for the trolleys and passengers to move easily and comfortably so as not to let any congestion in the check-in hall.

In order to decrease the usage of check-in desks in these limited areas, new technologies have been developed. One of them is Common Use Terminal Equipment (CUTE), which provides the ability to serve more air carriers and passengers with less physical ticket counter space than their exclusive-use counterparts. Another system which was developed to make things easier in check-in and check-in area is Common Use Self-Service (CUSS), which offers check-in for multiple air carriers. For example, in Baltimore airport terminal, the area features more than 50 ticketing positions, including numerous rapid check-in kiosks for faster check-ins. All these facilities at the airports enable the effective usage of the area and provide easiness to the airlines they work with.

Even though electronic tickets are replaced with manual tickets and check-ins are mostly replaced with self check-in kiosks at many airports, there are still several time consuming processes for passengers, such as security checks and boarding queues. Nowadays, some airports have started to invest in extremely technological improvements to hasten the boarding and check-in, such as personal digital assistance (PDAs)[31] and bookings on mobile phones running WAP.

All these facilities help the handler to maintain quick check-ins and to direct the passenger to the gate as soon as possible.

3.6.4 Wayfinding and Orientation

Inside the terminal, there are some other facilities that have to be settled in the most suitable way, such as guidance, announcing systems, information displays systems, maps and signing, so that the passengers can find their way more easily and quickly. All these way-finding facilities have to be arranged well in a terminal for the best passenger orientation, especially nowadays, there are huge terminals, with many levels to handle large volumes of passengers - so, in these very big terminals, way finding is very important.

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[31] The PDA runs a tiny browser wirelessly networked to a server. Transcoding software connects PDAs, gate readers and displays to the legacy reservation and departure control system. Gate readers cause digital photographs of passengers to appear during boarding for security check. Flight attendant PDAs and reception desk laptops receive digital photographs and flight records of passengers as they approach to allow personalized greetings.

Signs are important to provide the information for passengers to orient themselves in the airport, and all sign types, such as arrival signs, departure and transfer signs, airport information and baggage signs, have to be located in the way which is most useful for traffic flow at airports. Especially in the transfer flights movements, the quick flow is crucial for handlers, and clear signage is one of the facilitators of this quick movement.
In check-in halls, departure flight information displays (FIDS) have to be located in the most appropriate place where passengers can easily reach and see their check-in points.
Announcing systems have to be clear and understandable in order to allow the passengers to be aware of the flight situations.

3.6.5 Number of Passport Control

This facility is outside the handler's or airline's responsibility, and it is one of the reasons for the delays in most of the airports. For quick movement, a sufficient number of control points and staff members have to be located for this function. In most of the airports worldwide, immigration services, customs and passport control are provided by the government, and it makes it even more difficult to intervene or take corrective action immediately because of the ponderous structure of government bodies at most airports.

3.6.6 Baggage Handling Systems and Baggage Sorting Area

Baggage Handling systems are the interface for the baggage to be delivered from check-in belts to chutes/baggage making area for ground crew to sort them in baggage carts. Baggage Handling system is composed of 3 main parts, such as inbound baggage system, outbound baggage system and transfer bag system. From the moment a bag is put onto a conveyor at the check-in counter, till its loading on a truck or other handling system at the sorting area, efficient working of the baggage handling system is crucial for an airline to be on time and for an airport to have proper operations. Depending on the size of the airport and the traffic amount, the system of baggage handling differs among airports.

The airports with a huge amount of traffic have more complicated and automatic distribution systems, whereas small airports have manual systems and simple race-tracks, or simply use the baggage trucks due to less amount of baggage. For instance, mid-sized airports such as Istanbul and Lisbon airport usually use the trucks to transfer the bags from the accumulating area to airplanes, and large size airports such as Pittsburgh airport use the high-speed material handling systems. Whether baggage systems are automated or simple conveyor belts, they require regular maintenance and control, because any disruption in the system causes bags to be delivered late or not to be delivered to the aircraft, boosting the delays or causing additional costs for mishandled baggage. In the following figure, there is an example of 2 different airport and baggage room designs.

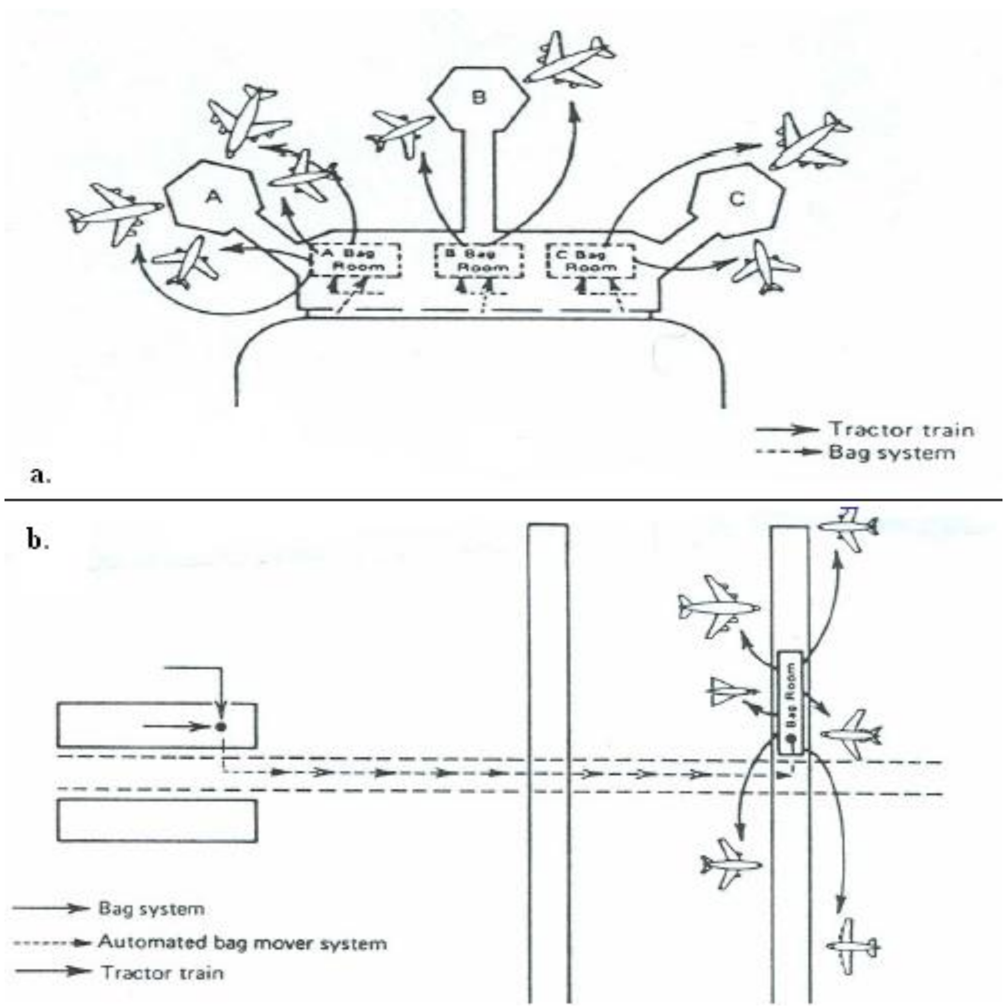


Figure 3-14 Distance of Different Designed Bag Rooms
Source: Ashford, Stanton and Moore (1997)

The area where the bags are sorted manually, especially at the small or medium sized airports, has to provide enough space for baggage tractors and ground crews. There has to be enough space for manoeuvring all the equipment of different airlines and handlers which try to serve at the same period of time. During the peak hours, most of the airline's operations are handled at the same time from the same baggage sorting area. During these periods, the number of the ground crew, tractors and the containers increase at the baggage sorting area, making quick movement less likely. The time that tractors spend at the area increases because of the congestion.

3.6.7 Number of Boarding Gates and Stands

"Aircraft parking stands and gates have two functions: they are parking positions in an apron area for aircraft; and for passengers, they are gates corresponding to the terminal building entrance or exit." (Cheng, 1998). One of the duties of airport operators is to accommodate landed aircraft to these parking stands and to gates. This duty requires the evaluation of some criteria, such as the size of the aircraft, the type of the aircraft, wing width of aircraft and ground time of the aircraft. An airport operator has to manage all these factors and make the best gate planning to increase gate-stand utilization, and also has to consider the question of how to manage the best gate usage for handlers and airlines' operations, especially for the transfer flights.

Improving gate arrangement methods helps to reduce the time and walking distance that passengers traverse in the terminal to reach the departure flight. "Gate assignment should consider the overall passenger walking distance and baggage handling distance as well as ground time periods and dwell durations. Planners have to consider some basic factors while assigning the gates to the aircraft, such as

1. Walking distances for transfer, terminating, and originating passengers;
2. Baggage handling distance for transfer, terminating, and originating passengers;
3. Time tables of flight schedules;

4. Aircraft-gate size compatibility.

For instance, the mean for walking distance per passenger at Terminal No. 2 of Toronto International Airport in Canada was reduced from 923 ft in 1973 to 800 ft in 1975. This improvement resulted from a change in the gate assignment policy by Air Canada, the terminal's sole user. The decision represented a saving of over 100 ft per passenger." (Haghani, and Chen 1998);

To make the proper arrangements, it is essential to work hand in hand with the airlines and the handlers, and stay in close contact and follow their variable schedules. Especially at a time when airport business has become a commercial and global business, airport operators try to provide new solutions to the airlines in the congested, peak hours. For example, Washington Dulles Airport initiated several efforts to monitor and evaluate actual gate usage by receiving gate use schedules from 3 airlines that leased the gates. The airport authority used this data to develop Gantt charts of the hourly use of all preferentially leased and permit controlled gates. Having updated the flight, as well as the gate information, also allows handlers to perform better staff and equipment planning and have better orientation in the apron area.

In addition to passengers' walking distance, gate and stand assignment is also important for baggage transport. Gate arrangement of the airport authority is essential for handlers, especially when there is limited time for transferring the bags from one flight to the other. With well-planned gate arrangements, the equipment and staff utilization of handlers can also increase. At the airports, especially at the congested ones, handlers have limited areas to park and leave their equipment. Every time an aircraft turnaround ends, handlers have to bring back the equipment to the equipment parking area or bring them to the parking stand of the next landing aircraft. Accommodating close parking stands to the consecutive flights or to transfer flights will help handlers to move the equipment quickly, without bringing them back and forth to the equipment area, or transfer the bags immediately at transfer operations. Especially at the transfer flights, if the parking stand of each flight is close by, it is easy for handlers to transfer the bags, and as a result, the probability of undelivered bags to the transfer destinations can decrease.

3.7 Airside Facilities and Handling Relationship

The emergence of several major global alliances and code sharing that are involved at the airports, calls for special attention, particularly regarding the space and co-location of partner airlines, security arrangements, and the requirements for passenger handling. Generally, the distance between parking positions, number of remote parking positions and gates, the location of equipment area, as well as the location of the external supplier facilities have to be arranged in such a way that it should meet the requirements of the aviation system, as well as all airport users. Airport facilities are built and designed in the construction period, and it is really difficult to rearrange them according to new demands, but small adjustments can be made to allow the airport users to adopt their management and operations according to airport conditions. Airside facilities and some facts which have an impact on handling operations are explained in the following:

3.7.1 Service Roads and Signing

In the apron area, there are different vehicles moving around. There are different roads and signs to provide the safety flow of all these vehicles to indicate the direction which they have to follow. There are certain roads for different vehicles which are indicated with different signs. Each sign on the road guides the related aircraft or vehicle to arrive at the desired point at the airport. The lines which indicate the taxiing way for aircraft differ from the signs which the ground vehicles have to follow on the apron area. There are some different areas or separations for ground vehicles to not hinder the aircraft movement at the apron area. This concept usually differs in North America and Europe. A difference which is related to ground vehicles arises from the location of *aircraft Contact Stands.* In North America, the usual agreement is that aircraft in the contact stands are right next to the passenger building. The aircraft nose may be as close as 10m. In this arrangement, the telescopic, movable air-bridges connect the passenger building and the aircraft. In Europe, however, aircraft at the "contact" stands typically park relatively far from the passenger building. The nose of the aircraft may easily be 25-40 metres. The system of bridges can correspondingly be up to 70 m long. Airport operations in Europe and in many countries worldwide, except for the vehicles operating on the airfield, will normally not intersect the paths of aircraft. Ground vehicles will circulate on two-lane roads laid out at the face of each passenger building (De Neufville and Odoni, 2003).

Figure 3-15 Apron Lay out of Munich Airport

Source: De Neufville and Odoni (2003)

Figure 3-16 Apron Layout of New Jersey Airport
Source: De Neufville and Odoni (2003)

In these two different designs, Europe concept, which has a two-lane road for ground vehicles, is more efficient in terms of the flow in the apron area. In the U.S. concept, ground vehicles wait for pushback of aircraft because the roads for vehicles are at the back of the aircraft parking stand. In peak hours, flow of all ground vehicles, such as loaders, dollies and stairs, are crucial to speed up the operations. In the European style, ground vehicles can continue their movements in front of the aircraft whether the aircraft start to pushback or not, and it helps to have quicker operations for handlers.

3.7.2 Location of Equipment Parking Area

In the apron area, there are certain places allocated to the handlers and to the airlines. Equipment park areas are one of those assignment places to handlers where they keep all their equipment. These areas can be adjacent to the handler's or airline's office building, which is also in the apron area, or can be away from the buildings where all the companies leave their equipment in a common place. Handlers or any company are not supposed to leave their equipment and vehicles at any part of the apron, except during the working period. The location of the equipment area and distance between the operational places has an impact on handling operations. Particularly in the case of equipment breakdown, auxiliary equipment has to be brought in the shortest time period so as not to hinder the aircraft turnaround and not to cause longer delays. Heavy and slow equipment, such as loaders, can consume a longer time if they are brought from a far off equipment area to the parking stand.

3.7.3 Technical Atelier Facilities

During the peak seasons, the amount of equipment is almost limited for most of the handlers. Especially in the peak hours, the necessity of the equipment pool increases. The equipment which is used frequently in turnarounds, such as busses, VIP vehicles, loaders and tractors, needs to be in good condition in order to be used at the operations without any disruption. To use the equipment in an optimum manner, it is beneficial to have Vehicle Maintenance and Planting Facilities at the airport; thus, the time that vehicles stay in maintenance will be less, and the aircraft turnarounds will not be hindered due to a lack of equipment.

3.7.4 Location of Fuel Farms

Fuelling is one of the main parts of the critical path in aircraft turnaround. The quicker the fuelling is completed, the faster the rest of the aircraft turnaround progresses. Location of fuel farms comes on the scene more, when there is any disruption in the fuelling process, such as breakdown of equipment or lack of fuel on the track. The extent to which the fuel farm is closer and well located will decide how quickly and easily it will be to intervene in the faulty process. Although now it is more common for airlines to get the fuel via a fuel hydrant system just near the parking stands, this process also requires a special truck to complete the fuelling process, so that the importance of the fuel farm's location will appear in any fuel breakdown in the turnaround process.

3.7.5 Other Facilities

Airport Cleaning Facilities, platforms for loading and offloading at the entrance of the apron (for cargo), water supply facilities, location of de-icing, the vehicle restriction procedures and vehicle licensing procedures are the other important issues of airports which have an impact on handlers' activities. These units, which are also a part of the chain, can influence the turnaround process indirectly. Good condition of these facilities have a positive impact on aircraft operations, such as easier entrance and arrival of cargo to the apron area, quicker de-icing solutions, faster snow cleaning, and so on.

4. CASE STUDY

The case study is composed of four stages. The first part gives a brief description of Lisbon Airport and the handling market in Lisbon. In the second part, there is more explanation of the data coming from one of the handling companies at Lisbon Airport. In the third part, the data analysis method used to interpret the data, called Multiple Correspondence Analyses (MCA), is presented. Finally, in the last part, a factor analysis is applied to one of the variables of MCA to conclude the statistical analysis.

4.1 Lisbon Airport and the Handling Market in Lisbon Airport

Portela Airport (*Aeroporto da Portela* or *Aeroporto da Portela de Sacavém*) is located inside the city of Lisbon, capital of Portugal, although it takes its name from the neighbouring parish of Portela, also known as Portela de Sacavém. It is also known as the Lisbon Airport. The airport is the main international gateway to Portugal and a major European hub. The airport has two main runways capable of accommodating large-size aircraft. TAP Portugal and Portugalia use it as their main base. The airport is run by State-owned company, Aeroportos de Portugal. The airport was opened on October 15, 1942. It quickly expanded, with extended runways and a new terminal. It also expanded its parking facilities to allow more aircraft movements. The airport is now completely surrounded by urban development, being one of the few airports in Europe located inside a major city. This has led to a national debate on whether to keep the present location or to build a new airport.

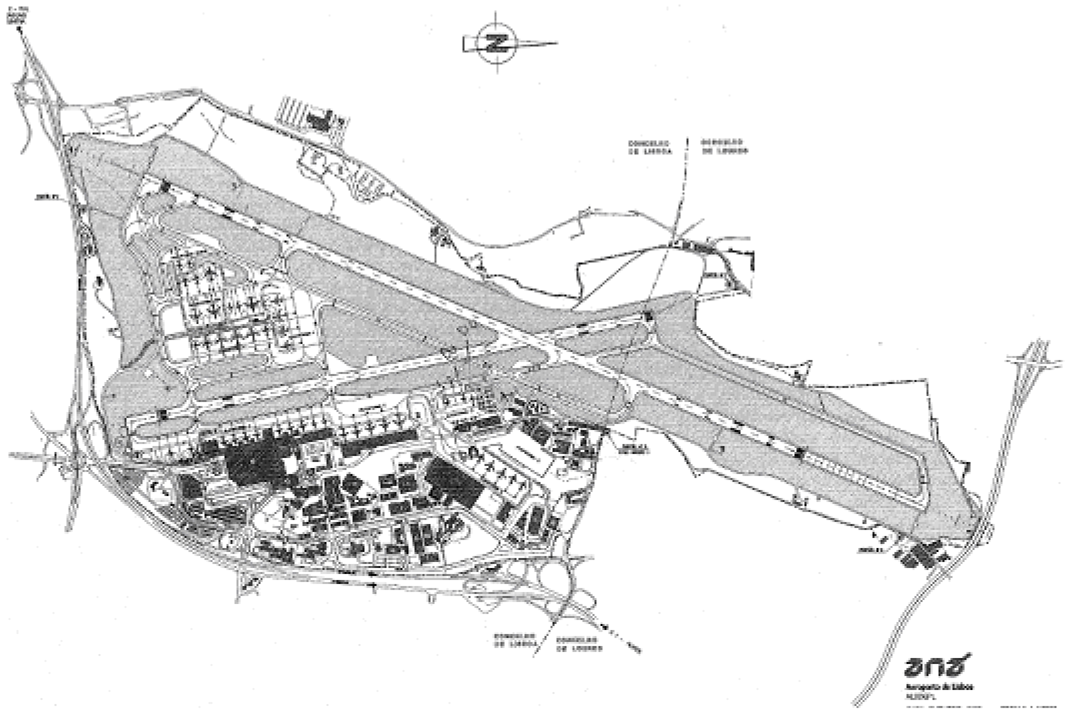


Figure 4-1 Lisbon Airport Layout

Lisbon airport is located just in the middle of the city. Landing and/ or take-off is forbidden by law between 00:00 and 06:00 am local mean time (LMT). Being in the middle of the city is also a disadvantage because of the fact that it does not have enough space to extend its facilities. Since the Lisbon airport has almost reached its full capacity, some additional facilities to relieve the congestion have already started until all the operations will be transferred to the new Airport. Traffic numbers of Lisbon is presented in Table 4-1.

Table 4-1 Traffic Numbers of Lisbon Airport

	Passengers	Cargo	Aircraft Movements
2000	9.213.724	103.293	110.059
2001	9.370.795	94.248	113.780
2002	9.382.828	92.376	115.746
2003	9.653.865	95.803	117.658
2004	10.723.951	100.086	128.085
2005	11.251.844	100.110	129.267
2006	12.333.548	99.620	137.109
2007	13.392.059	94.749	144.800
2008	13.603.620	101.129	144.751

In Lisbon airport, there are two handling companies that serve the airlines: Groundforce (formerly known as SPDH) and Portway. In the beginning of 2000, there were some unclear levels of implication of EU Commission Ground Handling Directive 96/97. Efforts to have a more liberal handling market were not very successful in Lisbon. Although there are two handling operators at Lisbon airport, neither was independent as one was SPDH (Serviços Portugueses de Handling, S.A.), run by flag carrier TAP, and the other is Portway, whose majority was owned by the airport ANA (Aeroportos de Portugal, S.A.).

Portway handling, one of the players of Lisbon, started its activity in July 1st, 2001 with the share of ANA being 60%, and the Frankfurt airport management and handling company, FRAPORT being 40%. In 2005, Fraport withdrew from the market and sold all its shares to ANA, which made ANA become the sole shareholder of Portway in 2006.

In 2004, the handling market of Lisbon airport became more liberal by the privatization of SPDH. SPDH was firstly shaped as a handling division of TAP in 2003, which served TAP and other airlines in Portugal. In 2003, Portugalia Airlines bought 6% of SPDH and it helped the company maximize its growth. Meanwhile, the privatization process of

SPDH was begun through the sell-off of 50.1% of its capital via an International Open Tender, which allowed the Globalia group to enter the shareholder structure. In 2005, Globalia Handling decided to launch a new brand with an image that would be renowned worldwide. Globalia Handling launched Groundforce as a brand to incorporate the Group's handling companies. For now, Groundforce serves 70 % of the handling market in Portugal.

4.2 Data Presentation and Analyses

SPDH has a wide range of airlines in its portfolio because of being one of the sole players in the handling market in Portugal. In this thesis, SPDH's data are received from a sample of airlines offering services at Lisbon Airport, Portugal. There are a large amount of flight data belonging to each airline between 2000 and 2005. Each flight has the following information: the scheduled arrival and departure time, actual arrival and departure time, gate and stand names, the date of the flight, type of and registration code of aircraft.

The depended-chain process of ground handling makes it more difficult to analyze what boosts the handling delays. Decomposing the problems in the complex structure of ground handling can help ascertain the characteristics of the delays. In this chapter, data will be decomposed and explained to prepare a concrete base for the next chapter's analyses. In order to do so, a kind of data mining will be done from the four year flight information of SPDH after presenting some general information about Lisbon airport and handling companies. All the steps in choosing the related handling delays and graphical presentation of the delays are presented in this chapter.

Between the years 2000 and 2004, SPDH had 410 788 flights, and 218 411 of them were delayed flights. In the first step, departure information of four European scheduled legacy airlines - Transportes Aéreos Portugueses (TP), Lufthansa (LH), Air France (AF) and Iberia (IB) - is extracted for the period 2000 and 2004 from the SPDH data base. In the following table, the number of delayed flights and their respective frequencies are shown.

Table 4-2 Distributions of Delayed Flights According to Each Airline

	Delayed Flights	
AIRLINE	**Occurrence Number**	**Frequency (%)**
AF	4393	3,0
IB	12837	8,9
LH	8307	5,8
TP	118676	82,3
TOTAL	144213	100

After determining which airlines will be used in the study, the following steps are followed:

1. Presenting all delayed flights of each airline
2. Selecting handling delays from the delayed flights
3. Choosing seven handling delays to use in statistical analysis

Table 4-3 Steps in Evaluating Data

	All Delays						Handling Delays						7 Chosen Delays					
	2000	**2001**	**2002**	**2003**	**2004**	**Total**	**2000**	**2001**	**2002**	**2003**	**2004**	**Total**	**2000**	**2001**	**2002**	**2003**	**2004**	**Total**
AF	1024	1008	916	690	755	**4393**	93	64	85	52	84	**378**	61	42	62	32	54	**251**
IB	953	1041	2494	4357	3992	**12837**	5	5	193	273	245	**721**	3	3	72	135	115	**328**
LH	1690	1604	1519	1759	1735	**8307**	85	133	116	117	138	**589**	66	95	85	91	111	**448**
TP	19321	25410	24897	22995	26053	**118676**	2991	4030	2975	2016	2434	**14446**	2088	3006	1810	1399	1816	**10119**

Table 4-3 and Table 4-4 present some basic findings with respect to delay ratios. Air France had shown a decrease in the number of delays till the year 2003, but this was followed by a 1% increase in 2004. In 2002, even though there is a 2% decrease in delays, there is a 5% increase in handling delays in 2003.

In Iberia flights, there is a 11% increase in delays in 2002, and this increase reverberates to handling delays as 27%. In Lufthansa, there is a 1% decrease in the delays, while 9% increase in the handling delays in 2001. In TAP, in 2001, there is a 7% increase in handling delays versus 5% in all delays. In 2002 and 2003, TAP decreases its handling delays by 7%, and in 2004 there is a 3 % increase.

Table 4-4 Delay Frequencies in Years

	All Delays						Handling Delays						7 Chosen Delays					
	2000	2001	2002	2003	2004		2000	2001	2002	2003	2004		2000	2001	2002	2003	2004	
AF	0,23	0,23	0,21	0,16	0,17	1	0,25	0,17	0,22	0,14	0,22	1	0,24	0,17	0,25	0,13	0,22	1
IB	0,07	0,08	0,19	0,34	0,31	1	0,01	0,01	0,27	0,38	0,34	1	0,01	0,01	0,22	0,41	0,35	1
LH	0,20	0,19	0,18	0,21	0,21	1	0,14	0,23	0,20	0,20	0,23	1	0,15	0,21	0,19	0,20	0,25	1
TP	0,16	0,21	0,21	0,19	0,22	1	0,21	0,28	0,21	0,14	0,17	1	0,21	0,30	0,18	0,14	0,18	1

Airlines which are chosen, Iberia, Air France, Lufthansa and TAP, have quite different traffic density. While Iberia, Air France and Lufthansa have more or less the same amount of flights, TAP has much more traffic because of using Lisbon airport as its hub (Figure 4-2).

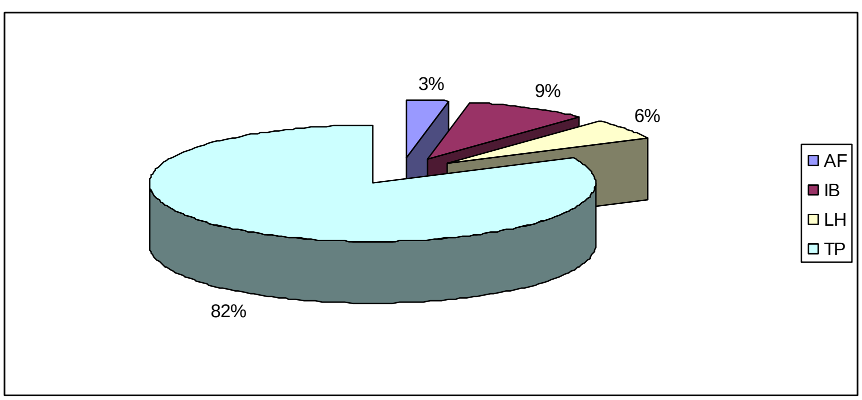


Figure 4-2 Delayed Flights' Shares for Each Airline during 2000-2004

After presenting all the delayed flights and their distribution according to the airlines, as a second step, only the handling delays are listed. During a five-year period, all flights which were delayed due to the handling are presented in the following tables.

Table 4-5 Delayed Flights Due to Handling

AIRLINE	Occurrence	Percentage (%)
AF	378	2%
IB	721	4%
LH	589	4%
TP	14446	90%
TOTAL	16134	100%

Handling delays have shown different distribution according to the airlines. TAP has again the largest percentage of handling delays due to having more flights in the observations. Table 4-5 displays these distributions.

After seeing the distribution of handling delays, Figure 4-3 is constructed in order to compare the other total delays with handling delays.

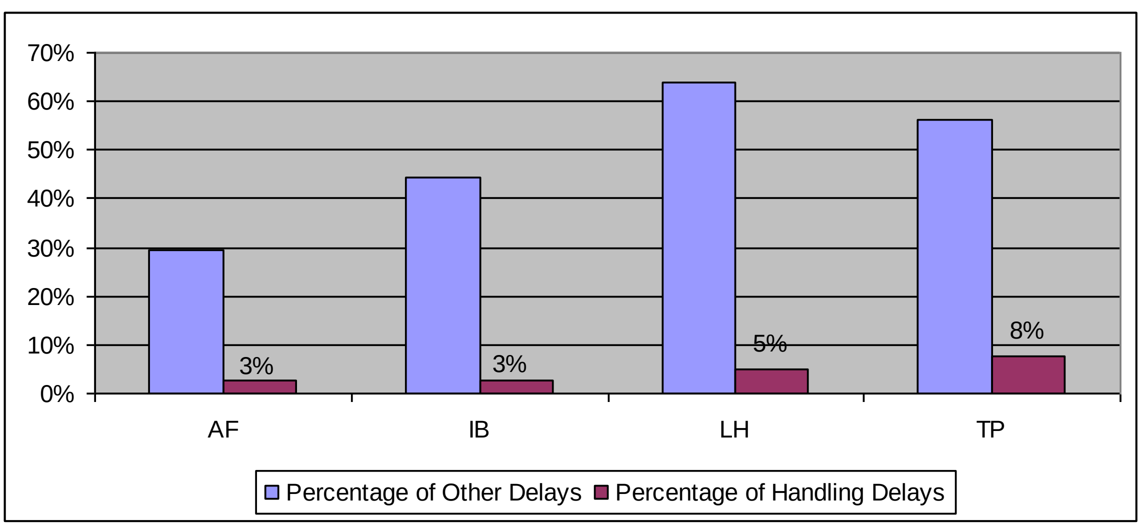


Figure 4-3 Percentage Handling Delays versus Other Delays

Figure 4-3 demonstrates that handling delays do not comprise a large percentage of the total delays in terms of occurrence time. Even though they are not frequently repetitive, the duration of handling delays, which are presented in Figure 4-4, are more problematic. In 2001, TAP lost almost 772 hours just because of handling delays.

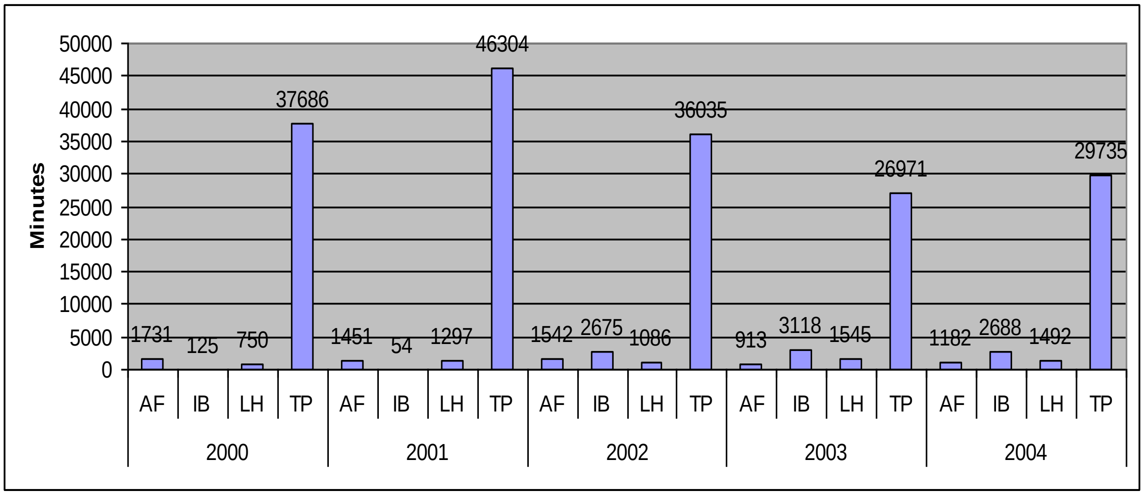


Figure 4-4 Duration of Handling Delays between 2000-2004

Descriptions of handling delays are given in Table 4-6. These are all handling delays listed from the most frequent ones to less frequent ones.

Table 4-6 Handling Delays and Their Occurrence During the Period 2000-2004

Delay Code	Description	Number of Occurrence
15	Slow Boarding, Discrepancies and paging, Missing Checked-in Passenger without Baggage	6944
14	Oversales/Booking Errors	1578
55	Departure Control System	1100
34	Servicing Equipment, Lack of breakdown, Lack of Staff	1037
18	Passenger Processing, Sorting, etc	992
32	Loading/Unloading, Bulky, Special, excessive Load, Cabin Load, Lack of Loading Staff, Volume difficulties	984
35	Aircraft Cleaning	917
77	Ground Handling Impaired by Adverse Weather Conditions	707
39	Technical Equipment, Lack of Breakdown	462
12	Late Check-in/Congestion in Check-in area	447
31	Aircraft Documentation Late/Inaccurate, Weight and balance, general declaration, Passenger manifest, etc	259
33	Loading equipment, lack or Breakdown (Container Pallet loader, lack of staff, etc)	190
11	Late Check-in/Acceptance after deadline	188
13	Check-in Error, Passenger and Baggage	126
52	Damage During the Ground Operations	66
38	ULD, Lack of or Serviceability	57
22	Cargo. Late positioning	36
21	Cargo. Documentation, errors, etc	13
28	Mail. Late Positioning	7
24	Cargo. Inadequate packing of ULDs	6
26	Cargo. Late Preparation in Warehouse	6
27	Mail. Documentation, Packing, etc	5
23	Cargo. Late Acceptance	4
56	Cargo system, Preparation/Documentation	3
29	Mail. Late Acceptance	0

As a third step, seven handling delay codes were selected from 25 handling delays. The reason that these seven codes were chosen is: their reputation and their duration ratio are the highest among all handling delays. The ones with the longer duration and more repetition are chosen as an observation cluster for the statistical analysis that will be discussed in the next part. These selected handling delays are listed in Table 4-7.[32]

Table 4-7 Chosen Handling Delay Codes Due to their Occurrence

Delay Code	Description	Occurrence
12	Late check-in/Congestion in check-in area	431
15	Slow Boarding, Discrepancies and paging, Missing Checked-in Passenger without Baggage	6586
18	Passenger Processing, Sorting, etc	925
32	Loading/Unloading, Bulky, Special, excessive Load, Cabin Load, Lack of Loading Staff, Volume difficulties	900
34	Servicing Equipment, Lack of or Breakdown, Lack of Staff, e.g. Stairs	990
35	Aircraft Cleaning	874
39	Technical Equipment, Lack of or Breakdown, e.g. Pushback	440

[32] Delay code 55 (DCS Systems), Delay code 14 (oversales and booking) and Delay code 77 (weather conditions) are not included in the study because these delays not only depend on the handling agent itself in a certain airport, but also on other external units. For instance, overbooking can be done by travel agents and DCS can be problematic from origin airport, and weather conditions are not controllable

Table 4-8 is designed so as to see the distribution of the chosen delays for each airline. According to the following tables, delay code 15 (Boarding) is one of the biggest handling problems for all airlines. Boarding delays are 60% of TAP's chosen handling delays. For the second highest percentage in Table 4-9, it can be said that delay code 18 (baggage processing) is especially problematic for Lufthansa, while loading/unloading delays are problematic for Air France and Iberia. Additionally, cleaning delays (code 35) are more problematic for Iberia compared to the other airlines.

Table 4-8 Delay code Distribution for Each Airline

Delay Code	AF	IB	LH	TP	TOTAL
12	20	6	21	384	431
15	**93**	**126**	**169**	**6198**	6586
18	17	27	124	757	925
32	41	46	46	767	900
34	32	34	14	910	990
35	11	46	18	799	874
39	37	43	56	304	440

Table 4-9 Delay Code Distribution for Each Airline in Frequencies

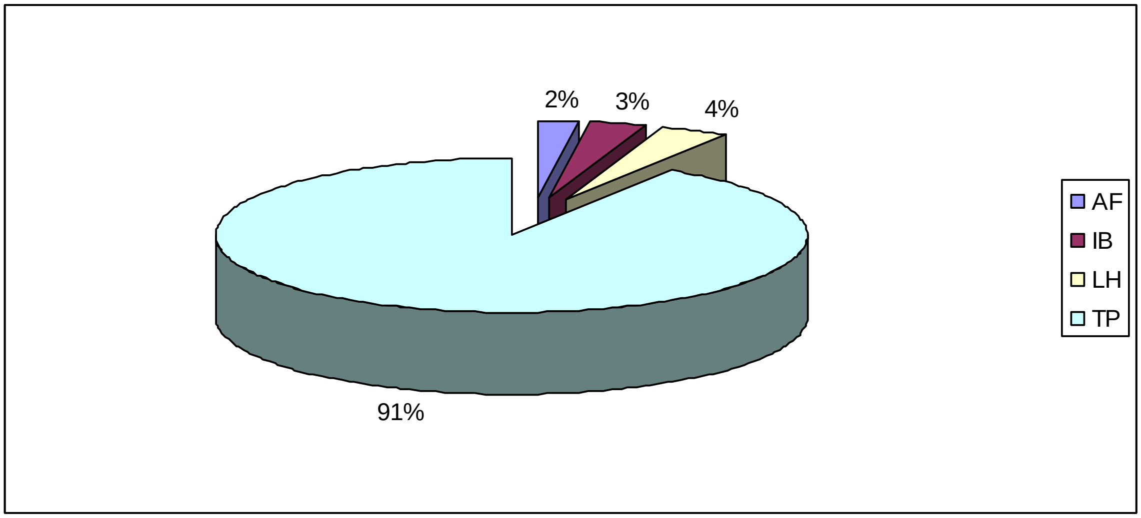
Delay Code	AF	IB	LH	TP
12	0,08	0,02	0,05	0,04
15	**0,37**	**0,38**	**0,38**	**0,61**
18	0,07	0,08	**0,28**	0,07
32	**0,16**	0,14	0,1	0,08
34	0,13	0,1	0,03	0,09
35	0,04	0,14	0,04	0,08
39	0,15	0,13	0,13	0,03
TOTAL	1	1	1	1

Distribution of the delayed flights due to the selection of seven handling reasons is represented in Table 4-9.

Table 4-10 Percentage of Delayed Flights due to Chosen Handling Reasons

	Delayed Flights Due to Chosen Handling Reasons	
AIRLINE	**Number**	**Percentage (%)**
AF	251	2%
IB	328	3%
LH	448	4%
TP	10119	91%
TOTAL	11146	100%

Figure 4-5 Distribution of Chosen Handling Delays



The duration of seven selected handling delays is presented in Figure 4-6.

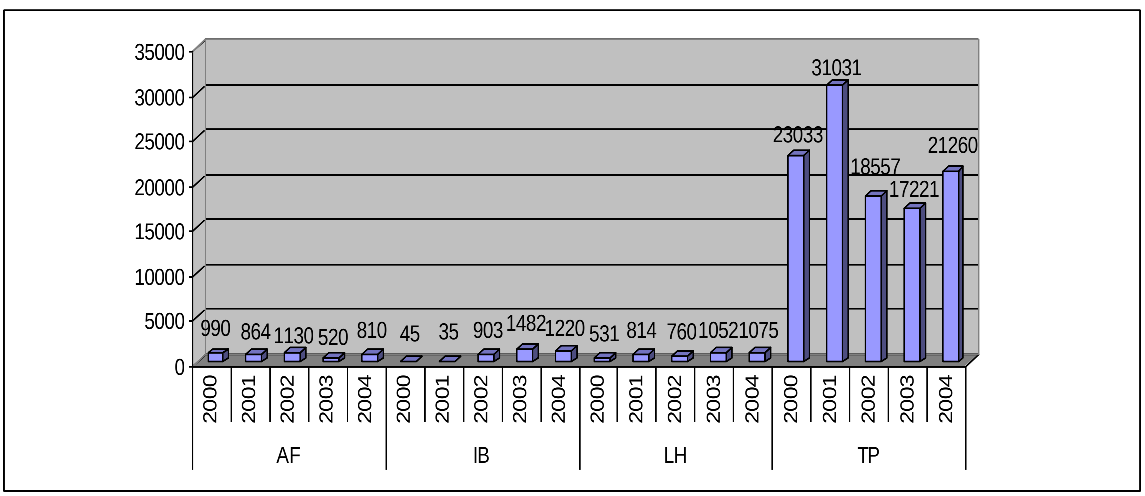


Figure 4-6 Duration of selected 7 delay codes in 2000-2004

4.2.1 Analysing the Variables

In the occurrence of delays, there are many factors which have an impact on the process of aircraft turnaround. These factors vary from meteorological conditions to airside restrictions. It has always been difficult to determine the percentage of each factor during the turnaround. There are some factors, such as ground crew and equipment pools, as well as airport congestion, that are more predictable than the others, while there are also some other variables that cannot be predicted and intervened in.

In the analysis of the past flight data of SPDH, there are some limitations because only the factors which are recorded by the handling agent can be worked on, which are aircraft type, gate, stand, season, time of day, day of week and route. Before measuring the interaction of variables with each other, each variable will be analyzed to see their pattern for each airline and each delay code.

Aircraft Type

Airlines operated 32 different types of aircraft at Lisbon airport during the five years chosen. The ones which are mostly used are selected to examine in the analyses. 10 different categories are composed; nine of which were the ones which were mostly used by the airlines, while the rest of the aircraft which are rarely operated are grouped under category 10. Aircraft which are under the category 10 are mainly the large aircraft which are used in continental flights and smaller regional jets. The coding of each aircraft is presented in Table 4-11.

Table 4-11 Aircraft Type Codes

Aircraft Type									
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
B733	AB6	RJ100	B734	A343	A321	A313	A320	A319	Others

Table 4-12 shows the distribution of the aircraft and Figure 4-7 shows the percentage of the distribution for each airline. Each airline has a different fleet structure so that the delays in aircraft vary within different airlines. For instance, A300-B6 is only operated by Lufthansa, and one of the biggest delay ratios belongs to this airline, while the others have no A300-B6 in their fleet. The most common 3 aircraft types operated by airlines in this sample are A319, A320 and A321. Air France's and Lufthansa's handling delays have mostly occurred in A320, while Iberia's and TAP's in A319.

Table 4-12 Distributions of Delayed Aircraft Type for Each Airline

	Aircraft Type									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
AF	3		4			**42**		**138**	**21**	**43**
IB						**19**		**92**	**168**	**49**
LH	1	**141**				**216**	22	**35**	**32**	**1**
TP	110		138	276	625	**926**	1229	**2197**	**4323**	**295**
Total	114	141	142	276	625	1203	1251	2462	4544	388

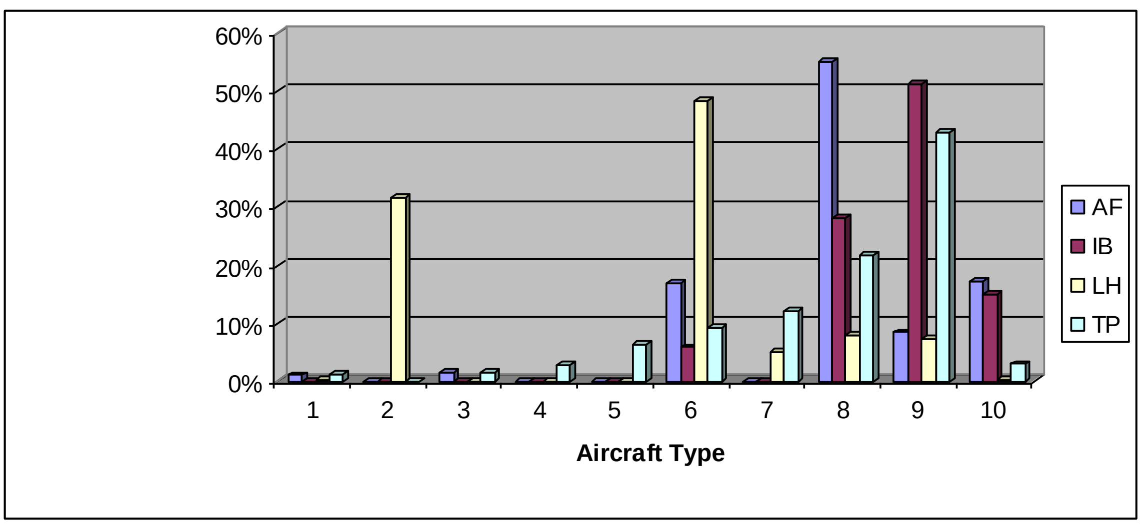


Figure 4-7 Distributions of Aircraft types

Considering the highest two percentages for each delay in Table 4-13, A320 and A319 are the aircraft with which most of the handling delays occurred.

Table 4-13 Numbers of Aircraft Type for Each Delay Code

	Aircraft Type										
Delay Code	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Total**
12	0,00	0,01	0,08	0,00	0,03	0,14	0,11	**0,22**	0,**39**	0,01	1,00
15	0,01	0,01	0,00	0,02	0,06	0,10	0,10	**0,23**	0,**44**	0,03	1,00
18	0,01	0,03	0,01	0,02	0,06	0,16	0,11	0,**19**	**0,36**	0,04	1,00
32	0,01	0,03	0,02	0,06	0,08	0,10	0,15	**0,18**	**0,30**	0,08	1,00
34	0,01	0,01	0,02	0,01	0,06	0,09	0,10	**0,24**	**0,44**	0,04	1,00
35	0,00	0,00	0,03	0,01	0,05	0,14	0,14	**0,24**	**0,37**	0,01	1,00
39	0,01	0,03	0,06	0,04	0,02	0,11	0,13	**0,20**	**0,27**	0,13	1,00

Gate

Gates which are used for the boarding of the passengers from terminal building to the aircraft are listed to see if they play a role in handling delays.

Table 4-14 Number of Delayed Flights in Each Gate for Each Airline

	GATES										
	0	1	2	3	4	5	6	7	8	9	Total
AF	32	20	20	24	18	20	16	**57**	19	25	251
IB	5	**86**	25	13	44	36	43	**63**	6	7	328
LH	7	15	10	13	56	52	55	**213**	12	15	448
TP	1294	**2160**	1024	953	409	398	337	716	1426	1402	10119
Total	1338	2281	1079	1003	527	506	451	1049	1463	1449	11146

Table 4-15 Distribution of Gates for Each Delayed Airline in Percentage

	GATES										
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**Total**
AF	13%	8%	8%	10%	7%	8%	6%	**23%**	8%	10%	100%
IB	2%	**26%**	8%	4%	13%	11%	13%	**19%**	2%	2%	100%
LH	2%	3%	2%	3%	13%	12%	12%	**48%**	3%	3%	100%
TP	13%	**21%**	10%	9%	4%	4%	3%	7%	14%	14%	100%

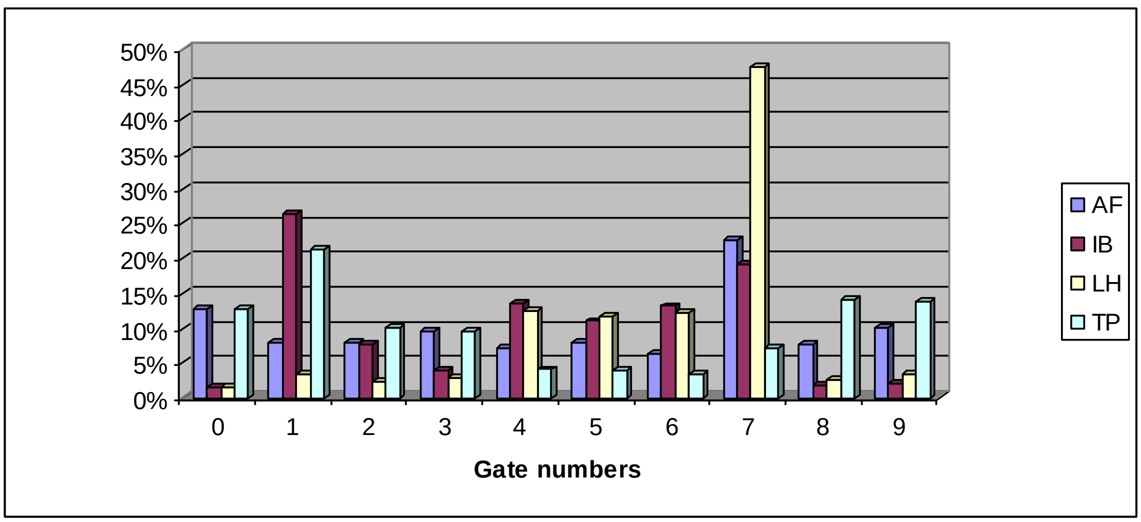


Figure 4-8 Distribution of Gates for Each Airline

Table 4-16 Gate Distribution for Each Delay Code

	GATES										
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**Total**
12	57	67	50	41	21	22	20	26	54	73	431
15	826	1412	641	579	243	258	238	572	906	911	6586
18	90	188	76	69	63	61	42	110	117	109	925
32	111	145	75	71	66	49	48	88	127	120	900
34	125	258	116	108	33	25	25	46	131	123	990
35	91	146	82	87	74	59	47	135	78	75	874
39	38	65	39	48	27	32	31	72	50	38	440

Table 4-17 Gate Distribution for Each Delay Code in Percentage

	GATES										
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**Total**
12	0,13	0,16	0,12	0,10	0,05	0,05	0,05	0,06	0,13	0,17	1,00
15	0,13	0,21	0,10	0,09	0,04	0,04	0,04	0,09	0,14	0,14	1,00
18	0,10	0,20	0,08	0,07	0,07	0,07	0,05	0,12	0,13	0,12	1,00
32	0,12	0,16	0,08	0,08	0,07	0,05	0,05	0,10	0,14	0,13	1,00
34	0,13	0,26	0,12	0,11	0,03	0,03	0,03	0,05	0,13	0,12	1,00
35	0,10	0,17	0,09	0,10	0,08	0,07	0,05	0,15	0,09	0,09	1,00
39	0,09	0,15	0,09	0,11	0,06	0,07	0,07	0,16	0,11	0,09	1,00

Table 4-16 and Table 4-17 display the distribution of delays according to gates. Gate 1 seems to experience more delays. The reason for this results from the fact that TAP mostly uses this gate and TAP has more flights in this study - so it is better to look at the other gates with high delay percentages following gate 1.

Stand

There are 9 different stand groups represented by different letters. Each letter indicates different terminal areas. Some of the stands, such as B, D, V and X to which the flights are rarely assigned, are combined and shown as a single letter, which is “W”.

Table 4-18 Number of Delayed Flights in Each Stand

STANDS							
	A	**E**	**F**	**J**	**L**	**W**	**Total**
AF	177	51	1	5	1	16	251
IB	224	33	5	31	17	18	328
LH	390	31	6	12	2	7	448
TP	3996	2062	851	1853	328	1029	10119

Table 4-19 Number of Delayed Flights in Each Stand in Percentage

STANDS							
	A	**E**	**F**	**J**	**L**	**W**	**Total**
AF	0,71	0,20	0,00	0,02	0,00	0,06	1,00
IB	0,68	0,10	0,02	0,09	0,05	0,05	1,00
LH	0,87	0,07	0,01	0,03	0,00	0,02	1,00
TP	0,39	0,20	0,08	0,18	0,03	0,10	1,00

As shown in the above presented tables, airlines had parked mostly at the stands in Terminal A and Terminal E.

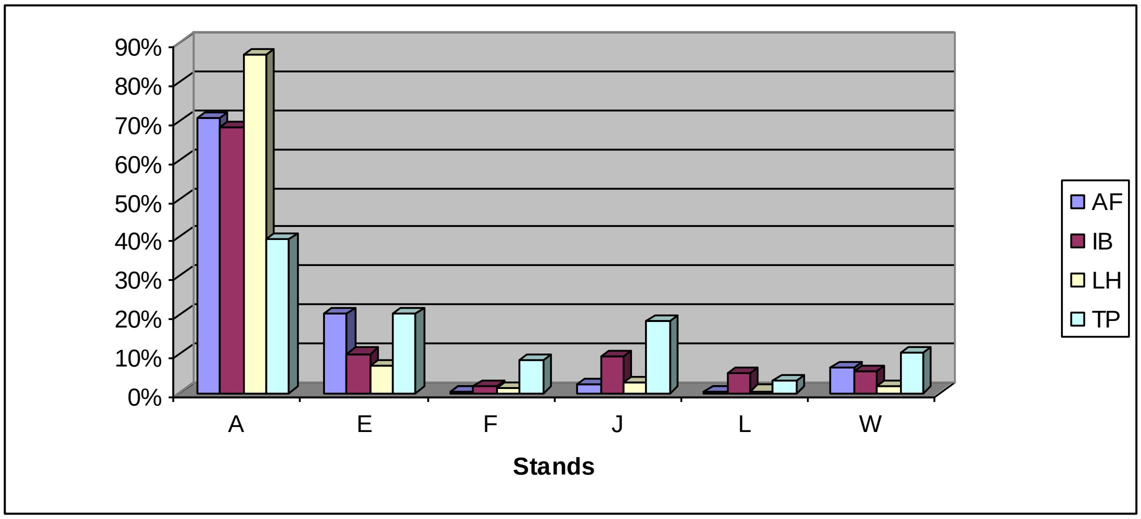


Figure 4-9 Stand Distribution for Each Airline

In Table 4-20 and Table 4-21, the number of handling delays in each stand is presented. The first three highest occurrences are at the gates A, E and J.

Table 4-20 Stand Distribution for Each Delay Code

STAND							
	A	**E**	**F**	**J**	**L**	**W**	**Total**
12	**170**	**94**	51	**75**	8	33	431
15	**2758**	**1396**	518	**1123**	143	648	6586
18	**406**	**150**	74	**169**	37	89	925
32	377	149	71	158	52	93	900
34	**336**	**201**	100	**218**	45	90	990
35	**501**	**134**	22	**105**	35	77	874
39	**239**	**53**	27	**53**	28	40	440

Table 4-21 Stand Distribution for Each delay Code in Percentage

STAND							
	A	**E**	**F**	**J**	**L**	**W**	**Total**
12	0,39	0,22	0,12	0,17	0,02	0,08	1,00
15	0,42	0,21	0,08	0,17	0,02	0,10	1,00
18	0,44	0,16	0,08	0,18	0,04	0,10	1,00
32	0,42	0,17	0,08	0,18	0,06	0,10	1,00
34	0,34	0,20	0,10	0,22	0,05	0,09	1,00
35	0,57	0,15	0,03	0,12	0,04	0,09	1,00
39	0,54	0,12	0,06	0,12	0,06	0,09	1,00

Season

High traffic, volatile between seasons, affects handlers and has an impact on delays. Usually, it is very common to have more delays in the summer season due to increased traffic demand in this period. Table 4-22 shows that TAP and other airlines also experience more delays in summer. On the other hand, Figure 4-23 shows that some delays occurred mostly in winter, while some of them occurred in summer. For instance, late check-in, boarding and loading delays (codes 12, 32 and 35) mostly occurred in winter.

Table 4-22 Delays in Seasons for Each Airline

SEASONS		
	Winter	**Summer**
AF	101	150
IB	127	201
LH	158	290
TP	4770	5349

Table 4-23 Delay Distribution for Seasons

SEASON			
Delay Code	Winter	Summer	Total
12	237	194	431
15	3053	3533	6586
18	348	577	925
32	479	421	900
34	375	615	990
35	470	404	874
39	194	246	440

Table 4-24 Delay Distribution for Seasons in Percentage

Delay Code	Winter	Summer	Total
12	0,63	0,37	1,00
15	0,56	0,44	1,00
18	0,39	0,61	1,00
32	0,51	0,49	1,00
34	0,44	0,56	1,00
35	0,47	0,53	1,00
39	0,44	0,56	1,00

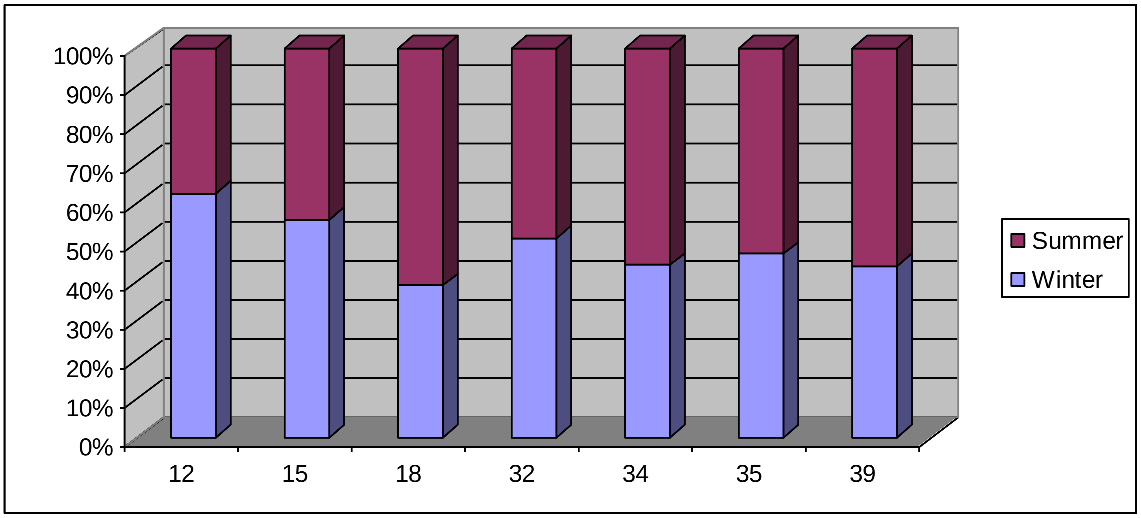


Figure 4-10 Delay Distribution in Seasons

Day

The following tables are prepared to ascertain on which day which airline was mostly delayed, and which delay codes appeared more on certain days. Airlines in the study were delayed on different days. For instance, Air France was delayed mostly on Friday and Saturday, while Iberia was mostly delayed on Monday. Also, the following tables show that different delay reasons appear on different days.

Table 4-25 Number of Delays According to the Days

	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday	Total
AF	37	29	19	20	**51**	**53**	42	251
IB	**58**	38	40	38	**56**	54	44	328
LH	**78**	60	50	47	62	68	**83**	448
TP	1577	1169	1162	1271	**1605**	1588	**1747**	10119
Total	1750	1296	1271	1376	1774	1763	1916	11146

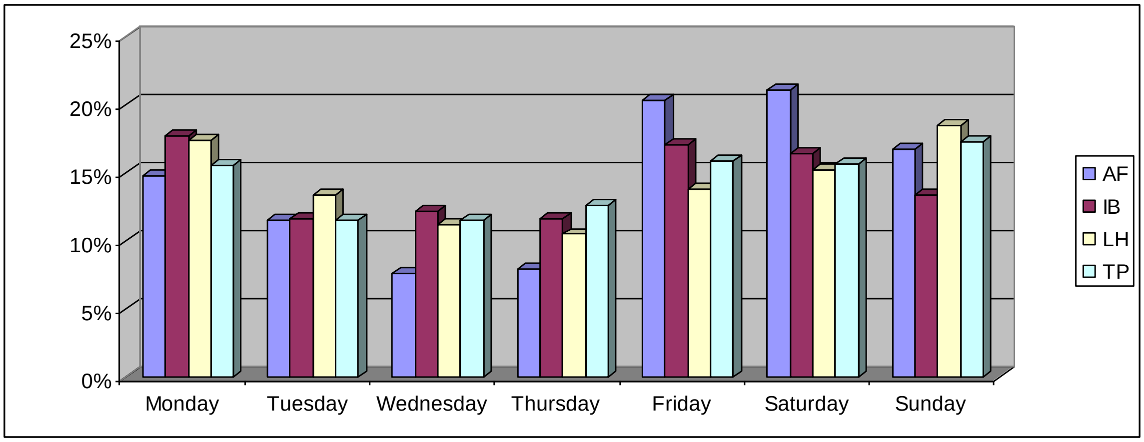


Figure 4-11 Delay Distributions According to the Days

Table 4-26 Number of Delays on Each Day

	Monday	**Tuesday**	**Wednesday**	**Thursday**	**Friday**	**Saturday**	**Sunday**	**Total**
12	75	26	25	28	64	**119**	**94**	431
15	987	772	816	848	**1034**	974	**1155**	6586
18	**181**	101	83	107	123	158	**172**	925
32	98	121	116	119	**156**	**156**	134	900
34	**190**	118	111	137	**180**	121	133	990
35	154	88	55	84	141	**190**	**162**	874
39	65	**70**	65	53	**76**	45	66	440

Table 4-27 Number of Delays on Each Day in Percentage

	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday	Total
12	0,17	0,06	0,06	0,06	0,15	**0,28**	**0,22**	1,00
15	0,15	0,12	0,12	0,13	**0,16**	0,15	0,**18**	1,00
18	**0,20**	0,11	0,09	0,12	0,13	0,17	**0,19**	1,00
32	0,11	0,13	0,13	0,13	**0,17**	**0,17**	0,15	1,00
34	**0,19**	0,12	0,11	0,14	**0,18**	0,12	0,13	1,00
35	0,18	0,10	0,06	0,10	0,16	**0,22**	**0,19**	1,00
39	0,15	**0,16**	0,15	0,12	**0,17**	0,10	0,15	1,00

The tables show that each delay reason occurred on different days. For instance, late check-in (code 12) and cleaning (code 35) occurred mostly at the weekends, boarding on Friday and Saturday, baggage processing on Mondays and Sundays, loading delays on Friday and Saturdays, servicing equipment delays on Monday and Friday, and technical equipment delays occurred on Tuesday and Friday.

Destination

Destination variable is only valid for TAP because TAP is the only airline in this study which has flights on different continental routes. In TAP, there are more daily flights to European destinations; inevitability, most of the delayed flights are in the route of Europe.

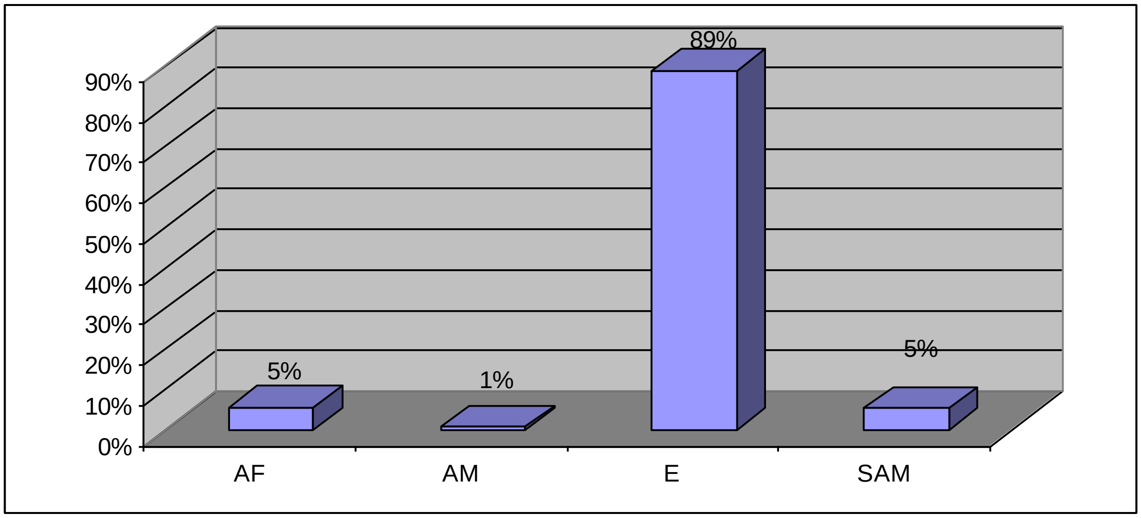


Figure 4-12 Distribution of Delays in Continents

Table 4-28 Number of Delayed Flights in Each Destination

DESTINATION-TAP					
	Africa	**America**	**Europe**	**S.America**	**Total**
12	**25**	0	**356**	3	384
15	**358**	36	**5538**	266	6198
18	30	7	**653**	**67**	757
32	55	8	**633**	**71**	767
34	18	11	**838**	**43**	910
35	**48**	0	**703**	**48**	799
39	14	2	**263**	**25**	304

Table 4-29 Number of Delayed Flights in Each Destination in Percentage

	Africa	America	Europe	S.America	Total
12	0,07	0,00	0,93	0,01	1,00
15	0,06	0,01	0,89	0,04	1,00
18	0,04	0,01	0,86	0,09	1,00
32	0,07	0,01	0,83	0,09	1,00
34	0,02	0,01	0,92	0,05	1,00
35	0,06	0,00	0,88	0,06	1,00
39	0,05	0,01	0,87	0,08	1,00

Figure 4-13 also shows the other way of looking at the destination. This graphic shows the distribution for Schengen/Domestic routes and Nonschengen routes.

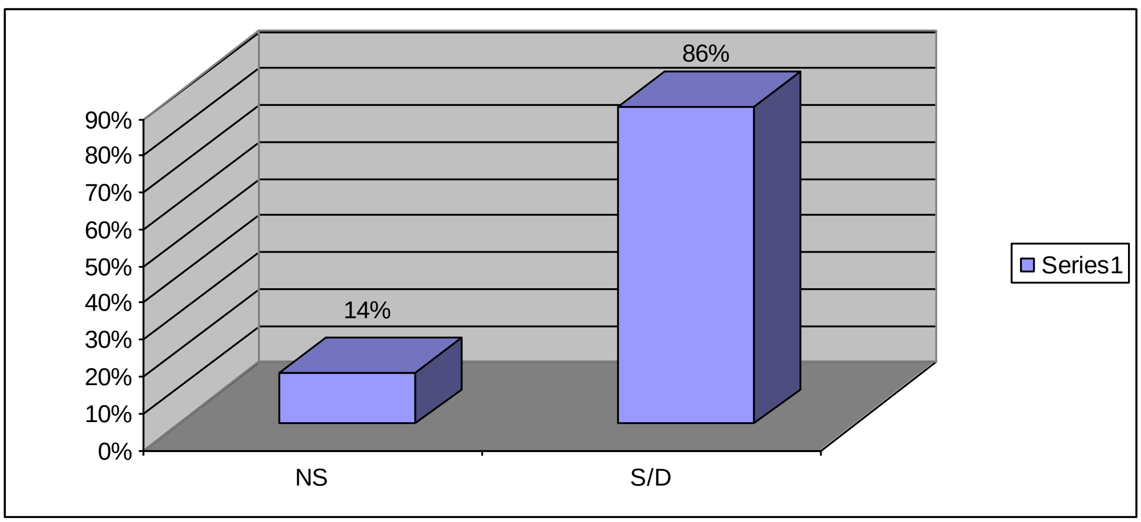


Figure 4-13 Distributions of Flights in Destination

Time Intervals

The variable of time intervals indicates the duration of the handling delays. The variable is categorized as in the following:

Coding of time intervals to use in analyses is performed as follows

If duration of delay is between 0 min and 5 min = 1

If duration of delay is between 5 min and 10 min = 2

If duration of delay is between 10 min and 15 min = 3

If duration of delay is longer than 15 min = 4

Table 4-30 shows delayed flights in each category. Four of the airlines' handling delays are mostly between 5 minutes and 10 minutes.

Table 4-30 Distribution of Flights in Time Intervals

	Time intervals				
	1	**2**	**3**	**4**	**Total**
AF	41	**70**	47	**93**	251
IB	83	**137**	70	38	328
LH	**131**	**184**	79	54	448
TP	3317	4376	1299	1127	10119

Here, Air France shows deviation in the time interval 4. This means Air France is experiencing longer (more than 15 minutes) delays in handling operations compared to other airlines.

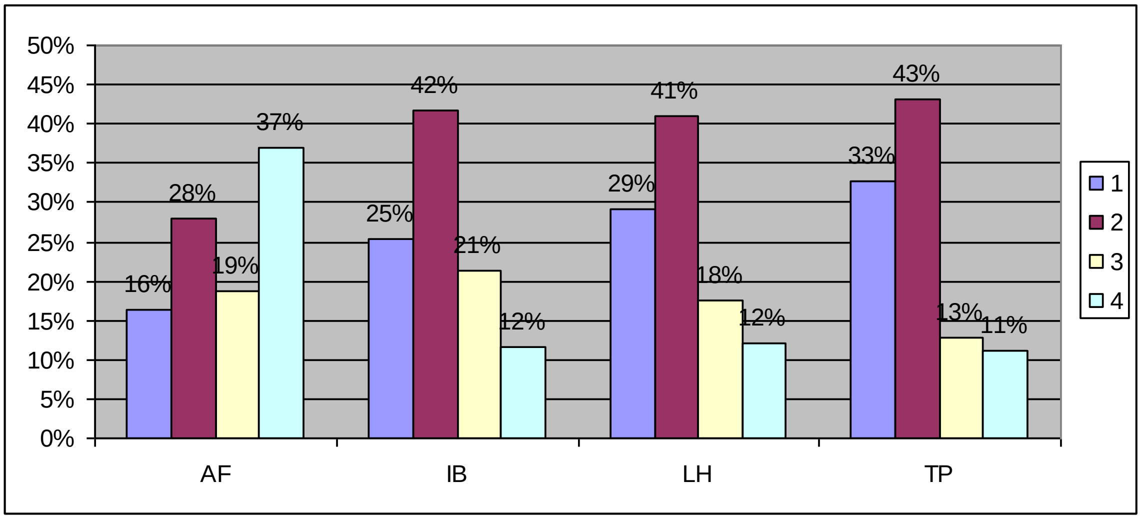


Figure 4-14 Delays in Different Time Intervals

In Table 4-31 and Table 4-32, duration of each delay is presented. Late check-in (Code 12) and loading/unloading delays are the ones which last more than 15 minutes frequently.

Table 4-31 Number of Different Delays in Each Time Interval

	TIME INTERVALS				
Delay Code	**1**	**2**	**3**	**4**	**Total**
12	48	**158**	102	**123**	431
15	2563	2888	646	489	6586
18	154	**412**	**186**	173	925
32	166	**303**	191	**240**	900
34	**313**	**461**	123	93	990
35	165	**378**	**181**	150	874
39	**163**	**167**	66	44	440

Table 4-32 Number of Different Delays in Each Time Interval in Percentage

Delay Code	1	2	3	4	Total
12	0,11	0,37	0,24	0,29	1,00
15	0,39	0,44	0,10	0,07	1,00
18	0,17	0,45	0,20	0,19	1,00
32	0,18	0,34	0,21	0,27	1,00
34	0,32	0,47	0,12	0,09	1,00
35	0,19	0,43	0,21	0,17	1,00
39	0,37	0,38	0,15	0,10	1,00

Time of Day

In order to see which delays were more frequent in which time of the day, a day is divided in to four different time periods. The fourth period has a longer time interval compared to the rest since there are no night flights in Lisbon due to noise restriction. These time periods are as follows:

Period 1: 06:00:00 - 10:00:00

Period 2: 10:00:00 - 14:00:00

Period 3: 14:00:00 - 18:00:00

Period 4: 18:00:00 - 06:00:00

Table 4-33 Delay Distribution in Time Periods of a Day

	1	**2**	**3**	**4**
AF	28	51	**132**	40
IB	**117**	79	96	36
LH	169	60	**215**	4
TP	3193	1905	**3210**	1811

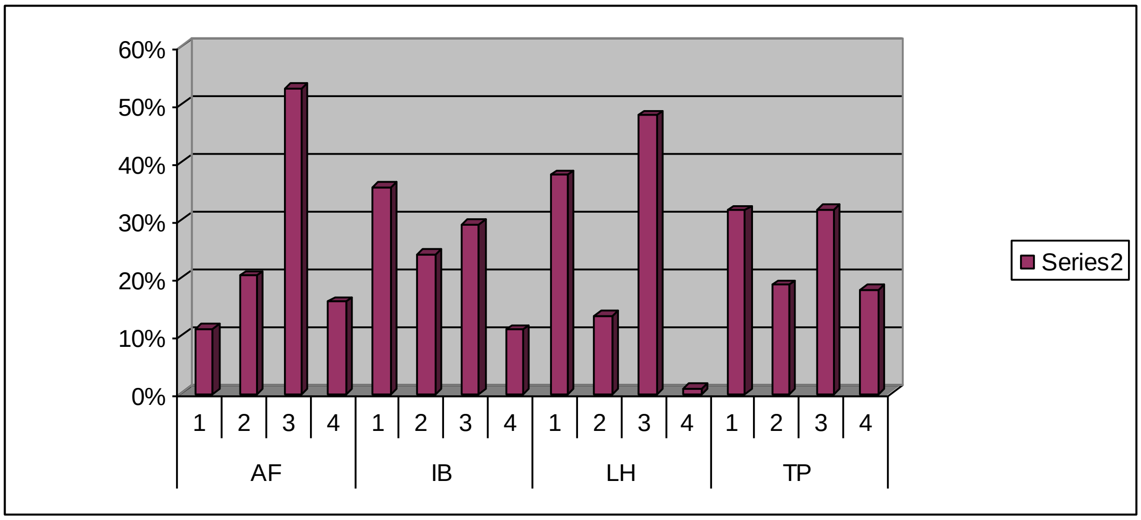


Figure 4-15 Delay Distribution in Time Periods of a Day

While Iberia experienced delays, especially in the morning, the others experienced the handling delays between 14:00 and 18:00.

Table 4-34 shows that boarding and technical equipment delays mostly occurred between 14:00 and 18:00, while the other delays occurred in the morning between 6:00 and 10:00.

Table 4-34 Delay Distribution in a Day for Each Delay Reason

	1	2	3	4	TOTAL
12	**324**	46	20	41	431
15	1711	1180	**2371**	1324	6586
18	**361**	202	285	77	925
32	**320**	198	257	125	900
34	**335**	209	284	162	990
35	**333**	146	290	105	874
39	123	114	**146**	57	440

5. MULTIPLE CORRESPONDENCE ANALYSIS

To gain insight into the nature of delays in ground handling operations, the experiences of a number of European airlines are examined using advanced descriptive techniques. Given the various dimensions of ground handling, it is necessary to tease out the key linkages.

Multiple correspondence analysis is an extension of correspondence analysis (CA), which allows one to analyze the pattern of relationships of several categorical dependent variables. As such, it can also be seen as a generalization of principal component analysis when the variables to be analyzed are categorical instead of quantitative. MCA has many equivalent methods, known under a large number of different names, such as optimal scaling, optimal or appropriate scoring, dual scaling, homogeneity analysis, scalogram analysis, and quantification method (Abdi and Valentin, 2007)
Correspondence analysis, a well-established procedure that has its pedigree in the work of Hirshfield (1935), is a statistical visualization method for depicting associations between levels in a two-way contingency table. It is a descriptive/exploratory technique designed to analyze simple two-way and multi-way tables containing some measure of correspondence between the rows and columns. The results provide information that is similar in nature to those produced using factor analysis techniques, and they allow exploration of the structure of categorical variables included in tables.

The technique has a number of attractive features for the purposes of this research. For example, it produces a visual representation of the relationships between the row and the column categories in the same space. The technique is also versatile and can be used with frequency data, with percentages, with data in the form of ratings and with heterogeneous data sets. In terms of output and insights, multiple correspondence analysis can suggest unexpected dimensions and relationships in the tradition of exploratory data and, although model-free itself, the results of correspondence analysis are often a useful preliminary to more structured and traditional multivariate modelling. It remains, however, a technique that has been relatively little used in social science research in the UK and the US, although there it has been widely used in French studies. For instance, MCA was used in social studies such as poverty measurement in Vietnam (Asselin and Anh, 2005), transport modelling (Carvalhido and Abrentes, 2006), job stress models (Catrien and Bijleveld, 2000) and also attitudes of Jewish (Hartman, 2001)

From the perspective of this research, this technique can be used to help define the interaction between the delays and facts in turnaround processes at airports, and bring some solution to induce external effects on the aircraft turnaround - or mainly, how to manage and take action against these external effects.

The purpose of this chapter is to identify dominant fact patterns on delays, and correlation between the variables in categories to see which combination of facts has a bigger effect on handling related delays for each airline. After presenting the percent and duration of the delays in chapter four, the correlation between facts which can boost the handling delays will be presented. In this chapter, to group and to see the relation between the variables, a technique of multiple correspondence analysis is used. A technique, HOMALS, which was developed by De Leeuw and Van Rijckevorsel (1980), Young (1981) and Gifi (1981), is also used for precise interpretation of Multiple Correspondence Analysis. It is proved by Greenacre and Blasius (1994) that HOMALS and MCA produce identical results, despite their methodologies being different.

Multiple Correspondence Analysis, quantifies nominal (i.e. categorical) data by assigning numerical values to the objects (flights in this case) and to the categories, such that in a low dimensional representation, objects within the same category are close together and objects in different categories are far apart. The categories divide the objects into homogeneous subsets (Carvalhido and Abrentes, 2006)

The input matrix for this analysis is composed of *n* flights (rows), classified according to *m* variables (columns). The values that each variable can assume are called categories. Since each *flight* is defined by *m* variables, an *m*-dimensional space would be needed in which to project all the categories. Obviously, it would not be possible to visualize categories in this *m*-multidimensional space, so it is necessary to define spaces with fewer dimensions in order to visualize the graphics. In this perspective, HOMALS can be seen as a data reduction method since it allows the representation of relationships between categories in a smaller dimensional space, without necessarily implying a great loss of initial information. In this way, HOMALS can be seen as a type of Principal Components Analysis for categorical variables.

For variable j (where $j=1,\ldots,m$), h_j is an n-vector with categorical observations, k_j is the number of valid categories of variable j, G_j is the indicator matrix for variable j, of order $n \times k_j$ in which

$$g_{(j)ir} = \begin{cases} 1 & \text{if the } i\text{th object is in the } r\text{th category of variable } j \\ 0 & \text{if the } i\text{th object is not in the } r\text{th category of variable } j \end{cases} \quad (1)$$

M_j is a binary, diagonal $n \times n$ matrix, with diagonal elements defined as

$$m_{(j)ii} = \begin{cases} 1 & \text{if the } i\text{th observation is within the range } [1,k_j] \\ 0 & \text{if the } i\text{th observation is outside the range } [1,k_j] \end{cases} \quad (2)$$

D_j is a diagonal matrix containing the univariate marginals, i.e., the column sums of G_j.

The quantification matrices are X (object scores, of order $n \times p$), Y_j (category quantifications, of order $k_j \times p$) and Y (concatenated category quantifications matrices, of order $\sum_j k_j \times p$), where p is the number of dimensions chosen.

HOMALS' aim is to find object scores X and a set of Y_j so as to minimize the loss function:

$$\sigma(X,Y) = \frac{1}{m}\sum_{j=1}^{m} tr[(X - GjYj)^T.Mj.(X - GjYj)]$$

Under the normalization restriction $X^T M_* X = mn\boldsymbol{I}$, where $M_* = \sum_j M_j$ and $\boldsymbol{I}$ is the identity matrix of order p. The inclusion of M_* in the loss function ensures that there is no influence of data values outside the range $[1,k_j]$ and contains the number of active data values for each object.

The minimization of σ is achieved by using the following algorithm (Meulman and Heiser, 2005):

Initialization (the object scores X are initialized with random values, which are normalized so that $u^T M * X = 0$ (*u* is a *n*-vector with ones) and $X^T M * X = mnI$ yielding $\overline{X}$. Then the first category quantifications are obtained as $\overline{Yj}$ $=Dj^{-1}Gj^T\overline{X}$

2. Update object scores (Z=$\sum jM\,jGj\;Yj$) and centre Z with respect to M*, obtaining $\overline{Z}$:

$\overline{Z}$=$\{M * -(M * uu^T\ M */u^T M * u) =\}Z$

.

3. Orthonormalization (find an M*-orthonormal X+ that is closest to Z in a least squares sense:

$X^+ = m^{1/2} M^{*-1/2} GRAM(M^{*-1/2}\overline{Z})$, where *GRAM* is a Gram-Schmidt transformation.

4. Update category quantifications (Yj^+=$Dj^{-1}Gj^1Y^+$, for every *j)*

5. Convergence test (if the difference s(X ,Y)- s(X^+ ,Y^+)>e , e being a small positive number specified, steps 2 to 4 are repeated until convergence is achieved).

6. Rotation. Solutions in different dimensionality are nested, i.e., the *p*-dimensional solution is equal to the first *p* columns of the *(p+1)*-dimensional solution. Nestedness is achieved by computing the eigenvectors of the matrix $\boldsymbol{\frac{1}{m}\sum_j Yj^T\ DjYj}$

This case study presents the data derived from the Ground Force handling company (previously knows as SPDH) with respect to the departure information of four airlines: Air France, Iberia, Lufthansa and TAP,

Each airline has quite a different number of flights, especially TAP which has a higher deviation from the others in terms of the number of delayed flights. Therefore, in order to arrive at more accurate conclusions, TAP data was evaluated separately from the other airlines. The reason for TAP experiencing more delays is that TAP, as a home carrier at Lisbon airport, has more flights to many more destinations. This unbalanced amount of traffic has a negative impact on the statistical analysis and makes it more difficult to see the conclusions in spatial representation. Consequently, the first part of the study focuses on the 3 airlines, Lufthansa, Iberia, Air France, and the second part of the study focuses on only TAP.

5.1 Selecting Variables

To select the variables which have a strong relationship between each other, discrimination measure tables were used (Table 5-1 and Table 5-2). For instance, variables *time intervals* and *day* have low discrimination measures, which means that these variables are the least useful ones for identifying different delay categories. As a result, these variables were removed from the analyses. With selected variables, the variance explained by them is 69 % for TAP and 91 % for the other airlines in the first three dimensions (see Table 5-3 and Table 5-4)

Table 5-1 Discrimination measures of AF, IB and LH

	Dimension				Mean
	1	2	3	4	
Year	0,139	**0,281**	**0,203**	0,118	,185
Time of Day	0,132	0,176	**0,226**	**0,357**	,223
Aircraft Type	**0,636**	**0,382**	**0,585**	**0,321**	,481
Airline	0,678	**0,626**	0,079	0,000	,346
Delay Code	**0,231**	0,125	0,053	**0,396**	,201
Gate	**0,449**	**0,385**	**0,374**	0,181	,347
Stand	**0,286**	0,113	0,167	0,103	,167
Active Total	20,550	20,088	10,687	10,475	1,950
% of Variance	36,432	29,834	24,099	21,077	27,861

Table 5-2 Discrimination measures of TAP

	Dimension				Mean
	1	2	3	4	
Time_of_Day	0,053	0,023	**0,444**	**0,472**	,248
Aircraft_Type	**0,674**	0,053	**0,317**	0,047	,273
Time_Intervals	0,043	0,**261**	0,060	0,066	,107
Continent	**0,605**	0,035	0,096	**0,485**	,305
Delay_Code	0,036	**0,509**	**0,209**	0,182	,234
Gate	**0,353**	0,172	0,101	0,047	,168
Stand	**0,486**	0,152	**0,244**	0,029	,228
Year	0,029	**0,507**	0,063	0,022	,155
Active Total	2,279	1,712	1,534	1,350	1,719
% of Variance	28,488	21,398	19,174	16,881	21,485

Table 5-3 Variances of Dimensions for TAP

Dimension	Cronbach's Alpha	Variance Accounted For		
		Total (Eigenvalue)	Inertia	% of Variance
1	0,641	2,279	0,285	28,488
2	0,475	1,712	0,214	21,398
3	0,398	1,534	0,192	19,174
4	0,297	1,350	0,169	16,881
Total		6,875	0,859	
Mean	0,478(a)	1,719	0,215	21,485

Table 5-4 Variances of Dimensions for AF, IB, LH

Dimension	Cronbach's Alpha	Variance Accounted For		
		Total (Eigenvalue)	Inertia	% of Variance
1	0,709	2,550	0,364	36,432
2	0,608	2,088	0,298	29,834
3	0,475	1,687	0,241	24,099
4	0,376	1,475	0,211	21,077
Total		7,801	1,114	
Mean	0,568(a)	1,950	0,279	27,861

5.2 Interpretation of Dimensions through Quantification of the Categories

Discrimination measures were used to select the variables that were part of this analysis. It is now important to identify the categories that contribute the most to forming distinctive groups. In order to do this, it is necessary to complement the previous analysis with the quantification of the categories. Two categories with opposite sign values are said to oppose each other, and categories with similar signed values are said to be associated. This analysis can be carried out separately for each dimension or for two dimensions at once on a plane. This section deals with the analysis of single dimensions.

The categories' quantifications (Table 5-5 and Table 5-6) allow the identification of the most important categories (i.e. those with the greater absolute coordinate value) for the first three dimensions. Values close to zero indicate a category that is not strongly correlated with any particular category in the other variables. That is the case, for example, for the Table 5-6 category *"delay code 39"* in dimension 1. This means, for example, delay code 39 is not a certain delay type that has impact on describing airlines' delay pattern related to aircraft type (Assuming that *aircraft type* is the most important variable in dimension 1).

Table 5-5 Quantification of Categories of Lufthansa, Air France and Iberia

Variables	Category	Frequency	Coordinates			
			Dimension			
			1	2	3	4
Year	2000	116	0,102	**-0,993**	**-0,755**	-0,77
	2001	133	0,891	**-0,592**	0,178	0,189
	2002	201	-0,091	0,005	**-0,525**	-0,002
	2003	256	-0,113	**0,667**	0,114	-0,145
	2004	279	-0,298	0,079	**0,503**	0,364
Time of Day	1	302	0,299	0,608	**-0,376**	**0,213**
	2	185	-0,504	-0,076	-0,151	**0,896**
	3	418	0,153	-0,308	**0,512**	**-0,284**
	4	80	-0,762	-0,514	**-0,908**	**-1,393**
Aircraft Type	2	138	**0,98**	**-0,352**	**1,715**	**-0,318**
	6	274	**0,908**	0,146	**-0,494**	0,137
	8	264	**-0,527**	**-0,615**	**-0,594**	**-0,321**
	9	217	**-0,759**	**1,019**	0,189	**-0,283**
	10	92	**-0,87**	**-0,548**	0,158	**1,657**
Airline	AF	243	**-0,52**	**-1,234**	-0,445	-0,015
	IB	323	**-0,837**	**0,873**	-0,009	0,002
	LH	419	**0,947**	0,043	0,265	0,007
Delay Code	12	46	**0,322**	-0,307	-0,873	0,083
	15	363	-0,043	-0,119	0,03	**-0,663**
	18	165	**0,866**	0,36	-0,089	**0,422**
	32	132	-0,164	-0,24	0,245	**0,856**
	34	76	**-1,045**	-0,248	0,099	**-0,236**
	35	73	**-0,373**	10,015	0,268	**-0,451**
	39	130	-0,107	-0,199	-0,12	0,808
Gate	0	43	**-0,911**	**-1,96**	**-0,316**	-0,086
	1	118	**-1,164**	**0,703**	**0,383**	-0,479
	2	52	**-0,912**	0,043	**0,642**	0,468
	3	47	**-0,602**	**-0,623**	**0,733**	0,716
	4	111	0,184	**0,546**	**-0,716**	0,143
	5	104	0,**408**	**0,286**	**-0,995**	0,44
	6	112	0,188	**0,392**	**-0,755**	0,256
	7	320	0,654	-0,092	**0,382**	-0,323
	8	35	-0,314	**-0,898**	**0,806**	1,077
	9	43	-0,694	**-1,05**	**0,41**	-0,516
Stand	A	764	**0,287**	0,061	-0,214	-0,009
	E	114	**-0,923**	-0,763	0,927	0,19
	J	48	**-1,005**	0,489	0,588	-0,884
	L	20	**-1,202**	1,214	0,572	-0,784
	W	39	**-1,066**	-0,185	0,467	1,108

Table 5-6 Quantification of Categories of TAP

Variable	Category	Frequency	Dimensions			
			1	2	3	4
Year	2000	1852	0,212	**0,499**	-0,324	0,113
	2001	2682	0,001	**0,528**	0,205	-0,077
	2002	1571	-0,32	**0,203**	-0,273	0,098
	2003	1066	0,051	**-0,995**	0,121	0,187
	2004	1302	0,04	**-1,229**	0,27	-0,273
Aircraft Type	5	593	**2,476**	-0,453	**-1,451**	-0,059
	6	777	-0,067	-0,287	**0,406**	0,599
	7	1024	**0,987**	0,055	**1,082**	-0,204
	8	1904	**-0,307**	-0,044	**-0,174**	-0,015
	9	3916	**-0,477**	0,18	-0,031	-0,078
	10	259	0,099	-0,718	-0,42	0,431
Time Intervals	1	2776	**-0,212**	0,567	-0,309	-0,051
	2	3700	-0,008	0,011	0,045	-0,191
	3	1065	**0,171**	-0,852	0,344	0,264
	4	932	**0,469**	-0,762	0,35	0,608
Destination	AF	475	**1,864**	-0,447	-1,257	**2,293**
	AM	58	**2,256**	0,847	-0,232	**-2,107**
	E	7458	**-0,286**	0,056	0,088	-0,022
	SAM	482	**2,31**	-0,525	-0,097	**-1,673**
Delay Code	12	337	0,017	-0,011	1,607	1,934
	15	5289	-0,07	**0,408**	-0,297	-0,045
	18	634	**0,285**	**-0,775**	0,512	-0,267
	32	593	**0,534**	**-0,785**	0,438	0,384
	34	746	0,082	**0,268**	0,263	-0,268
	35	658	**-0,293**	**-1,985**	0,387	-0,284
	39	216	-0,005	**-0,43**	-0,022	-0,401
Gate	0	1203	**0,508**	0,165	0,322	-0,058
	1	1987	0,093	0,2	-0,06	-0,258
	2	930	**-0,251**	0,21	0,301	0,375
	4	355	**-0,975**	-1,227	-0,105	0,064
	5	351	**-1,029**	-0,755	-0,384	-0,096
	6	315	**-1,114**	-0,567	-0,587	0,155
	7	690	**-1,134**	-0,702	-0,784	-0,289
	8	1332	**0,479**	0,224	0,178	0,184
	9	1310	**0,489**	0,208	0,087	0,114
Stand	A	3474	**-0,758**	-0,399	**-0,362**	-0,024
	E	1848	**0,255**	0,403	**0,175**	0,124
	F	729	**0,372**	0,726	**1,172**	0,395
	J	1688	**1,057**	-0,047	**-0,28**	-0,241
	W	734	**0,145**	0,257	**0,755**	-0,034
Time of Day	1	2620	-0,115	0,055	**0,845**	0,356
	2	1599	0,476	-0,313	**-0,611**	-0,276
	3	2766	-0,11	0,069	0,053	-0,78
	4	1488	-0,106	0,112	**-0,93**	10,12

In order to understand the pattern of handling delays for each airline, the data was explored by MCA, basically in two ways. First, the data is decomposed by using quadrants in each dimension to see the different homogenous groups (Table 5-7 and Table 5-8). Positive and Negative quadrants of each dimension show the flights which are in the same group with similar properties. Flights with the different properties are opposed to each other, and thus listed in different quadrants. After listing the group of flights with common properties, the next step was to explore the interaction between the flights in different quadrants by using the joint plot of category points. By representing the categories against the dimensions for which the respective variables show significant discrimination measures, it is possible to observe the spatial configuration of associations and oppositions between those categories. Groups of categories in opposite quadrants oppose each other, whereas groups of categories in adjacent quadrants are associated with each other (Figure 5-1)

5.3 Interpretation of TAP's Data Base

Using discrimination table (Table 5-2) and quantification of categories (Table 5-6), the following descriptions are made for each dimension and clusters.

Dimension 1 composes of the variables aircraft type, continent, stand and gate. Flights are grouped according to type of aircraft in each quadrant, because aircraft type has the highest discrimination value in dimension one. Flights in negative quadrants in Table 5-7 are the ones which are delayed, with A319 and A320 in Europe destination grouped at the stand A and the gate 7,6,4,5. The flights in negative quadrants are the ones which were delayed with the aircraft A313 and A343 in the destination of America, South America and Africa and the ones at the stand J and the gate 0, 9, 8.

In quadrants of dimension 2, handling delays were grouped according to delay reason. In positive quadrant, there are late check-in, boarding and servicing equipment delays in 2000, 2001, 2002, which is around 5 minutes delays, while in negative quadrant there are flights which were delayed in 2003 and 2004 because of cleaning, passenger processing, technical equipment and loading, and last longer than 15 minutes (Table 5-8).

Table 5-7 Quadrants of Dimension 1

Positive Quadrants (Q1)	**Negative Quadrants (Q2)**
Aircraft Type: A313 and A343 **Continent :**America, South America and Africa **Stand :** J, F,E **Gate :** 9,8,0	**Aircraft Type:** A320 and A319 **Continent :**Europe **Stand :** A **Gate :** 7,6,5,4,2

Table 5-8 Quadrants of Dimension 2

Positive Quadrants (Q3)	**Negative Quadrants (Q4)**
Delay Code : Late Check-in Boarding Servicing Equipment **Year :** 2000, 2001,2002 **Time Intervals:** 1	**Delay Code :**Aircraft Cleaning Baggage Processing Technical Equipment Loading/unloading **Year :**2004 and 2003 **Time Intervals:**3, 4

In Table 5-7 and Table 5-8, variables in dimension 1 and dimension 2 and categories of those variables are presented. Now, as a next step in Figure 5-1, interaction between those variables which are in the dimension 1 and 2 is presented. Flights (objects) within the same category are plotted close together, and objects in different categories are plotted far apart. Each object is as close as possible to the points of categories that apply to the object. In this way, the categories divide the objects into homogeneous subgroups. Variables are considered homogeneous when they classify objects in the same categories into the same subgroups. In Figure 5-1, there are 3 clusters of delayed flights, and each of the clusters represents different characteristics of the variables.

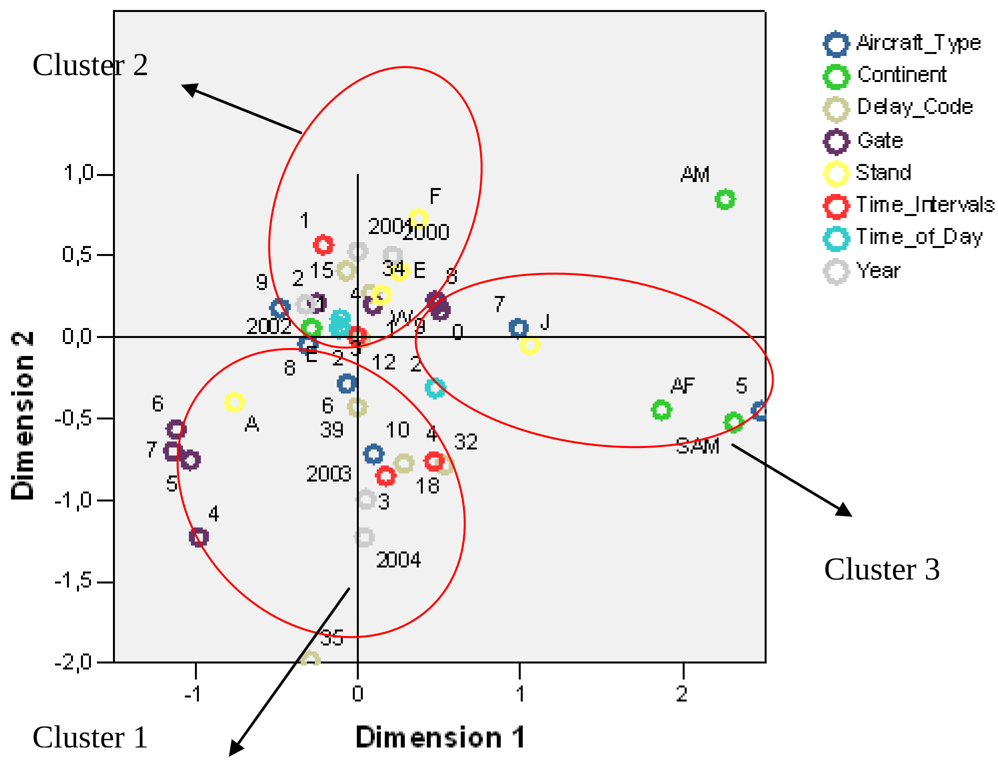


Figure 5-1 Spatial Presentation of Dimension (2, 1)

For instance, Cluster 1 shows the flights which are delayed because of baggage processing, loading/unloading, technical equipment and cleaning in 2003 and 2004, while the Cluster 2 shows the flights which are delayed due to boarding, servicing equipment and late check-in in 2000, 2001 and 2002. In Cluster 3, delays are the ones that occurred in continental flights in certain type of aircraft (A313 and A340). These are the ones which are in the stand J. In Cluster 1, delays are the ones which last more than 15 minutes and with the A321, A320 and with other aircraft types at the stands A. Cluster 3 only shows the group of delayed flights with the A340 and A313 in the route of America, Africa and South America at the stand J.

Table 5-9 Clusters of Dimension (2, 1)

Cluster 1	Cluster 2	Cluster 3
• 2003, 2004	• 2000, 2001, 2002	• A/C 5, 7
• Delay 18, 32, 39, 35	• Delay 12, 15, 34	• Gate 8, 9, 0
• Stand A	• Stand E, F, W	• Stand J
• Gate 4, 5, 6, 7	• Gate 1, 2	• Destination America, Africa, S. America
• A/C 6, 10	• A/C 9,8	
• Time Int. 3, 4	• TOD 2, 3, 4	
	• Destination Europe	
	• Time Int. 1, 2	

Dimension 3 composes of the variables, year, season and gate. Year has the highest discrimination, so flights are grouped according to year in each quadrant. Flights in positive quadrants are the ones which are delayed in 2001 and 2002 in a summer season at the gates 3, 2, 1.

The flights in negative quadrants are the ones which were delayed in the years 2000 and 2003 in winter season at the gate 7, 5, 6 and 4

Table 5-10 Quadrants of Dimension 3

Positive Quadrants (Q5)	Negative Quadrants (Q6)
Time of Day :1 **Aircraft Type:**A313, A321 **Stand** :F, W, E **Delay Code** :Late Check-in Baggage Processing Loading/unloading Cleaning Servicing Equipment	**Time of Day** :2, 4 **Aircraft Type:**A34,others, A320 **Stand** :A, J **Delay Code** :Boarding

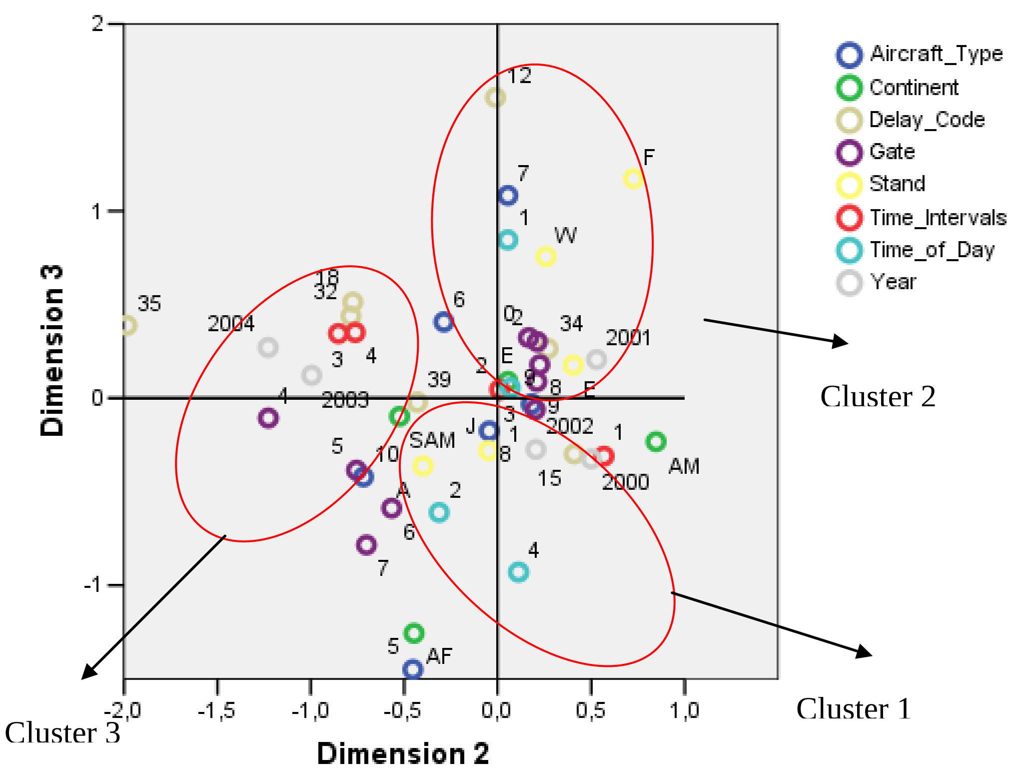


Figure 5-2 Spatial Presentation of Dimension (3, 2)

In dimension (3,2), there are 3 main clusters, which means there are 3 groups of homogenous flights different from each other. Cluster 1 shows that flights in 2000 and 2002 are the ones that were delayed due to boarding. These delays occurred at the stands J and A at the time period, 10am-14pm and 18pm-06am, with the aircraft A320. In cluster 2, flights are the ones which were delayed in 2001 due to late-check-in and servicing equipment at the gates 6, 7 and at the stands W, F, in the route of Europe with the A321, A319 and A313, and these delays mostly occurred at 6am-10am and 14pm-18pm, and lasted between 10minutes to 15 minutes. Flights in cluster 3 are the ones which were delayed in 2003 and 2004 because of baggage processing, loading/unloading. Cleaning and technical equipment were experienced, especially with the other types of aircraft at the gates 4 and 5. These delays lasted between 10 minutes to 15 minutes, and more than 15 minutes in the route of South America.

Table 5-11 Clusters of Dimension (3, 2)

Cluster 1	**Cluster 2**	**Cluster 3**
• 2000, 2002	• 2001	• 2003, 2004
• Delay 15	• Delay 12, 34	• Delay 18, 32, 35, 39
• Stand J, A	• Stand W, F	• Gate 4, 5
• Gate 6, 7	• Gate 0, 2, 8, 9	• A/C 10
• A/C 8	• A/C 6, 7, 9	• Time Int. 2, 4
• Time Int. 1	• Time Int. 2	• Destination S. America
• TOD 2, 4	• TOD 1, 3	
	• Destination Europe	

Critical Finding on TAP's Handling Delays

Using the clusters in dimension (2, 1), (3, 2), there are some main conclusions derived.

- Boarding delays mostly occurred in 2001 and time intervals of these delays were 06 am-10 am and 10am – 14 pm. A319 was most frequently delayed aircraft type in 2001 because of boarding at the gates 1, 8, 0. On the other hand, boarding delays with A319 were mostly experienced in the time between 14 pm and 18 pm.
- Servicing Equipment delays mostly occurred at the gate 1 in 2001(followed by gates 8, 0) at the stand A. Most of the servicing equipment delays were between 5 minutes to 10 minutes, and these delays occurred at the time between 06 am and 10 am.
- Late check-in delays occurred between 06 am and 10 am in the route of Europe with mostly A319 in 2001 at the stand A.
- Africa, South America, and America flights were delayed mostly at the stand J with the aircraft A340 and A313.
- Technical Equipment delays were the highest in 2004.
- Loading/unloading delays were the highest in 2001 and 2004.

5.4 Interpretation of Iberia, Lufthansa and Air France's Data Base

Explanation of dimensions and quadrants of these airlines is as follows:

Dimension 1 composes of the variables, aircraft type, airline, delay code, stand and gate. Flights in positive quadrants are the Lufthansa's flights which were delayed with A300 and A321 because of late check-in and baggage processing at the stand A and the gate 7, 6, 4, 5. Flights in negative quadrants belong to Air France and Iberia which were delayed with A320, A319 and other aircraft at the gates 0, 1, 2, 3 with various delay reasons at the stands L, W, J, E.

Table 5-12 Quadrants of Dimension 1

Positive Quadrants (Q1)	Negative Quadrants (Q2)
Airline :LH **Aircraft Type:** 2, 6 **Gate** : 4, 6, 7, 5 **Stand** : A **Delay Code** : 18, 12	**Airline** : AF, IB **Aircraft Type:** 8, 9, 10 **Gate** : 0, 1, 2,3 **Stand** : L, W, J, E **Delay Code** : 32, 34, 35, 39

In Dimension 2, the highest discrimination measures belong to airline, gate, aircraft type and year. In positive quadrants of dimension 2, there are Iberia's flights delayed in 2003 with A321 and A319 at the gates 1, 4, 5, 6. In the negative quadrant, there are flights of Air France in 2000 and 2001 at the gates 0, 3, 8, 9.

Table 5-13 Quadrants of Dimension 2

Positive Quadrants (Q3)	Negative Quadrants (Q4)
Airline : IB **Gate** : 1, 4, 5, 6 **Aircraft Type:** 6, 9 **Year** : 2003	**Airline** : AF **Gate** : 0, 3, 8, 9 **Aircraft Type :** 2, 8, 10 **Year** : 2000, 2001

In the combination of these two dimensions, in Figure 5-3, there are 3 clusters of flights which have common properties. In cluster 1, there are Lufthansa's flights, which occurred in 2001 with the aircraft A300-6 and A321 at the stand A. These flights are the ones which were delayed because of late check-in, boarding and baggage processing at the gates 4, 5, 6, 7 in the morning.

In cluster 2, there are Iberia flights which were delayed in 2003 and 2004 with the aircraft A319 at the stand J, because of cleaning at the gate 1 and gate 2 between 10 am and 14 pm.

In cluster 3, there are delayed flights of Air France because of loading/unloading, servicing equipment and technical equipment at the gate 3, 8, 9 between 18 pm-06am and 14pm-18pm at the stand E with A320 and other aircraft.

Figure 5-3 Spatial Presentation of Dimension (2, 1)

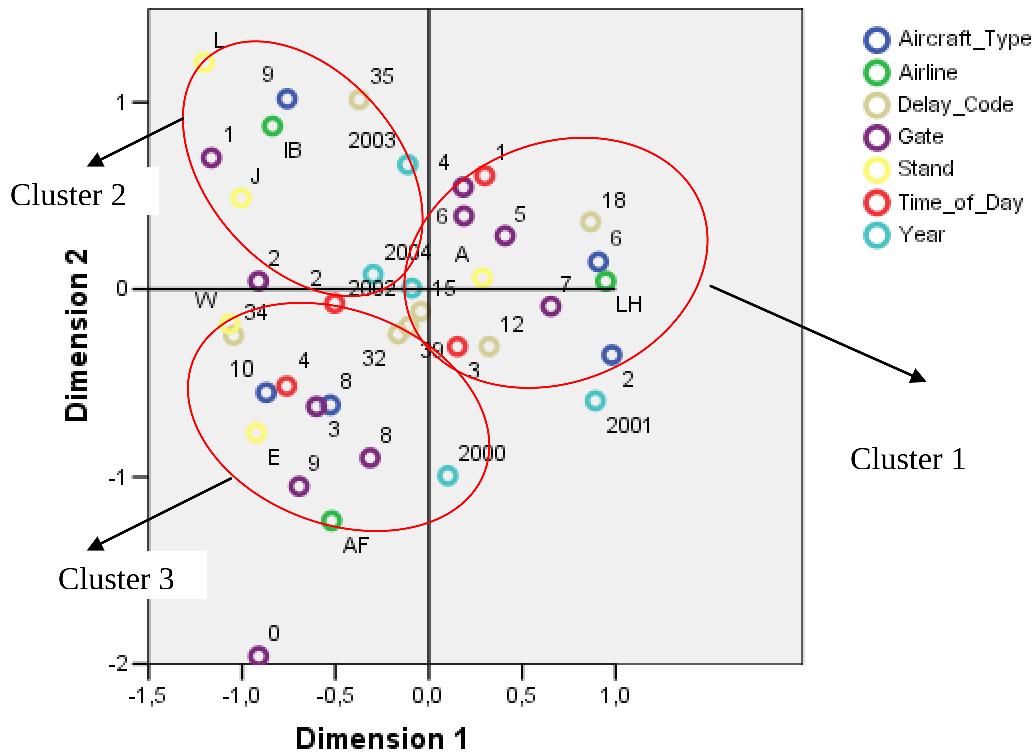


Table 5-14 Clusters of Dimension (2, 1)

Cluster 1	Cluster 2	Cluster 3
• Airline Lufthansa • Year 2001 • A/C 6, 2, 7 • Stand A • TOD 3 • Delay Code 12, 15,18 • Gate 4, 5, 6, 7	• Airline Iberia • Year 2003, 2004 • A/C 9 • Stand J • TOD 2 • Delay Code 35 • Gate 1, 2	• Airline Air France • Year 2000 • A/C 8, 10 • Stand E • TOD 4 • Delay Code 32, 34, 39 • Gate 3, 8, 9

In dimension 3, there are 5 variables with high discrimination measure values. Different properties of flights in different quadrants are presented in the following table.

Table 5-15 Quadrants of Dimension 3

Positive Quadrants (Q1)	**Negative Quadrants (Q2)**
Aircraft Type: 7, 8, 6, 9 **Gate** **:** 4, 6, 4 **Year** **:** 200,2003 **Season** **:** 1 **Stand** **:** A	**Aircraft Type:** 2, 10 **Gate** **:** 8, 9**,** 3, 2, 1, 7 **Year** **:** 2004, 2001 **Season** **:** 2 **Stand** **:** E, F W, L, J

In dimension (3, 1), there are 2 clusters. Flights in clusters are quite similar to the ones in dimension (2, 1). In cluster 1, there are flights of Lufthansa in 2000 and 2001. These are the flights which were delayed with A321 and A300-6 at the stand A at the gates 4, 5, 6, 7. They occurred because of late check-in baggage processing and boarding in the summer in the time period of 06 am-10 am and 14 pm- 18 pm

In cluster 2, there are flights of Air France and Iberia which were delayed in 2002, 2003 and 2004 with the aircraft A320, A319 and the other group of aircraft. Delays were because of servicing equipment, loading/unloading and aircraft cleaning at the gates 1, 2, 3, 8, 9.

Figure 5-4 Spatial Presentation of Dimension (3, 1)

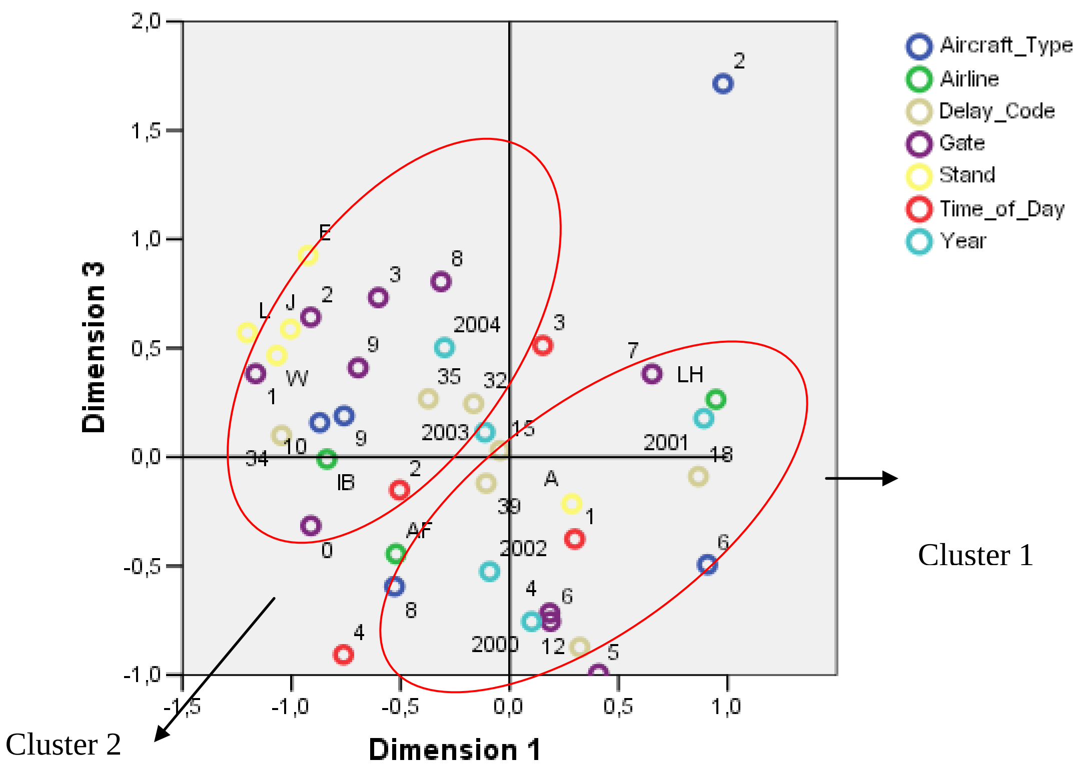


Table 5-16 Clusters of Dimension (3,1)

Cluster 1	Cluster 2
• Airline Lufthansa, Air France	• Airline Iberia
• Year 2000, 2001, 2002	• Year 2003, 2004
• A/C 6, 8	• A/C 9, 10
• Stand A	• Stand L, W, J, E
• TOD 1, 4	• TOD 2, 3
• Delay Code 12, 18, 39	• Delay Code 32, 34, 35
• Gate 4, 5, 6, 7	• Gate 0, 1, 2, 3, 8, 9

5.4.1 Critical Findings of LH, AF and IB's Delays

- Boarding and baggage processing of Lufthansa's occurred the most in 2001 with A321.
- A321 was the most frequently delayed airplane of Lufthansa in 2001
- In 2001, while A300 of Lufthansa was delayed at the time between 02 pm – 06 pm, delays with A321 occurred at the time between 06 am – 10 am.
- Boarding delays of Lufthansa occurred at the time between 02 pm – 06 pm, baggage processing delays occurred at the time between 06 am – 10 am with A321. Both of the delays occurred most at the gate group 7.
- In Lufthansa, delays in gate group 7 occurred at the time between 02 pm – 06 pm, delays at the gate groups 4, 5, 6 occurred at the time between 06 am – 10 am.
- Baggage processing and technical equipment delays of Lufthansa occurred most at the gate 7
- Cleaning delays of Iberia occurred mostly with A319 in 2003.

- In 2003, Iberia’s flights were delayed the most in Gate 1.
- Loading delays of Iberia is the highest in 2003 and 2004 with other aircraft types, while cleaning delays are the highest with A319.
- Loading and technical equipment delays of Air France occurred mostly with A320, and this combination ratio is the highest in 2000.
- Technical equipment delays of Air France occurred the most in 2002, especially at the stand A

5.5 Questions Regarding Critical Findings

- Boarding delays of TAP with A319 were mostly experienced during the time between 2 pm and 6 pm. Is there any relationship between boarding, aircraft type and time period? And is there any reason that boosts the boarding delays in 2001, especially at the gates 1, 8, 0?
- Servicing Equipment delays of TAP mostly occurred at the gate 1 in 2001(followed by gates 8, 0) at the stand A. Is there any relationship between gate, stand and servicing equipment delays in 2001?
- Why did late check-in delays of TAP occur the most during 06 am and 10 am in the route of Europe? Was there a staff allocation problem?
- Africa, South America, and America flights were delayed mostly at the stand J with the aircraft A340 and A313. What is the location of stand J? Is it far away from the main facilities and baggage areas?
- Why were Technical Equipment delays the highest in 2004? Is there an equipment problem in the handling company or in the airline?
- Loading/unloading delays of Lufthansa were the highest in the years 2001 and 2004. Was it because of an equipment problem or staff problem? Boarding and baggage processing delays of Lufthansa occurred the most in 2001 with A321. What was the problem?

- A321 was the most frequently delayed airplane of Lufthansa in 2001. Is there any other reason why the A321 is the most used aircraft in the Lufthansa's fleet?
- Why in 2001, A300 of Lufthansa did delay at the time between 02 pm – 06 pm, while delays with A321 occurred at the time between 06 am – 10 am? Is it only about scheduling of aircraft or are there any other reasons?
- Why did boarding delays of Lufthansa occur during the time between 02 pm – 06 pm, while baggage processing delays occurred during the time between 06 am – 10 am with A321? Both of the delays occurred the most at the gate group 7. Is there any relationship between the gate and the delays?
- In Lufthansa, delays in gate group 7 occurred at the time between 02 pm – 06 pm, delays at the gate groups 4, 5, 6 occurred at the time between 06 am – 10 am.
- Baggage processing and technical equipment delays of Lufthansa occurred most at the gate 7.
- Cleaning delays of Iberia occurred mostly with A319 in 2003. What was the problem in 2003?
- Why in 2003 did Iberia's flights delay the most in the gate 1?
- Why were Loading delays of Iberia the highest in 2003 and 2004 with other aircraft types, while cleaning delays were highest with A319?
- Why did loading and technical equipment delays of Air France occur mostly with A320? Why was this situation highest in 2000?
- Technical equipment delays of Air France occurred most in 2002, especially at the stand A. What is the relationship between the year, delay reason and stand?

5.6 Further Analyses for Dominant Factor

One of the main factors that boost the delay at Lisbon airport is the "time of day" that the flight was scheduled. There are 3 waves of flights: in the morning, at noon and at night. A group of aircraft arrive at the same time period to split most of the passengers on to other flights. For instance, passengers and baggage of the flights arrived from continental routes early in the morning, and distributed to domestic routes with another group of departure flights. This wave of arrivals and departure continues at noon and night. SPDH had serious problems due to waves in certain hours because equipment and staff was not sufficient and airport conditions were not suitable. For instance, most of the bags of continental flights have to be transferred to domestic/intra Europe routes for which aircraft are parked in a different terminal area. With regards to this problem, 3 groups of waves are determined, and for each wave, delays are examined separately. 3 different methods, –correlation matrix, factor analyses and hierarchical dendrogram- are used to have more concrete and specific results for this research.

In the first wave (07:15-12:00), cluster and box plot analyses show that Late check-in, boarding, loading/unloading and technical equipment delays occur at 08:00. Correlation matrix shows, in the morning peak, it is clear that servicing equipment delays combine with passenger service delays, such as late check-in, boarding and passenger processing.

According to component matrix and factor analyses servicing, equipment and baggage processing delay occurs at 09:00 (dimension 1), cleaning delays occur particularly at 11:00 (dimension 2) and late check-in delays at 08:00 (dimension 3)

Then dendogram is used for time period and delay analyses to see the relationship between each other. Dendograms give the information that cleaning delays and passenger processing occur in the same group of flights at the same time, while boarding and servicing equipment delays occur in another similar group of flights

6. CONCLUSIONS

Despite the extensive literature on airlines and airports, there have been a few studies investigating the operations of ground handling. This existing gap concerning the methods, procedures and the monitoring of handling operations, becomes even more salient when the increase in the percentage of the handling delays in airline operations is considered. Ground handling delays and the uncertainty of their occurrence can impose major costs on an airline, and can be a significant inconvenience for passengers.

This dissertation study has identified the major patterns of the handling delays and correlations between the variables that have the biggest effect on delays for selected European airlines operating out of Lisbon Airport over a four-year period.

The methodology this dissertation follows is a case study, which mainly relies on firstly identifying and analyzing the problems, and then, as a second and complementary part, confirming and finding out the reason for these problems with the help of people from the TAP and SPDH. The main hypothesis of this research was that handling delays is not independent from many other factors involved in the aircraft turnaround. The findings in the previous chapter showed that the main problems in Lisbon airport are: late check-in and boarding delays occurred in a certain time period with a certain type of aircraft (interaction of 3 variables - time period, delay code and aircraft type). Loading/unloading problems, servicing and technical equipment delays occurred in certain years (interaction of two variables-different delay codes and year).

The findings indicate that handling delays show different characteristics according to the airline involved, and a variety of other factors contribute to this phenomenon, such as the type of aircraft and the time of service. Therefore, there appears to be no universal solution to the problem, but rather the need for bespoke approaches for each airline, and for various dimensions of their ground handling activities.

Although the methodology has been applied to the data derived from a single company at Lisbon Airport, it can be generalized to any airport or airline and handling company, as long as there are valid data input.

Generally, this analysis is an attempt to classify various kinds of variables and to assess the influence of factors on these variables. In the present study, some factors were highly dominant and they indicate the importance of other variables due to the characteristics of Lisbon Airport. For instance, airport design and capacity problems are the biggest impact on "time of day" and "delay reason", and lack of equipment of handling company has the largest impact on loading delays and servicing equipment delays.

One of the reasons for late check-in delays between the years 2000 and 2004 was that the handling company was not able to see the outstation online, so that the number of passengers onboard, number of transfer passengers and arrival times were not able to seen through the computer systems. Late check-in delays did not result from the local passengers, but they were because of the transfer passengers. The same problem also had an impact on boarding delays.

Another fact which boosts the late boarding and check-in of transfer passengers is the location of fingers and distance of remote positions of Lisbon Airport. The late arrival of an inbound leg combines with congestion and design restrictions of Lisbon airport, and it causes more delays on boarding of passengers from different flights to the following flight.

Lisbon Airport has many remote positions. Proportion of the remote positions to finger positions is unbalanced. This design hinders not only the boarding and check-in operations, but also the ramp operations. It requires more time to transfer the bags and it causes more occupation of vehicles travelling between the remote positions and fingers. The occupation of vehicles and equipment is very crucial for SPDH which had serious equipment problems between 2000 and 2004. Besides equipment, staff occupation in peak hours is also another big problem for SPDH because labour union and government regulations on working hours and worker rights, restricts the flexible use of workers of SPDH, while one of the most common applications of other handling companies all over the world is seasonal and part time workers to cope with peak times.[33]

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[33] In Lisbon, this buffer is not profitable because of regulations. Workers have to work 7,5 hours which means company can not make them work less

Heavily regulated worker rights and the cumbersome structure of government does not allow handlers to work the way the handling company desires. Furthermore, airports are under the control of the government, and this situation slows down the investment decisions on airports for any improvement in the capacity. Airports are not able to meet the increasing demand since they lack strategic planning and future master plans. This leads handlers to work in poor airport conditions, despite the high traffic numbers. For instance, one of the reasons for the loading delays and mishandled bags is inefficient baggage handling bands in baggage sorting area. The limit of the baggage band in Lisbon is 1500 bags per hour, but around 750 bags per hour can shut down the system so that workers have to separate the bags in a different area, which is called Transfer Baggage Terminal (TBT). TBT was built away from the main terminal area to recover the deficiency of the baggage system of Lisbon airport. In this building, all the containers and baggage are separated manually and distributed to other flights.

Using the results of MCA and combining the confirmation of "time of day" is one of the biggest handicaps of Lisbon Airport; the present study also explored the relationship between the delay reason and delay time. For instance, passenger services delays always occur exactly at 08:00 am because of the morning wave, which means SPDH has to accommodate more experienced staff, especially in this hour.

The purpose of this dissertation study was to identify the dominant patterns for the factors that bring about delays, as well as to examine the correlation between these variables in categories to see which combination of facts have a larger affect on handling related delays. This kind of analysis can be used by the handling companies to visualize the interaction effects among these factors that boost their delays, and take action for each fact separately, to induce their mutual effect.

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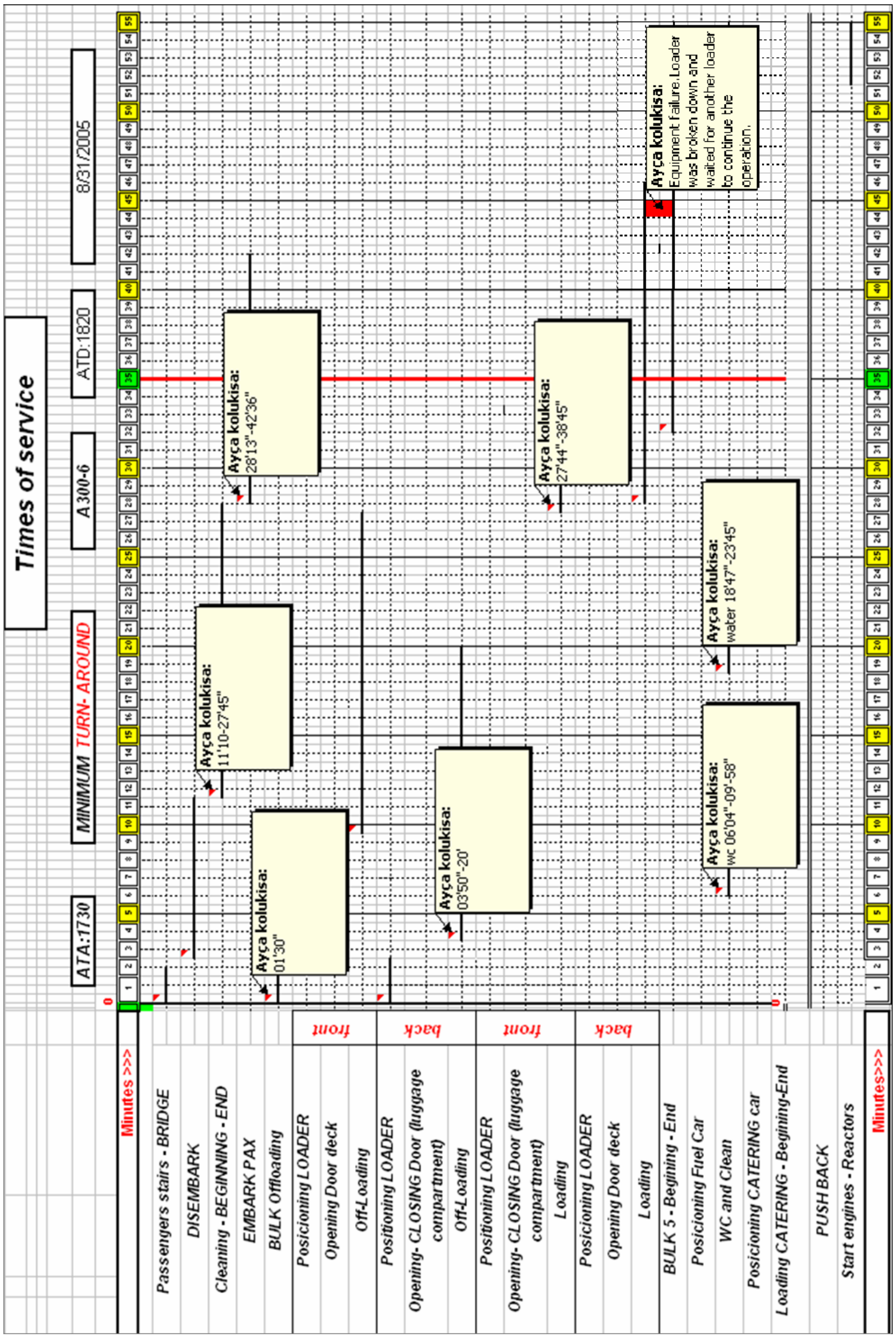
APPENDIX A

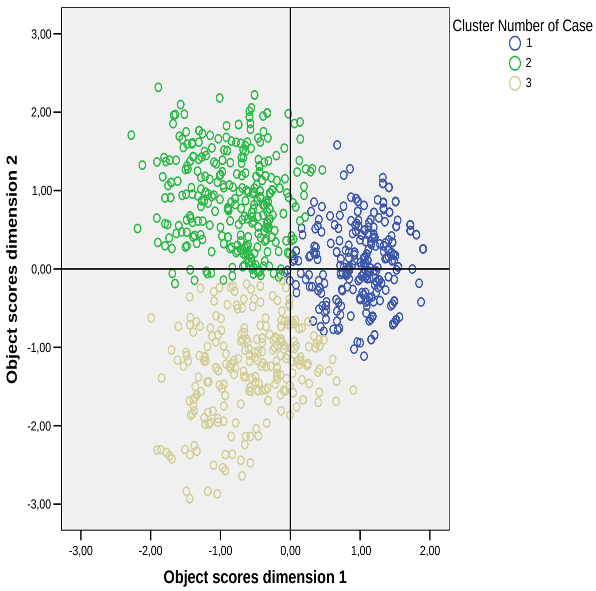

Times of service
ATA:1730
MINIMUM TURN-AROUND
A300-6
ATD:1820
8/31/2005
Minutes >>>
Passengers stairs - BRIDGE
DISEMBARK
Cleaning - BEGINNING - END
EMBARK PAX
BULK Offloading
front
Posicioning LOADER
Opening Door deck
Off-Loading
back
Positioning LOADER
Opening - CLOSING Door (luggage compartment)
Off-Loading
front
Positioning LOADER
Opening - CLOSING Door (luggage compartment)
Loading
back
Posicioning LOADER
Opening Door deck
Loading
BULK 5 - Begining - End
Posicioning Fuel Car
WC and Clean
Posicioning CATERING car
Loading CATERING - Begining-End
PUSH BACK
Start engines - Reactors
Minutes>>>
Ayça kolukisa: 01'30"
Ayça kolukisa: 11'10-27'45"
Ayça kolukisa: 28'13"-42'36"
Ayça kolukisa: 03'50"-20'
Ayça kolukisa: 27'44"-38'45"
Ayça kolukisa: wc 06'04"-09'58"
Ayça kolukisa: water 18'47"-23'45"
Ayça kolukisa: Equipment failure. Loader was broken down and waited for another loader to continue the operation.

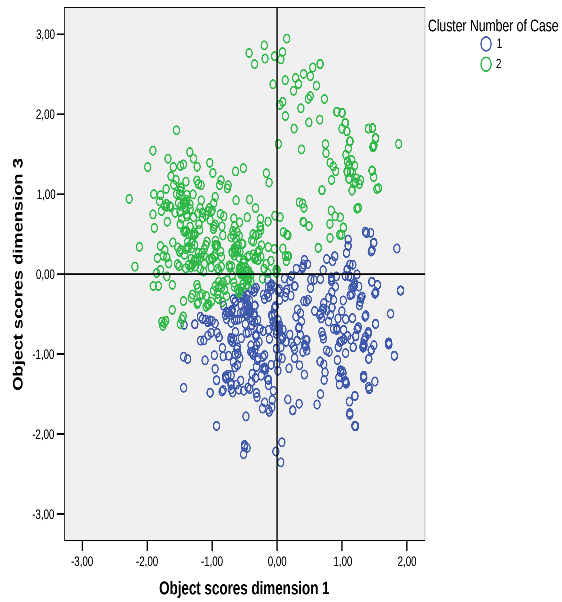
APPENDIX B
TABLES

Aircraft Type	Count
ER4	78
M88	37
762	31
AR1	29
735	15
L15	15
763	11
752	11
M87	7
318	5
312	4
AB4	4
ER3	3
757	2
AR8	2
332	1
722	1
AT4	1
CR1	1
F70	1
M83	1
737	1

APPENDIX C

HOMALS of LH IB AF



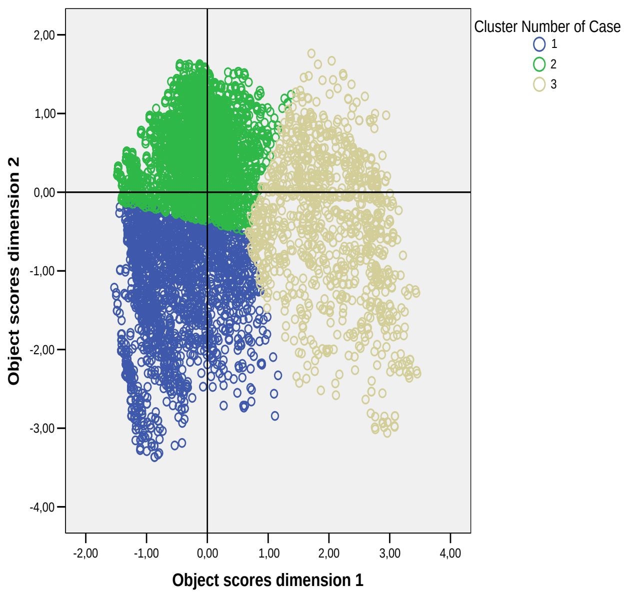


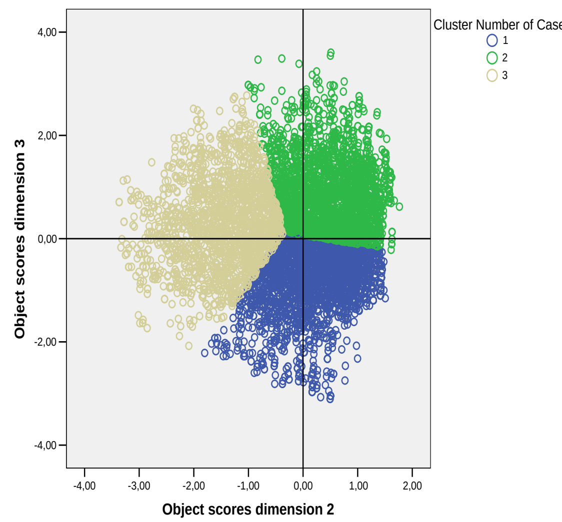
Number of Cases in each Cluster

Cluster	1	501,000
	2	484,000
Valid		985,000
Missing		,000

Cluster	1	384,000
	2	335,000
	3	266,000
Valid		985,000
Missing		,000

HOMALS OF TAP





Number of Cases in each Cluster

Cluster	1	3596,000
	2	2994,000
	3	1883,000
Valid		8473,000
Missing		,000

Cluster	1	3596,000
	2	2994,000
	3	1883,000
Valid		8473,000
Missing		,000

APPENDIX D

TAP Data – Effective Values

Interpretation of the 3 Clusters

CLUSTER 1 (0730 am – 1200 am)

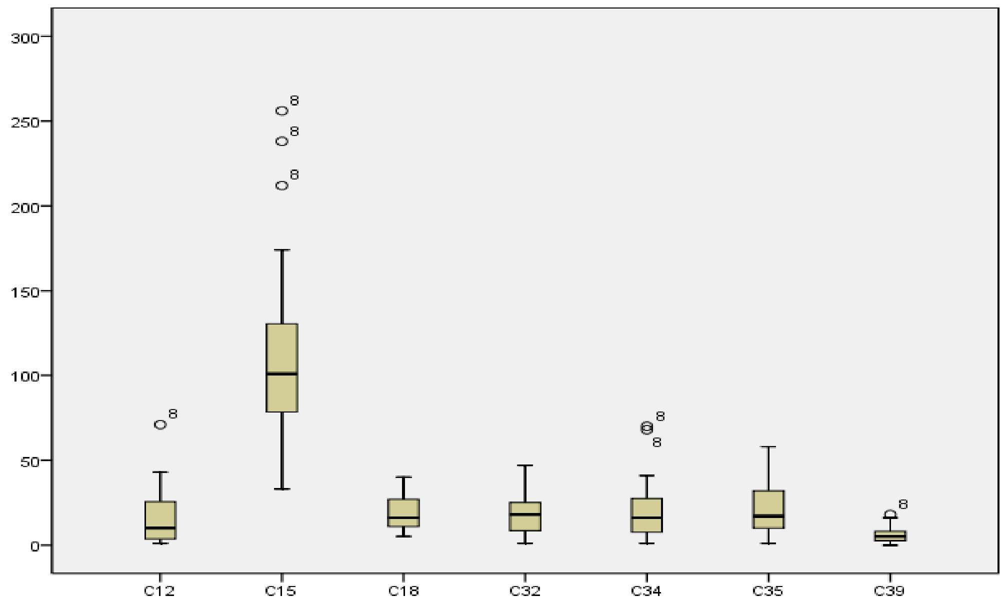
	Periods of a day	C12	C15	C18	C32	C34	C35	C39	All the Delays
1	7,3	4	33	14	3	1	1		56
2	7,45	13	101	9	17	2	10	7	159
3	8	27	174	16	21	29	29	9	305
4	8,15	43	256	39	21	41	31	18	449
5	8,3	40	238	37	47	70	44	16	492
6	8,45	71	212	40	41	68	31	9	472
7	9	33	93	17	27	28	21	3	222
8	9,15	24	89	17	37	15	10	9	201
9	9,3	11	99	14	14	10	17	5	170
10	9,45	14	118	23	24	22	41	1	243
11	10	6	134	33	26	20	58	6	283
12	10,15	10	117	30	18	27	40	2	244
13	10,3	3	68	24	22	16	33	3	169
14	10,45	10	64	13	7	15	17	5	131
15	11	1	38	7	1	4	13	4	68
16	11,15	5	55	5	1	1	6	2	75
17	11,3	3	93	7	4	5	6	1	119
18	11,45	3	127	13	13	19	12	5	192
19	12	2	102	7	10	11	10	5	147
	TOTAL	323	2211	365	354	404	430	110	4197

Descriptives

Descriptive Statistics

	N	Range	Minimum	Maximum	Mean	Std. Deviation
C12	19	70,00	1,00	71,00	17,0000	18,54125
C15	19	223,00	33,00	256,00	116,3684	63,11824
C18	19	35,00	5,00	40,00	19,2105	11,52089
C32	19	46,00	1,00	47,00	18,6316	13,25900
C34	19	69,00	1,00	70,00	21,2632	19,98289
C35	19	57,00	1,00	58,00	22,6316	15,64612
C39	19	18,00	,00	18,00	5,7895	4,80253
Valid N (listwise)	19					

Box-Plot



Factor Analysis

Correlation Matrix

		C12	C15	C18	C32	C34	C35	C39
Correlation	C12	1,000	,763	,689	,744	,859	,331	,660
	C15	,763	1,000	,771	,679	,857	,568	,834
	C18	,689	,771	1,000	,749	,835	,804	,587
	C32	,744	,679	,749	1,000	,814	,614	,596
	C34	**,859**	**,857**	**,835**	**,814**	1,000	,611	,676
	C35	,331	,568	**,804**	,614	,611	1,000	,335
	C39	,660	**,834**	,587	,596	,676	,335	1,000

Communalities

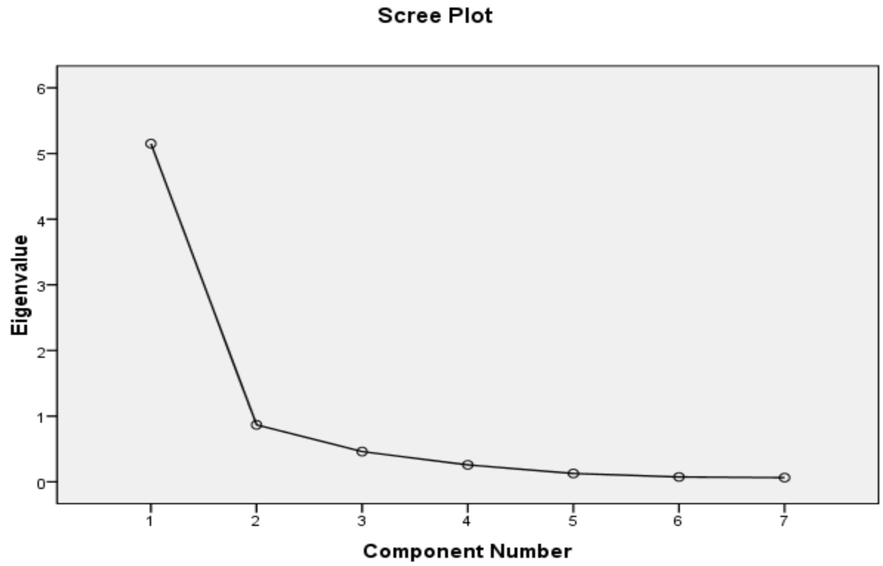
	Initial	Extraction
C12	1,000	,945
C15	1,000	,931
C18	1,000	,908
C32	1,000	,846
C34	1,000	,924
C35	1,000	,976
C39	1,000	,947

Extraction Method: Principal Component Analysis.

Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	5,150	73,573	73,573	5,150	73,573	73,573
2	,868	12,399	85,972	,868	12,399	85,972
3	,460	6,574	92,546	,460	6,574	92,546
4	,258	3,689	96,235			
5	,126	1,804	98,039			
6	,074	1,056	99,096			
7	,063	,904	100,000			

Extraction Method: Principal Component Analysis.

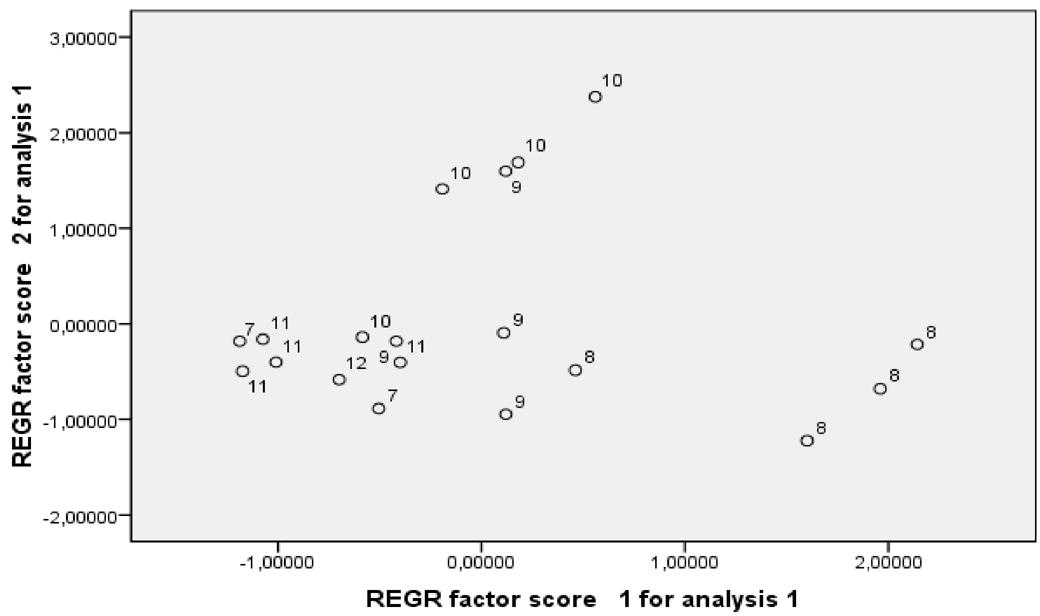


Component Matrix[a]

	Component		
	1	2	3
C12	,852	-,337	**-,325**
C15	**,917**	-,166	,250
C18	**,906**	,293	,018
C32	,869	,074	-,293
C34	**,949**	-,040	-,147
C35	,701	**,678**	,161
C39	,784	**-,417**	,398

Extraction Method: Principal Component Analysis.

Plan Axes 1-2 - Cluster1



Plan Axes 1-3 - Cluster1


Plan Axes 2-3 - Cluster1
REGR factor score 3 for analysis 1
REGR factor score 2 for analysis 1
3,00000
2,00000
1,00000
0,00000
-1,00000
-2,00000
-3,00000
-2,00000
-1,00000
0,00000
1,00000
2,00000
3,00000

CLUSTER ANALYSIS

I - Cluster for the time of a day periods (15 minutes)

Case Processing Summary[a,b]

Cases					
Valid		Missing		Total	
N	Percent	N	Percent	N	Percent
19	100,0	0	,0	19	100,0

a. Squared Euclidean Distance used

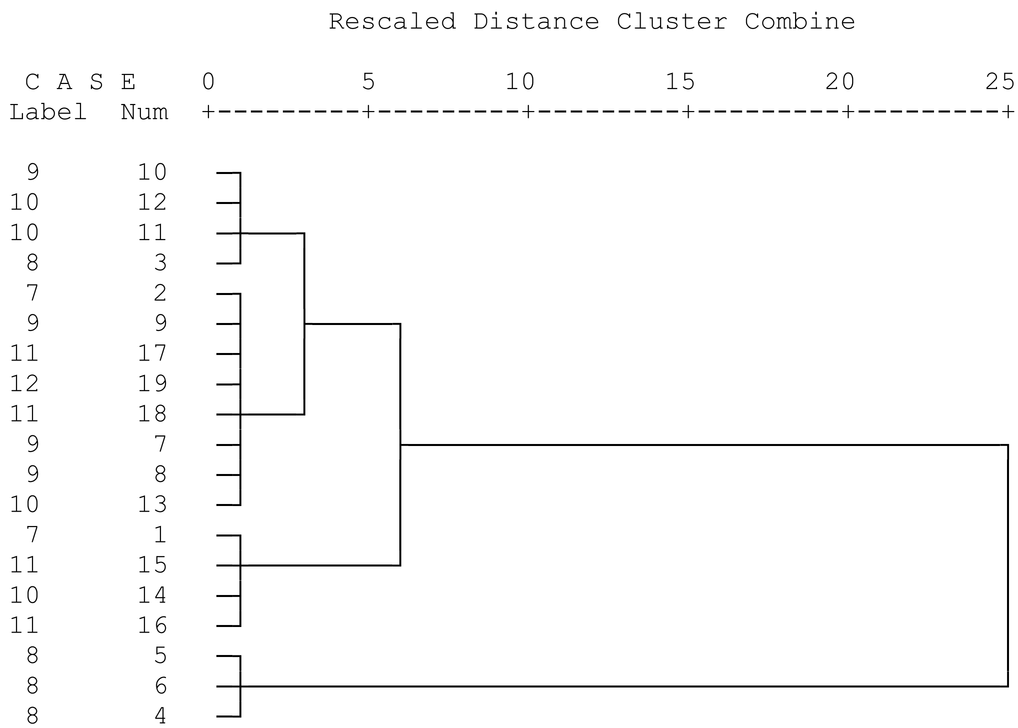
b. Ward Linkage

Ward Linkage

Agglomeration Schedule

Stage	Cluster Combined		Coefficients	Stage Cluster First Appears		Next Stage
	Cluster 1	Cluster 2		Cluster 1	Cluster 2	
1	10	12	64,500	0	0	8
2	2	9	144,000	0	0	5
3	17	19	237,000	0	0	5
4	1	15	365,000	0	0	9
5	2	17	597,250	2	3	10
6	7	8	858,750	0	0	12
7	14	16	1124,750	0	0	9
8	10	11	1606,250	1	0	15
9	1	14	2266,250	4	7	17
10	2	18	3049,500	5	0	14
11	5	6	4001,500	0	0	13
12	7	13	5117,333	6	0	14
13	4	5	6786,000	0	11	18
14	2	7	9072,542	10	12	16
15	3	10	11641,792	0	8	16
16	2	3	18502,000	14	15	17
17	1	2	32289,292	9	16	18
18	1	4	95461,263	17	13	0

Dendrogram using Ward Method



II – Cluster for the delay codes

Complete Linkage

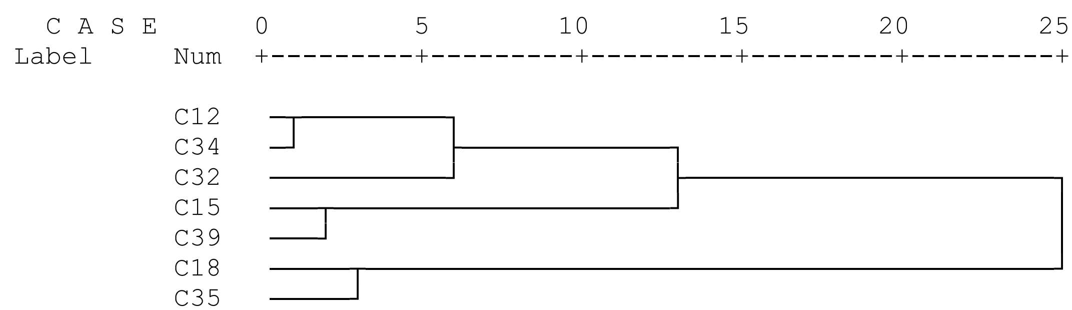
Agglomeration Schedule

Stage	Cluster Combined		Coefficients	Stage Cluster First Appears		Next Stage
	Cluster 1	Cluster 2		Cluster 1	Cluster 2	
1	1	5	,859	0	0	4
2	2	7	,834	0	0	5
3	3	6	,804	0	0	6
4	1	4	,744	1	0	5
5	1	2	,596	4	2	6
6	1	3	,331	5	3	0

Dendrogram

Dendrogram using Complete Linkage

Rescaled Distance Cluster Combine



CLUSTER 2 (1315 am – 1745 pm)

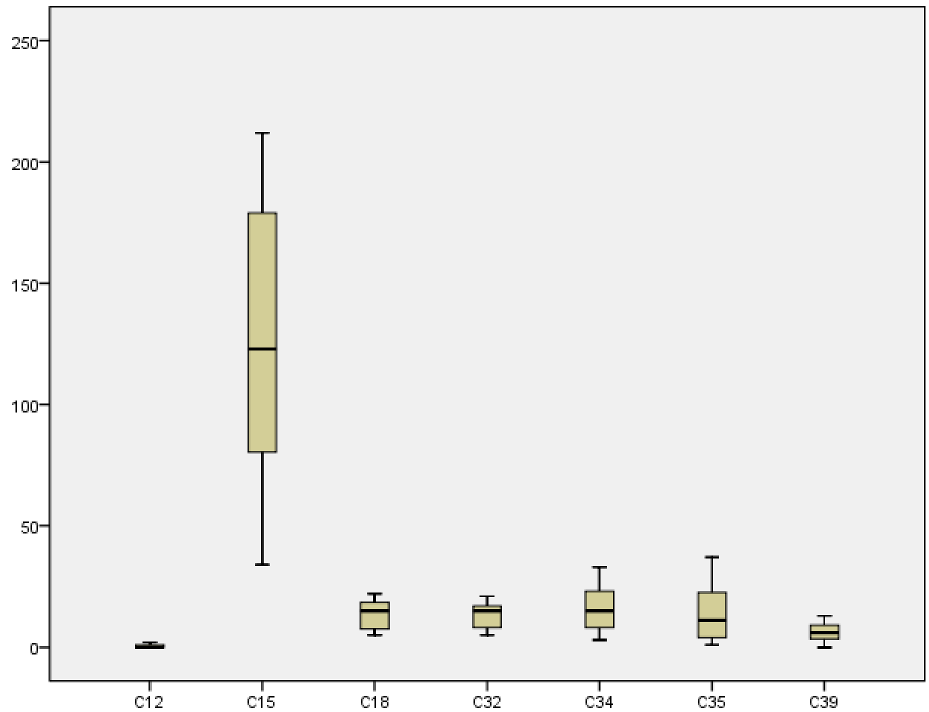
Periods of a day	C12	C15	C18	C32	C34	C35	C39	All the Delays
13,15		110	9	15	18	2	10	**164**
13,3	1	63	8	21	11	3	8	**115**
13,45		39	7	7	7	4	5	**69**
14		34	13	5	9	4	3	**68**
14,15	2	79	5	9	4	2	4	**105**
14,3		90	7	7	10	5		**119**
14,45	1	191	15	19	16	11	8	**261**
15		160	16	21	23	31	6	**257**
15,15	2	175	19	11	33	13	3	**256**
15,3		183	16	16	24	25	9	**273**
15,45	1	212	22	17	26	37	10	**325**
16		205	22	13	23	27	6	**296**
16,15	1	202	19	17	32	32	13	**316**
16,3		123	18	20	22	20	6	**209**
16,45	2	155	21	16	15	19	11	**239**
17	1	145	18	16	13	13	3	**209**
17,15	1	94	11	7	7	5	9	**134**
17,3		67	7	6	3	4	1	**88**
17,45		82	5	9	3	1	4	**104**
TOTAL	**12**	**2409**	**258**	**252**	**299**	**258**	**119**	**3607**

Descriptives

Descriptive Statistics

	N	Range	Minimum	Maximum	Mean	Std. Deviation
C12	19	2,00	,00	2,00	,6316	,76089
C15	19	178,00	34,00	212,00	126,7895	58,61700
C18	19	17,00	5,00	22,00	13,5789	5,98439
C32	19	16,00	5,00	21,00	13,2632	5,43489
C34	19	30,00	3,00	33,00	15,7368	9,45658
C35	19	36,00	1,00	37,00	13,5789	11,88050
C39	19	13,00	,00	13,00	6,2632	3,55656
Valid N (listwise)	19					

Box-Plot



Factor Analysis

Correlation Matrix

		C12	C15	C18	C32	C34	C35	C39
Correlation	C12	1,000	,254	,245	,132	,156	,037	,243
	C15	,254	1,000	,824	,594	,819	,835	,502
	C18	,245	,824	1,000	,523	,794	,835	,436
	C32	,132	,594	,523	1,000	,580	,584	,571
	C34	,156	,819	,794	,580	1,000	,791	,466
	C35	,037	,835	,835	,584	,791	1,000	,493
	C39	,243	,502	,436	,571	,466	,493	1,000

Communalities

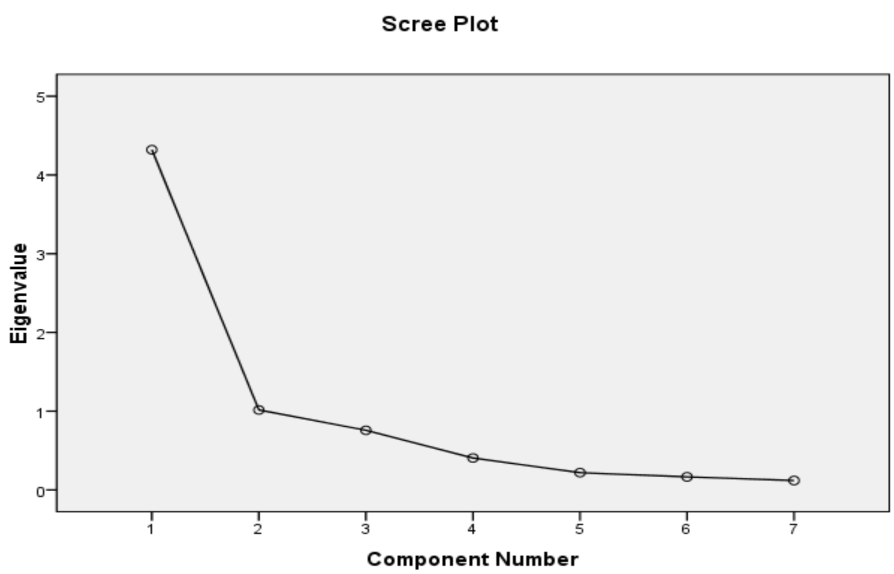
	Initial	Extraction
C12	1,000	,945
C15	1,000	,931
C18	1,000	,908
C32	1,000	,846
C34	1,000	,924
C35	1,000	,976
C39	1,000	,947

Extraction Method: Principal Component Analysis.

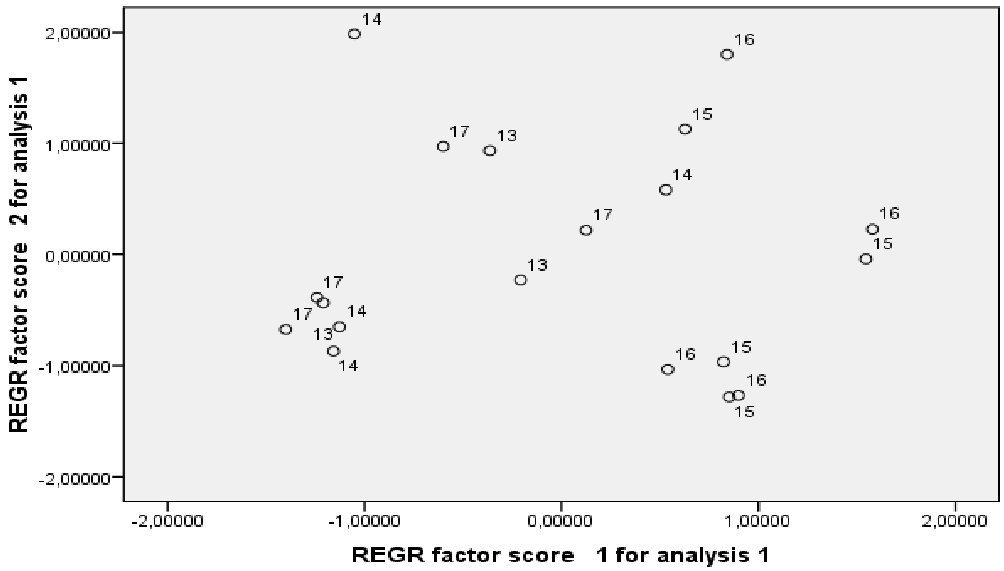
Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	4,320	61,718	61,718	4,320	61,718	61,718
2	1,015	14,497	76,215	1,015	14,497	76,215
3	,757	10,814	87,029	,757	10,814	87,029
4	,405	5,784	92,813			
5	,218	3,121	95,934			
6	,166	2,367	98,301			
7	,119	1,699	100,000			

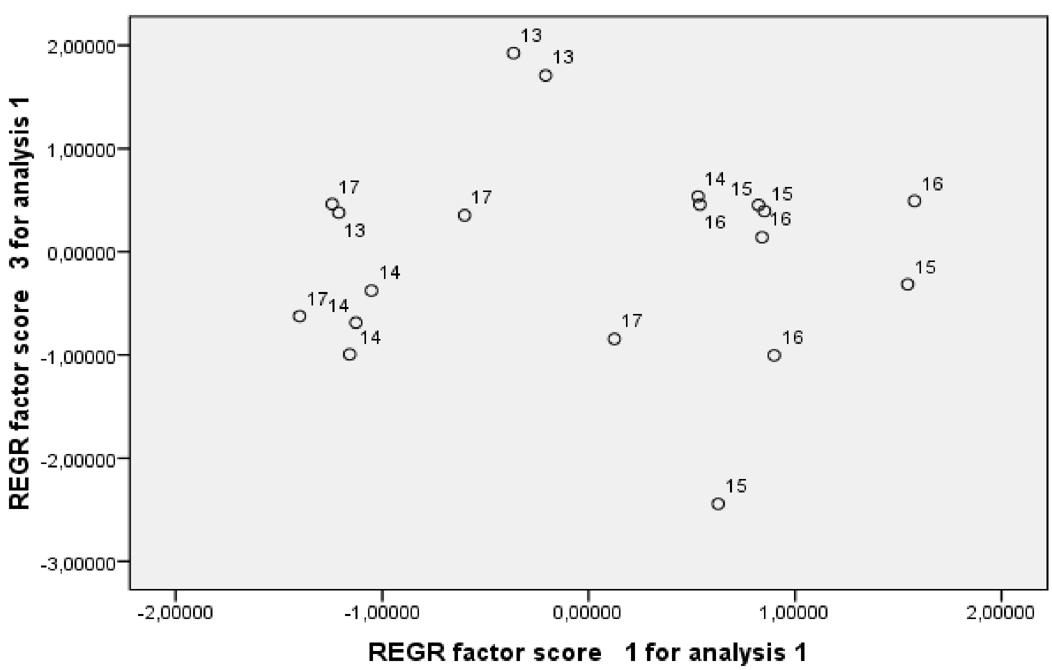
Extraction Method: Principal Component Analysis.



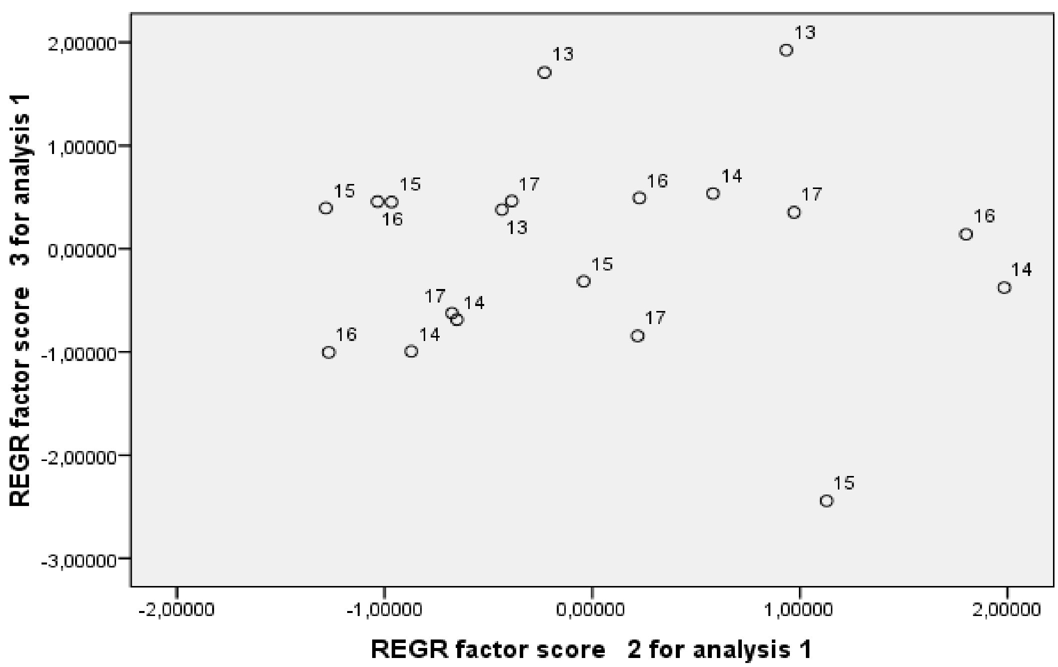
Plan Axes 1-2 Cluster 2



Plan Axes 1-3 Cluster 2



Plan Axes 2-3 Cluster 2



CLUSTER ANALYSIS

I - Cluster for the time of a day periods (15 minutes)

Case Processing Summary[a,b]

Cases					
Valid		Missing		Total	
N	Percent	N	Percent	N	Percent
19	100,0	0	,0	19	100,0

a. Squared Euclidean Distance used

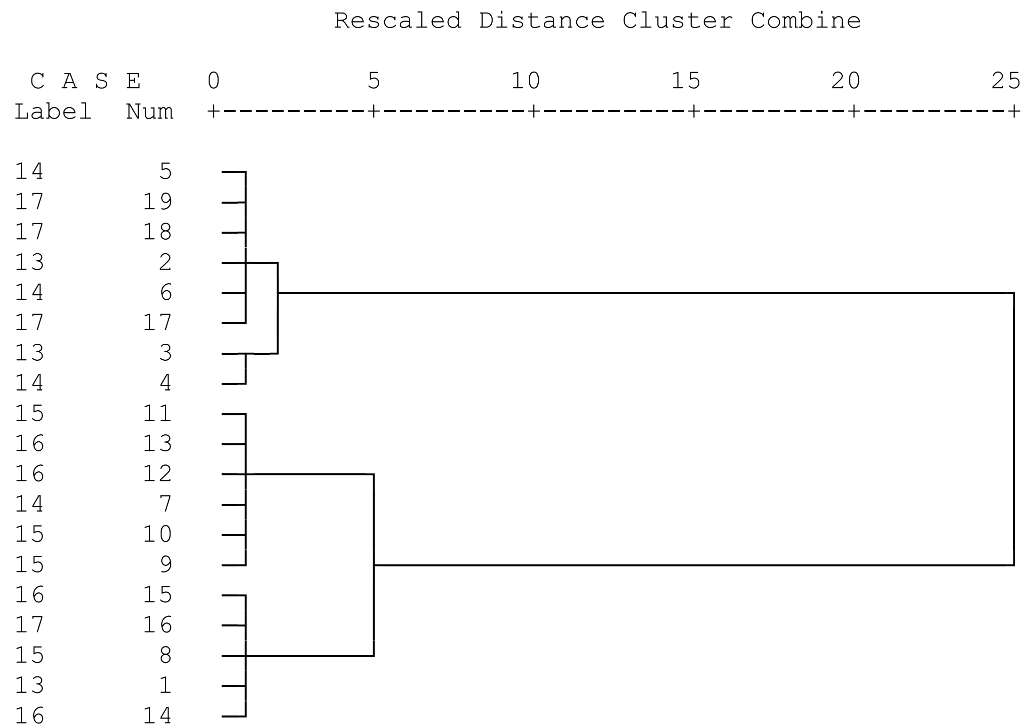
b. Ward Linkage

Ward Linkage

Agglomeration Schedule

Stage	Cluster Combined		Coefficients	Stage Cluster First Appears		Next Stage
	Cluster 1	Cluster 2		Cluster 1	Cluster 2	
1	5	19	7,500	0	0	7
2	3	4	44,000	0	0	16
3	6	17	105,500	0	0	13
4	11	13	195,000	0	0	5
5	11	12	292,167	4	0	14
6	15	16	399,167	0	0	10
7	5	18	540,333	1	0	12
8	7	10	708,333	0	0	9
9	7	9	991,667	8	0	14
10	8	15	1289,333	0	6	15
11	1	14	1604,833	0	0	15
12	2	5	1925,667	0	7	13
13	2	6	2476,500	12	3	16
14	7	11	3714,000	9	5	17
15	1	8	5504,233	11	10	17
16	2	3	8274,650	13	2	18
17	1	7	17170,750	15	14	18
18	1	2	67411,895	17	16	0

Dendrogram using Ward Method



II – Cluster for the delay codes

Complete Linkage

Agglomeration Schedule

Stage	Cluster Combined		Coefficients	Stage Cluster First Appears		Next Stage
	Cluster 1	Cluster 2		Cluster 1	Cluster 2	
1	3	6	,835	0	0	2
2	2	3	,824	0	1	3
3	2	5	,791	2	0	5
4	4	7	,571	0	0	5
5	2	4	,436	3	4	6
6	1	2	,037	0	5	0

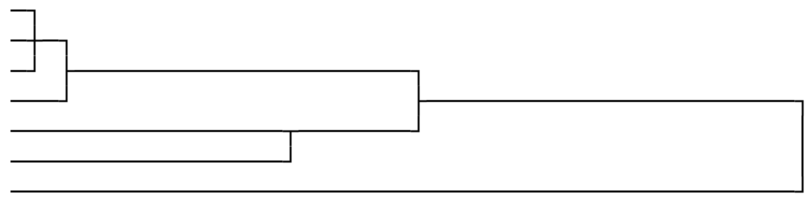
Dendrogram

```
 Dendrogram using Complete Linkage

                         Rescaled Distance Cluster Combine

    C A S E      0         5        10        15        20        25
  Label     Num  +---------+---------+---------+---------+---------+

            C18
            C35
            C15
            C34
            C32
            C39
            C12
```



CLUSTER 3 (1900 pm – 2315 pm)

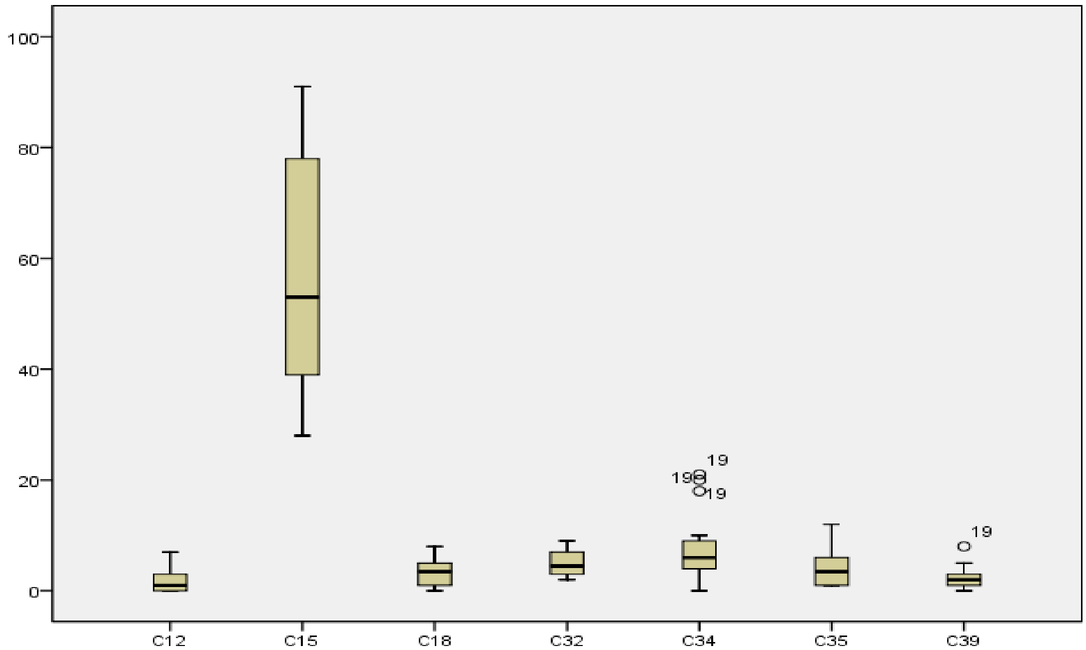
Periods of a day	C12	C15	C18	C32	C34	C35	C39	All the Delays
19	1	85	1	3	18	6		**114**
19,15	4	75	7	5	21	12	8	**132**
19,3		51	5	3	10	4	5	**78**
19,45		89	4	2	20	9	5	**129**
20		51	4	9	5	1	3	**73**
20,15		36	2	7	1	3	2	**51**
20,3	1	33	1	8	5	2	1	**51**
20,45	1	39	1	2	6	2	3	**54**
21		28		4	4	1		**37**
21,15		52	1	3	3	1		**60**
21,3		43	4	3	6	1	1	**58**
21,45	3	74	3	2	2	2		**86**
22	2	56	1	5	6	1	1	**72**
22,15	1	91	5	3	6	9	2	**117**
22,3	2	83	8	7	7	11	4	**122**
22,45	6	78	2	6	9	6	1	**108**
23	3	54	5	9		5	2	**78**
23,15	7	33	4	7	4	4	2	**61**
TOTAL	**31**	**1051**	**58**	**88**	**133**	**80**	**40**	**1481**

Descriptives

Descriptive Statistics

	N	Range	Minimum	Maximum	Mean	Std. Deviation
C12	18	7,00	,00	7,00	1,7222	2,13667
C15	18	63,00	28,00	91,00	58,3889	21,31042
C18	18	8,00	,00	8,00	3,2222	2,26367
C32	18	7,00	2,00	9,00	4,8889	2,44682
C34	18	21,00	,00	21,00	7,3889	6,19429
C35	18	11,00	1,00	12,00	4,4444	3,64969
C39	18	8,00	,00	8,00	2,2222	2,15722
Valid N (listwise)	18					

Box-Plot



Factor Analysis

Correlation Matrix

		C12	C15	C18	C32	C34	C35	C39
Correlation	C12	1,000	,128	,220	,298	,018	,288	,065
	C15	,128	1,000	,441	-,294	,575	,738	,262
	C18	,220	,441	1,000	,207	,245	,714	,712
	C32	,298	-,294	,207	1,000	-,354	-,007	,050
	C34	,018	,575	,245	-,354	1,000	,632	,579
	C35	,288	,738	,714	-,007	,632	1,000	,659
	C39	,065	,262	,712	,050	,579	,659	1,000

Communalities

	Initial	Extraction
C12	1,000	,864
C15	1,000	,798
C18	1,000	,816
C32	1,000	,801
C34	1,000	,743
C35	1,000	,904
C39	1,000	,874

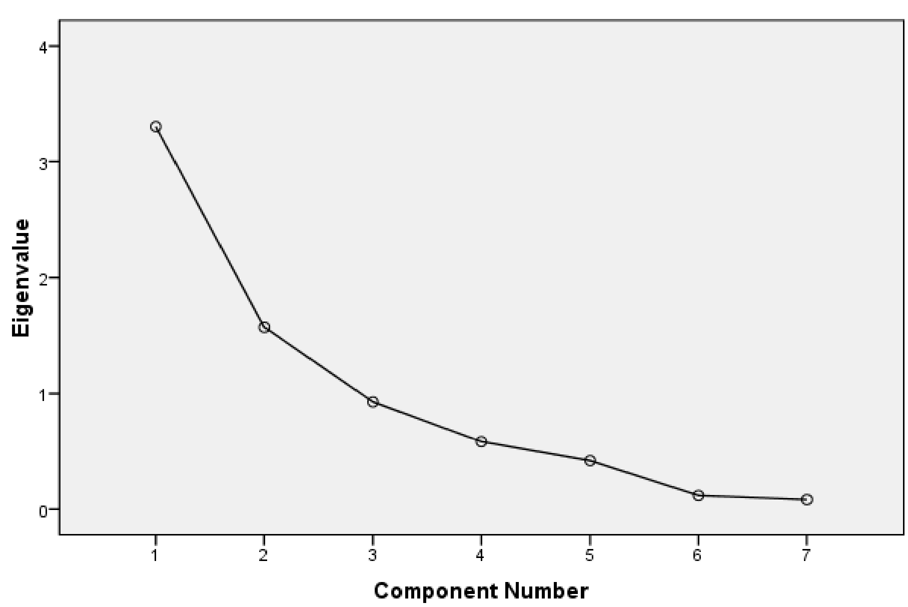
Extraction Method: Principal Component Analysis.

Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	3,301	47,160	47,160	3,301	47,160	47,160
2	1,571	22,443	69,603	1,571	22,443	69,603
3	,928	13,251	82,855	,928	13,251	82,855
4	,583	8,331	91,186			
5	,418	5,968	97,154			
6	,117	1,676	98,830			
7	,082	1,170	100,000			

Extraction Method: Principal Component Analysis.

Scree Plot



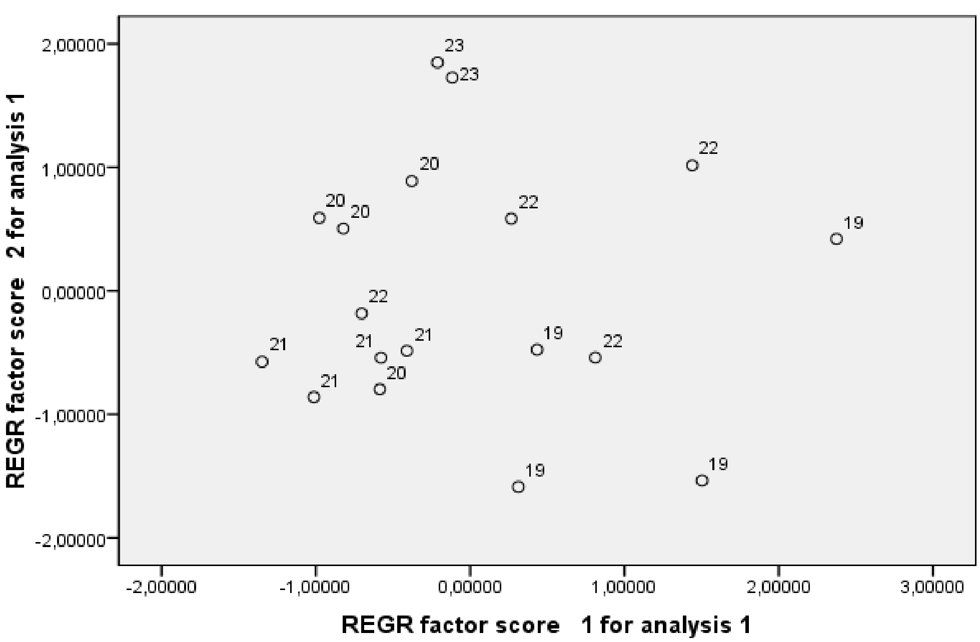
Component Matrix[a]

	Component		
	1	2	3
C12	,250	,583	,680
C15	,752	-,297	,379
C18	,775	,394	-,246
C32	-,095	,880	-,135
C34	,744	-,435	,016
C35	,943	,073	,097
C39	,788	,141	-,483

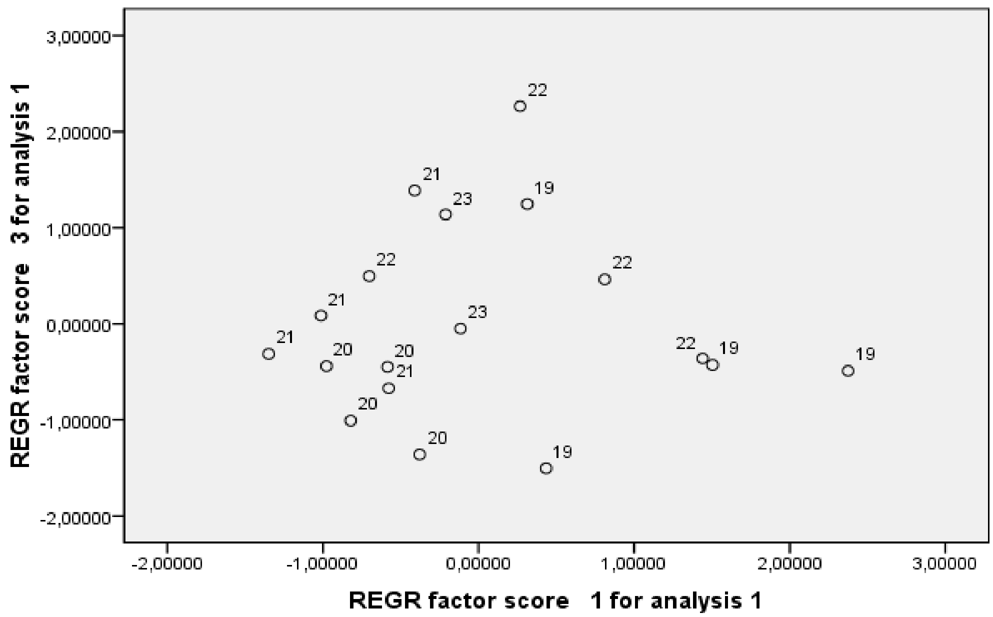
Extraction Method: Principal Component Analysis.

a. 3 components extracted.

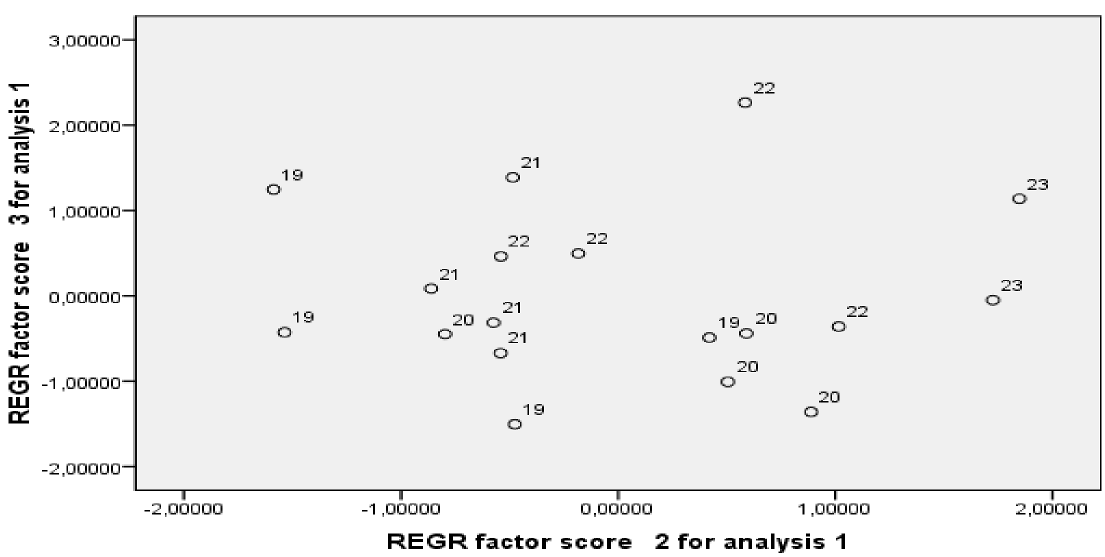
Plan Axes 1-2 Cluster 3



Plan Axes 1-3 Cluster 3



Plan Axes 2-3 Cluster 3



CLUSTER ANALYSIS

I - Cluster for the time of a day periods (15 minutes)

Case Processing Summary[a,b]

Cases					
Valid		Missing		Total	
N	Percent	N	Percent	N	Percent
18	100,0	0	,0	18	100,0

a. Squared Euclidean Distance used

b. Ward Linkage

Ward Linkage

Agglomeration Schedule

Stage	Cluster Combined		Coefficients	Stage Cluster First Appears		Next Stage
	Cluster 1	Cluster 2		Cluster 1	Cluster 2	
1	6	7	15,000	0	0	6
2	8	11	31,000	0	0	12
3	10	13	48,000	0	0	9
4	5	17	78,500	0	0	9
5	1	4	111,000	0	0	13
6	6	18	147,333	1	0	8
7	14	15	196,833	0	0	14
8	6	9	247,000	6	0	12
9	5	10	298,750	4	3	11
10	12	16	352,750	0	0	14
11	3	5	418,700	0	9	16
12	6	8	550,533	8	2	16
13	1	2	708,700	5	0	15
14	12	14	898,950	10	7	15
15	1	12	1247,105	13	14	17
16	3	6	2086,935	11	12	17
17	1	3	8944,611	15	16	0

```
Dendrogram using Ward Method

                     Rescaled Distance Cluster Combine

  C A S E      0         5        10        15        20        25
 Label  Num     +---------+---------+---------+---------+---------+

 20         6   ─┐
 20         7   ─┤
 23        18   ─┤
 21         9   ─┼─────┐
 20         8   ─┤     │
 21        11   ─┘     ├──────────────────────────────────────────┐
 21        10   ─┐     │                                          │
 22        13   ─┤     │                                          │
 20         5   ─┼─────┘                                          │
 23        17   ─┤                                                │
 19         3   ─┘                                                │
 19         1   ─┐                                                │
 19         4   ─┼─┐                                              │
 19         2   ─┘ ├──────────────────────────────────────────────┘
 22        14   ─┐ │
 22        15   ─┼─┘
 21        12   ─┤
 22        16   ─┘
```

II – Cluster for the delay codes

Complete Linkage

Agglomeration Schedule

Stage	Cluster Combined		Coefficients	Stage Cluster First Appears		Next Stage
	Cluster 1	Cluster 2		Cluster 1	Cluster 2	
1	2	6	,738	0	0	3
2	3	7	,712	0	0	5
3	2	5	,575	1	0	5
4	1	4	,298	0	0	6
5	2	3	,245	3	2	6
6	1	2	-,354	4	5	0

```
Dendrogram using Complete Linkage

                         Rescaled Distance Cluster Combine

    C A S E      0         5        10        15        20        25
  Label     Num  +---------+---------+---------+---------+---------+

            C12
            C35
            C34
            C18
            C39
            C12
            C32
```